Online Collaborative Sketching and Communication to Support Product Ideation by Design Teams

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Abstract. In recent decades, the team creative process has been shifting online. Many design teams for novel products work together via collaborative software or applications. When generating new ideas, team members sketch to express their ideas and discuss them with each other. However, access has yet to be effectively supported by the current communication tools or creativity support tools online. Therefore, this study aims to clarify the needs of design teams, when they ideate new products online and sketch collaboratively, and the required features of tools to support this process. We conducted individual in-depth interviews with six designers from different design teams in China to identify needs. In addition, after the first two interviews, we demonstrated a preliminary design prototype with potentially useful features for collaborative ideation. The last four interviews also included a heuristic evaluation of the design. The results suggested that design teams working online had several barriers to co-creativity, including collaboration in batches, untransparent processes, and inefficient visual expression. We outlined the features required in an online collaborative tool for product design: integration of creative teamwork and taskwork, version control and visualization, and efficient toolsets.

Keywords: Team Creativity · Product ideation · Communication tools · Creativity Support Tools

1 Introduction

Product design involves a series of creative processes, including problem identification, ideation, and evaluation. These creative processes require the effective collaboration of teams in organizations [1]. Team members need to exchange information and knowledge and also manipulate shared work-in-progress crafts so as to generate more diverse, valuable, and novel ideas [2]. In product design, members often need to collaboratively sketch to visualize and discussion on their ideas [3].

In recent years, increasing product design teams have been working online, and this trend is increasing because of the COVID-19 pandemic. On the one hand, they use communication tools such as Slack, Microsoft Teams, WeChat, and Tencent Meeting. On the other hand, they also use creativity support tools (CSTs) such as XMind, Fabrie,

P.-L. P. Rau (Ed.): HCII 2023, LNCS 14023, pp. 315–330, 2023.
https://doi.org/10.1007/978-3-031-35939-2_23

Sketchboard, and Drawpile. Some communication tools are also integrated with CST features, such as Mural in Microsoft Teams and the Post-it notes on whiteboards in Meta Workrooms. However, most of these current tools need more support specific to product design processes, such as collaborative sketching or quick modeling for effective and efficient discussion.

Some previous studies have proposed collaborative sketching tools, for example, classroom sketching [4, 5], graphic interface design [6] as well as face-to-face product design [7]. Most of these tools are designed for face-to-face collaborative sketching and focused more on taskwork, which is different from the online design team in this study. When working in the online context, on the one hand, team members can interact more in flexible ways, and their discussions can be easier to track and document, providing new opportunities for innovative functions of collaborative tools to support creativity. On the other hand, they lose some extent of media richness, which may reduce social presence, trust, and cohesion in the long term [8]. What is even less clear is the needs of product design team members and their requirements for functions in different processes. Although some researchers [9] identified specific needs of online product design teams based on commercial communication and collaborative tools such as Zoom and MS Team, little attention has been paid to the needs for collaborative sketching and modeling.

Therefore, this study aims to clarify the needs of online design teams when they ideate new products and sketch collaboratively and to identify the required features of tools to support this process. We conducted individual in-depth interviews with six designers from different design teams in China to identify needs. After the first two interviews, we demonstrated a preliminary design prototype with potentially desired features for collaborative ideation. The last four interviews also included a heuristic evaluation of the design. Through the interviews, we identified several current barriers and needs and outlined critical features of an online collaborative tool for product design.

2 Literature Review

2.1 Product Ideation Progress

As a kind of creative design, product design usually includes four stages: problem analysis, conception, evaluation, and implementation [10]. The first step of problem analysis is the most fundamental part of the design. The purpose is to clarify the design objectives and collect and reorganize information [11]. The second step uses various (creative) methods to produce original mental images and ideas for responding to critical challenges [12]. This step has multiple design options, thus requiring a third-step evaluation to screen out the most developmental potential for implementation. A successful product design needs well planned, implemented, and appropriately supported [13].

