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Development of Online Collaboration Tools (OCT) for Collaborative Innovation Design

Zhao Yu, Zhinan Zhang*

Shanghai Jiao Tong University

*Corresponding author, E-mail: zhinanz@sjtu.edu.cn

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Abstract

With the development of information technology and systematic innovation theory, the innovative design of products and service is no longer confined to individuals or one team. There are more and more cross-regional and multi-disciplinary collaborative design integrate the time, human and other resources to promote more innovation activities. However, there is still a lack of systematic and effective tools to cover the whole process of collaborative design activities. To address this gap, we provide a case example to solve this problem of using online collaboration tools (OCT) in collaborative design context, and further illustrate some implications through the systematic innovation perspective. In the present paper, we discuss how the adoption of online collaboration tools has influenced the collaborative design activities based on the IDEEA drone design workshop. Discuss the impact of online collaboration tools on the participants' learning and collaboration effect in the distributed systems. Online collaboration tools can be used to access knowledge that originates from external as well as internal sources, but it seems that online tools increase the visibility and accessibility of internal expertise and therefore the use of internal knowledge. The main contributions of this paper include:1) Our research revealed that the online collaboration tools can promote innovative design of multi-disciplinary and innovation design. The design tasks of the workshop are completed by each team with almost no traditional offline collaboration. 2) The implementation of collaborative design is divided into five types according to the design thinking process: empathize, define, ideate, prototype and test. Analyzing the attributes of different collaboration tools in the process of innovative design. 3) Discuss from the project what kind of technical methods and tools are suitable for the specific collaborative design system. Provide guidance for future collaborative design activities.

Keywords: Collaborative Design; Systematic Innovation; Computer-aided problem solving; Online Collaborative Tools.

1. Introduction

With the rapid development of cloud storage and mobile Internet, the way people work and learn is undergoing tremendous changes. It has become an accessible reality to use personal computers, smartphones, tablets and other devices to carry out online collaborative work or learning in teams anytime and anywhere. Online collaboration tools developed in recent years have challenged traditional office tools. The new appliances are widely used and make modern office working pattern move into new age. It makes up for the shortcomings of traditional online communication tools and document editing software in collaborative work, mobile storage and other aspects. More and more people have realized its increasing importance from the need of social development.

Collaboration refers to the coordination of resources, technology and information between departments and individuals in the process of achieving a certain goal. People need a certain place (office or classroom) where they can gather to realize face-to-face communication among members before the Internet and smartphones. If they want to cooperate in different places, they need to use telephone, letter, fax and other inefficient communication tools. Whether face-to-face or in different places, traditional methods are difficult to achieve synchronization and real-time collaboration. The inefficient way of information transmission cost a lot of time and energy while the team can’t achieve the desired goals many times. With the advent of the information age, people began to use some social software such as Email, BBS, Blog, IM, Wiki for collaborative work and learning. These online tools shorten the distance between people. But this kind of social software is not developed for people to work and learn together. Like there are some online collaboration functions are integrated Facebook and WeChat, but they are mainly focus on social contact. The entertainment functions which unrelated to collaboration work will distract the attention of team members, and reducing the collaboration effect.

Through online collaboration tools, people can improve the way of information exchange, reduce the space barriers, save time and energy, and improving the quality of group works. It will gradually become an important tool of innovative work and solve many problems in the process of people's office work or learning, such as process log, task assignment, delegation, administration, online communication and so on. Online collaboration tools play an increasingly important role in business and collaboration work recently. And there are a variety of online collaboration tools for team collaboration showed up while they have many limitations for different reasons. Unlike the business activities, the innovative design involves more divergent thinking and design thinking. This paper will argue that whether the collaborative tools can really assist the process of innovative design and help people from different disciplines to communicate effectively in collaborative design? We explore the development and characteristics of online collaboration tools around the innovative design. Discussing the impact of online collaboration tools (OCT) on distributed participants' course learning and project collaboration. The research could provide support for future design learning and practice from the analysis of case study and discuss what kind of tools to implement specific collaborative design system.

2. Related work

2.1 Innovative Design Methods

The innovative design methods mainly focus on the innovative and application method and the to the engineering project while now there is no systematic innovative design theory and method. Some interdisciplinary methods, such as TRIZ and design thinking, are used to guide innovative design. Under the guidance of innovative design, different professionals work together to complete the design of industrial products or services. Innovative design methods lead people to develop their professional knowledge and constructing the framework of innovative design for carrying out innovative practice.

In the theory of innovation, TRIZ is a series of solving principles of patent problems for invention put forward by Altschuller, a former Soviet scientist. TRIZ is the acronym for the Russian phrase, “Teoriya, Resheniya, Izobreatatelskikh, Zadatch”, roughly translated into English as "Theory of Inventive Problem Solving" (Sheu and Hou, 2015). Its core lies in organizing and managing patent knowledge through technical contradictions to facilitate its reuse in the process of product innovation and design. TRIZ solves how to give reference answers according to the problems and provide ideas and cases to solve technology conflicts. Since the early 1990s, TRIZ theory has attracted extensive attention of researchers in developed countries. Ang improved the standard engineering parameters and inventive principles of TRIZ, updated the contradiction matrix, and supported designers better to solve conflict problems (Ang et al, 2013). Zhang improved the ARIZ algorithm of TRIZ theory and proposed the RLI model based on Germany's WOIS theory, PI theory and MIS theory (Zhang, 2013). Song-Kyoo replaces TRIZ's material-field model with queuing theory model in order to improve the efficiency of problem analysis (Kim, 2011). Chang focus on solving the problem of Ecological Innovation in product design by material-field analysis (Chang, 2005). Yan provided a simple way to master and use the standard solutions (Yan et al, 2012