Product ideation relies on creativity. Rhodes (1961) proposed that creativity was regarded as a dynamic phenomenon composed of four interactive components: person (people), process, product, and press [14, 15]. The four elements listed are also crucial at the team creation level. The flow of information between team members can improve the quality and flexibility of thinking, expand the knowledge and experience resources available between teams, and improve the creativity of teams [13, 16]. Besides, communication may also negatively affect ideation by increasing, for example, social loafing, cognitive load, and social anxiety [17, 18].

The sketch conception stage is the beginning of design activities, which plays a crucial role in the overall development process of design creativity. Designers usually carry out creative activities in the way of sketching to present the thinking process and results [3]. Through the sketches, designers can quickly try out various ideas on paper and use the sketches and their features to build an unexpected virtual world.

Collaborative sketches are significant in product ideation. Collaborative design implies the collaboration of distinct individuals to accomplish common goals simultaneously or chronologically and co-locationally or remotely [19]. Collaborative sketch has the following benefits:

1. Triggering and exploring the iterations of ideas in the dynamics of the product ideation process [20].
2. Encouraging communication between participants about the graphic externalization of ideas challenging to describe in words [21].
3. Highlighting and evaluating graphic proposals developed by the team [20].

In 2016, Wahl and Kitchel concluded that "robust real-time collaboration" tools, so-called "Collaboration 2.0", can be as effective as traditional, in-person activities [22]. Any useful collaborative sketch tool must have four primary attributes: virtual collaborative sketching environment, real-time collaboration, archival record of activity, and widely available [9].

2.2 Creativity Support Tools

Creativity support tools/systems (CSTs/CSSs) are information systems that support creative processes such as ideation and product design [23]. With the guidance of creativity theories, these tools are usually designed for team creativity tasks, decision-making, art design, and knowledge management.

CSTs can be generally categorized into individual or team types [23]. Team-level CSTs can be generally categorized into four classes [11, 24]: idea management systems, group support systems, computer-assisted creativity systems, and virtual team members. Idea management systems are the systems that support collecting, selecting, and evaluating ideas. Group support systems are the systems that support team creativity by facilitating coordination and communication. Computer-assisted creativity systems are the systems that assist the implementation of creative techniques. Virtual team members are artificial intelligence that can help monitor human cognitive processes, simulate human creativity, or generate ideas like human team members.

3 Method

3.1 Participants

We conducted individual semi-structured interviews with six product designers in China. We asked about the typical processes of product ideation and the needs of teams. After interviewing the first two participants, we proposed an initial design of an online collaborative tool for product ideation to demonstrate features fulfilling the potential needs. When interviewing the later 4 participants (P3 to P6 in Table 1), we also conducted a heuristic evaluation as well as the interviews about their needs. Finally, we improved the design as shown in Sect. 5.

Table 1 shows the information of the participants. They aged from 23 to 31 (M = 25.83, SD = 6.99). Five of them were females, and one was male. They worked in different organizations including the design industry, IT industry, and academy. Their team size ranged from 4 to 9, with most between 4 and 6 (N = 4). Three participants worked in a fully co-located team, and other members worked in other cities in China.

Table 1. Summary of the participants.

Participants	Age	Gender	Occupation	Team size	Team was formed	Location
P1	27	F	An HCI designer in a large IT enterprise	9 people	>2 years	CO
P2	31	F	A professor at a university	4 people	>2 years	DT
P3	27	F	An architect in a large design institution	7 people	>2 years	CO
P4	23	F	An industrial designer in a car manufacturing enterprise	4 people	<2 years	DT
P5	23	F	A service designer at a university	4 people	<2 years	DT
P6	24	M	A product design intern in a product design enterprise	6 people	<2 years	CO

Gender: F = female, M = male; Industry: HCI = Human-Computer Interaction, Location: CO = co-located; DT = distributed, but most members were co-located.

3.2 Data Collection

The individual semi-structured interviews included six questions listed below. We asked about participants' needs in the different stages of team creativity, including problem identification, ideation, evaluation, and documentation (Questions 1 and 3). In the interviews with P3, P4, P5, and P6, we also asked questions for heuristic evaluation (Questions 4 to 6). Each interview lasted for around one hour and was audio-recorded and transcribed to texts later. The six questions were:

4. How would you divide your work phases? What is the working process?
5. Which tools were to use in communication? What difficulties were encountered?
6. How to evaluate and organize ideas? Do you use tools? What can these tools do? Will the flash be ignored or forgotten?
7. Does the overall impression of our software meet their needs, does it use smoothly, and how can it be improved?
8. According to Nielsen's usability principles, what issues do you think might be possible?
9. Feelings and suggestions for features like the main interface, custom painting, real-time modeling, social conversations, and more. How do you feel about the main interface, custom painting, real-time modeling, social conversations, and more? Do you have any suggestions?

3.3 Data Analysis

The interview scripts were analyzed by thematic analysis with an affinity diagram. The scripts were coded iteratively for three rounds. In the first round, four researchers read the scripts and initially open-coded for each research question. In the first round of coding, researcher A generated 57 codes, researcher B generated 80 codes, researcher C generated 44 codes, and researcher D generated 39 codes, with 37 (67%) having the same or similar codes. Then, the four researchers discussed and generated an initial codebook. In the second round, researcher A modified and generated 59 codes, researcher B generated 73 codes, researcher C generated 47 codes, and researcher D generated 40 codes, with 51 (93%) having the same or similar codes. They finally discussed and developed a revised codebook with 54 codes. In the final round, Researcher A coded all the scripts.

4 Result

4.1 Product Ideation Progress

The teamwork process and product ideation characteristics were consistent with those suggested in the literature. But after precisely figuring out the workflow, we found some differences and identified the typical processes of ideation and the needs of product design teams. Overall, the current product design teams need more efficiency and visibility of communication, the accuracy and fairness of evaluation, the convenience and efficiency of online design and drawing, and the convenience of traceability after the meeting. These findings revealed a strong need to create online collaborative creative support tools for product ideation.

Problem Analysis. Participants often used the brainstorming approach (N = 4). Most of them could fully express their ideas without the help of tools (N = 5). For parallel innovation teams to explore and find problems together, problems might occur, such as repeated work, because the use of methodology is almost the same. For example, P1 said,

"Many times, like in the early days, we need to find a problem. Then we go to research, we may find the same content, and then we will look at some things repeatedly. Although there are differences in the subdivision direction, the background is similar, so the way of thinking is homogenized." [P1, 27, female]

It also might occur production blocking or extreme divergence. Besides, alternative ideas were mainly evaluated by team members' feelings and experiences (N = 3) or directly decided by the team leaders (N = 5). They lacked systematic approaches to evaluation for better validity and reliability.

Ideation. More than half of the participants (N = 5) said they usually sketched and designed individually, and these alternative ideas were evaluated and chosen by leaders or their feelings later. Two participants said they generated ideas both individually and collaboratively. The possible reason for less collaboration was that participants perceived paper-based sketching as more convenient and faster than computer-based ones. Also, collaborative sketching on a computer is complicated and has few corresponding collaborative CSTs. For example, P6 said,

"After the leader releases the task, we each design several sketches and then give them to the leader for evaluation. After selecting the plan, we use the computer for follow-up operations." [P6, 24, male]

Evaluation and Documentation. More than half of the participants (N = 5) said their ideas were evaluated mainly by their leaders according to experience though they could comment on the alternative ideas before final decisions. One participant noted that parallel teams evaluate ideas based on feelings, and there are no specific criteria. Overall, the evaluation and final decision lack fairness and accuracy and require a specific criterion. For example, P3 said,

"Generally, whether our project is feasible or not, the leader will judge it according to his experience. Of course, we will also issue some written feasibility study reports containing some judgments on the project's feasibility." [P3, 27, female]

Documentation. Half of the participants (N = 4) said that after the meeting, they would organize and document the content of the meeting with the help of mind mapping, semantic map, Nvivo software, or other methods. More than half of the participants (N = 5) said most teams would organize the creative process, relevant documents, project experience, and results after the whole project and then review the summary. Nevertheless, the documentation workload was heavy and tedious, and most people were reluctant to do this job.

4.2 Communication Tools and Creativity-Support Tools

During the product ideation process, the participants communicated with their team members via the following media: communication applications on smart devices, face-to-face communication, emailing, audio or video conferencing, phone calls, and short message service on mobile phones.

When co-located or distributed collaborating, besides the face-to-face method, the most frequently used communication tools were WeChat, Feishu, DingTalk, Tencent Conference, Slack, Microsoft Teams, and so on in China. Their team often used these apps to post notifications, transfer files, and non-face-to-face communication. They used Audio or video for online meetings during remote collaboration. They also used creativity support tools such as XMind, Fabrie, Sketchboard, and Drawpile, which helped them with collaborative sketching and designing. Most participants said the communication applications were practical because:

10. Team members can use these tools to transmit files and communicate accurately and quickly (N = 3).
11. Using shared documents featured with a real-time update function, teams can work together to edit information and increase communication efficiency (N = 4).
12. The information on the tools has data persistence, makes it easy to access these data at any time during the project process, and is also convenient for the evaluation and documentation of the whole project (N = 2).

Although there are many advantages of these communication tools, there are also points worth improving. Besides, most participants said the creativity-support tools for product ideation were efficient but still had problems. The following is something worth improving:

13. Information sharing efficiency is low. Furthermore, in asynchronous interaction, the team members might not be able to reply in time.
14. When communicating, they needed to open various communication and CSTs tools, and information sharing could be more convenient.
15. The sketching and designing tools for product ideation are designed for individual use, so it takes work to sketch and design collaboratively. As mentioned by P3,

> *"We divide it according to the type of work. Say I draw the plane CAD and then need someone to draw renderings, someone to build a model. Finally, someone to text expression... L the assembly line, this work method is more efficient. Still, its disadvantage is that everyone's work is more limited, unfavorable to the development of their work, everyone to complete the quality of the task has also limited." [P3, 27, female]*

16. The CSTs for product ideation were challenging to modify. Because the design on the computer is complex and time-consuming, the cost of the scheme modification is high.

In sum, the CSTs for collaborative sketching and designing have four challenges, interactivity, efficiency of CSTs, team cognition, and device.

Interactivity. As stated in the literature, the interaction between members is significant when creating collaboratively. Interactions between members continue throughout the product ideation process. The need for more interactivity emerged primarily in the ideation and evaluation phases. Some participants said they were independent during the ideation stage, lacking mutual communication. They might put forward several alternative ideas and then evaluate them together. For example, P5 said,

> *"We have leaders in our team. Most of the time, the results of team communication were not the discussion between our team members but what our leaders decided and informed us. And then we will draw some sketches and show them to the leaders." [P5, 23, female]*

The leader sometimes decided on the evaluation stage and was not discussed within the group, which P1 and P6 also mentioned.

Besides, the convenience of using tools can also affect team members' interactions. Most creativity-support tools for collaborative sketching and designing are complicated and need to support online collaboration. More than half of the participants mentioned a possible collaborative use of the CSTs during the problem analysis phase, but they all used the CSTs alone during the ideation phase. For example, P4 said they would use the computer to model after the schemes were decided. Computer modeling took a long time to model and is cumbersome to modify, so they would not model at the beginning.

The Efficiency of CSTs. According to the interview, although the team used communication tools and CSTs for collaborative sketching and designing in the product design process, the level of collaboration was low, even creating individually. Three participants mentioned that this phenomenon is related to the high cost of learning and the use of the software. As P4 said, *"Sketch on paper, you can draw several plans in an hour, but the speed on a computer is halved. Modeling takes even more time, taking at least a few hours to complete a model."*

Besides, the efficiency of CSTs also affects documentation and summary after the whole project is finished. Two participants mentioned that documentation was critical and helpful, which could help them accumulate experience and analyze their shortcomings and weaknesses.

Team Cognition. Two participants said their team members were analogous in majors, so the way to solve problems was similar, which led them to much repetitive work and a lack of innovation. As mentioned by P1,

> *"Although there are differences in the direction of this subdivision, such as psychology, colleagues specializing in industrial design, hardware, and software development. In general, at least in a certain job or study stage, they have*

learned the methodology of human-computer interaction. So, the background is the homogenization of the way of thinking." [P1, 27, female]

Device. Current electronic devices include mobile phones, computers, and tablets. Different devices have different characteristics. Mobile phones are easy to move and communicate with. However, with smaller screens, it is inconvenient to use CSTs and has limitations in performance. Computer performance is the most powerful. A computer is inconvenient to move, so people will only carry it if necessary. Computers support communication, sketching, and modeling. The tablet's size and performance are between computers and phones. Because of the capacitive pen, people can imitate the painting on paper, with the lowest learning cost and more comfortable using feelings. Also, the tablet can model products.

4.3 Evaluation of the Preliminary Design

Participants felt that the tool we designed was generally helpful and improved the efficiency of product conception. Then, they offered further hope. The participants hoped that the painting function could meet the basic requirements of quick sketch design and then have a customized brush to achieve the effect quickly (N = 2). Besides, under the premise of ensuring the running efficiency of the software, the modeling function could realize real-time rendering (N = 3). Moreover, more than half of the participants preferred the model library and component library (N = 4). As mentioned by P6,

"We can make a model material library, which can directly call the related products. For example, the A company is a chair, and he may have designed many chairs by himself, and then he can directly call his previous design in the model library. A new product may have many points related to this design, so we only need to modify his previous design slightly." [P6, 24, male]

Moreover, in the brainstorming stage, participants were reluctant to see other members' online status, which would affect their creation (N = 2). Some participants also emphasized the efficiency of synchronous and asynchronous communication (N = 2). Lastly, half of the participants hoped the whole process could be recorded and documented after the meeting (N = 3). As mentioned by P5,

"After the sketch evaluation process, there can be a section called the display of the evaluation results so that the results can be analyzed. Then we will record the results of this discussion. For example, each person uses a different color to mark it." [P5, 23, female]

5 Collaborative Sketching and Designing to Support Product Ideation

Due to the usage gap between communication tools and CSTs for product ideation, part of the design process's collaboration level was low. We explored the potential design to integrate communication tools with CST features to support team creativity in product design teams. Based on the findings of the interviews, we determined the following design goals:

17. Innovation goal: The tool can enhance the visibility of the team's drawing conception scheme, reduce the omission of ideas and information in the sketching, and promote the collision of the team's creative points.
18. Efficiency goal: The tool can reduce the stagnation of thinking during team communication and promote the progression of the design process. At the same time, it increases the data's durability and organizes the whole process to facilitate traceability after the meeting.

Fig. 1. Interface for sketch evaluation. The group members can hold meetings, comment and modify sketches.

19. Auxiliary goals: The tool can help product designers reduce the difficulty of sketching and modeling.

For these goals, we proposed potential tools which integrate communication, collaboration, and CSTs for product ideation features. According to the product ideation process, we offered three significant components for mobile devices.

First, we integrated communication, whiteboard function, sketch, and modeling functions so that members could design and communicate by voice and video.

Second, on the premise that the tool is functional for synchronous and asynchronous interactions, as shown in Fig. 1. In the upper right corner of the screen, the dual modes of painting and meeting can be switched. A function button is added to the host interface's left side of the dual-mode switch button to cover the whole staff. Click invite members in meeting mode to give members access to comment and modify. According to the specific needs, the members speak and comment in turns. Clicking the annotation function key, members will enter the drawing mode to modify the scheme. The modification results of different members will be presented as a dendrogram below the container, which will be saved in the meeting minutes after the meeting.

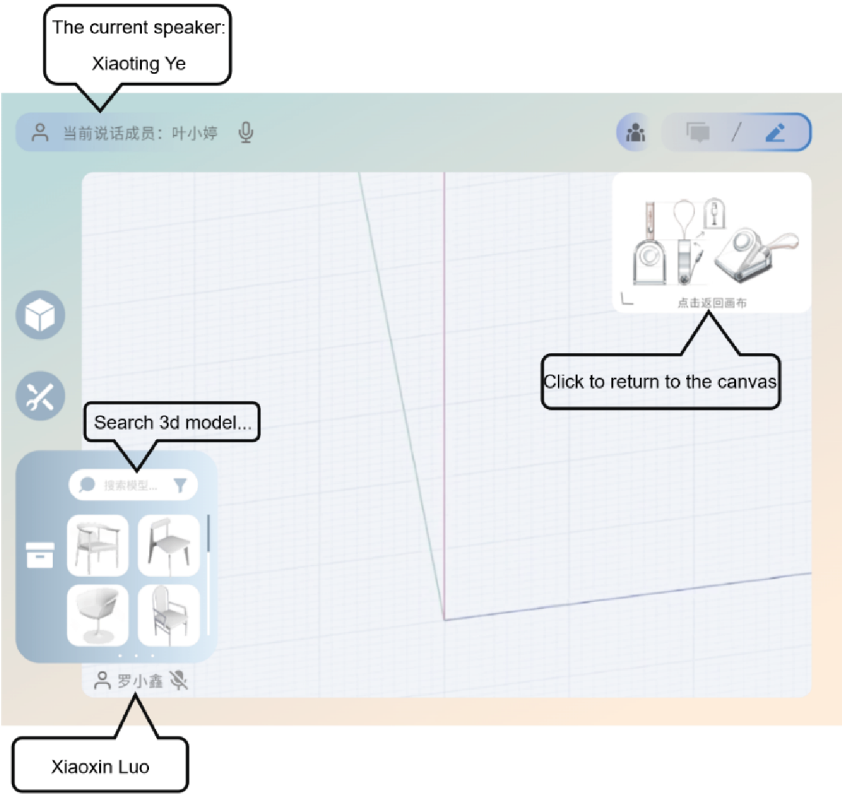

Fig. 2. Interface for modeling. The group members can rapidly model and use the model library.

Third, establish the model library and the product design particular brush material library. Searching for keywords in the model library presents the relevant model, as shown in Fig. 2. Members can modify the selected model's parameters, such as chamfer size, length, and width of different components. The brush material library can quickly show the effect of the product with the selected material when sketching.

Fourth, we have added a post-meeting traceability function. The tool records what the members do during the project and documents the content and process of the meeting. After the project ends, you can view all the operation records for the whole project. Figure 3 shows a clear project record. Figure 4 shows clear meeting minutes.

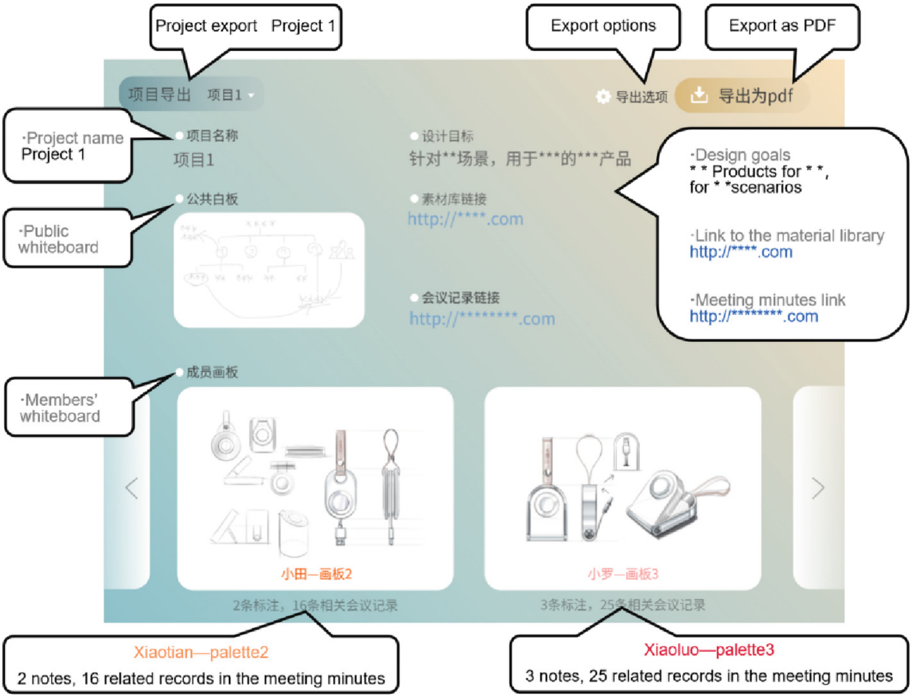

Fig. 3. Interface for documentation. The group members can locate all of the data in the project.

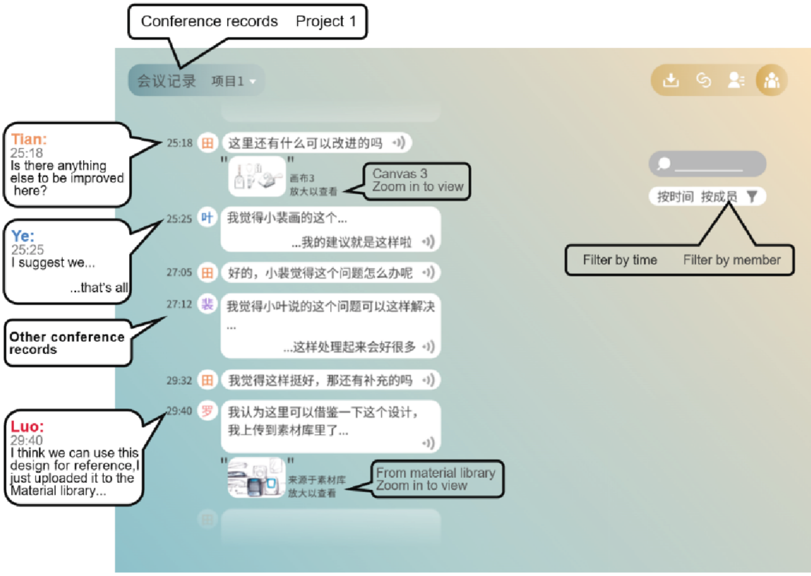

Fig. 4. Interface for documentation. The group members can view meeting minutes.

6 Discussion and Design Conclusion

This study conducted individual interviews with six designers in different product design teams in IT enterprises, design companies, and an academy and proposed a tool for collaborative product ideation for online teams. By qualitative interview analysis, we identified several barriers to creativity during online collaborative product ideation:

1. Collaboration in batches due to the separation of sketching and communication tools. In the ideation and evaluation processes, most of the interviewed teams tended to work in an in-batch fashion, like nominal brainstorming. Typically, team members sketched and formed ideas individually and then submitted alternative ideas in batches to their leader. The leader would summarize ideas and make decisions. This process had some flaws: it could not support members to be inspired by others, merge or expand their ideas and may harm team cognition and mutual understanding. Research suggests that when team members are open to new ideas and effectively communicate, they perceive support for creativity [25], which fosters team and organization [26]. A possible reason for such a process was the lack of convenient online sketching integrated into the communication tools. As a result, most participants still preferred sketching on paper individually. Although researchers have proposed various collaborative sketching tools such as [5, 7], they were not designed to support remote or online teams designing new products. It indicated a need to integrate collaborative sketching and communication functions to support product design teams working online.
2. Untransparent processes and potentially arbitrary selections of the final idea. In most teams, alternatives were selected arbitrarily or based on leaders' experience instead of a more solid evaluation. This arbitrary selection risked burying potentially creative

ideas. More severely, it could harm trust and team cohesion, as suggested by the participants who mentioned fairness. The shift to online platforms may aggravate this problem because of the lower media richness and transparency of social interactions and creative processes [8]. It suggested that online design teams needed more tracking and visualization of their ideation and evaluation processes as well as more support of creative techniques.

3. Inefficient visual expression. Many conventional sketching and modeling tools afforded powerful but complex functions and thus reduced learnability. In particular, most modeling software took designers a long time to learn and use. These tools could not well support divergent thinking or ideation to generate many alternative simple outlines. Such inefficiency in expressing ideas in visual objects online also contributed to the previous two barriers. Online design teams needed a quicker way to record and share their ideas in the form of visual objects instead of a comprehensive set of functions of sketching or modeling.

To remove these barriers, we also proposed and heuristically evaluated an initial design of the tools for online communication and collaborative sketching. We abstracted the following key functionality so as to generalize to other potential media in the future:

1. Integration of creative teamwork and taskwork online: The tool may integrate both synchronous and asynchronous communication functions with creativity supports, including whiteboards, sketching, and quick modeling. Team members need to flexibly choose synchronous (e.g., video conferencing) or asynchronous (e.g., commenting or annotating) interactions in different stages. For example, ideation requires synchronous interaction with both verbal and visual communication [20], whereas in the early stage of evaluation, team members carefully compare and analyze different ideas and thus may need to comment or annotate on others' ideas asynchronously. For example, some recent applications for UI design, such as Figma, supports asynchronous communication by commenting on others' ideas. In addition, some features of electrical brainstorming systems can be integrated to support creative ideation and more effective evaluation, as expected by the participants, and designed in this study.
2. Version control and visualization: The tool may track team members' interactions and manipulations of their alternative ideas, including those interactions in video conferencing. The function of automatic tracking and summarizing meeting minutes can be found in most conferencing platforms. Recently, MS Teams has been integrated with GPT features that can assign tasks to team members based on tracking verbal data [27]. In this study, tracking data involved image data as well as behavioral data and can be further used to support team creativity in many ways. First and most directly, the tracking data can link design alternatives with the discussions during video meetings, and the tool can generate graphical meeting minutes. Second, the tool can afford a higher editability by version control functions, which are available in many current collaborative tools. Third, the tool may further summarize and visualize the team process or alternatives. For example, the alternatives can be clustered manually by team members or automatically by some image processing algorithms or behavior analysis of team members. Some qualitative analysis tools, such as NVivo, provided manual or even automatic coding and clustering functions. Similar functions in co-creative tools can help team members to identify potential patterns and develop a

holistic understanding of their design process. It may also further facilitate better team cognition as well as socio-emotional aspects such as team cohesion.

3. Efficient toolsets: The tool may provide libraries of elements or shortcuts for quick modeling. The libraries may include frequently used brushes, materials, and components. These elements can be customized by team members and automatically recommended by algorithms based on the relevant domains and analyzing the existing alternatives.

This study has two main limitations. First, due to insufficient samples, it only partially covers the target users. The current interviewees are designers, including graduate students and employees from design institutes and design companies. Future research may enroll more product designers to increase the accuracy and reliability of the data. Second, we heuristically evaluated the designed functions of the communication and collaborative sketching tool with a few participants. Future studies may evaluate it more quantitatively, such as through user testing or controlled experimenting.

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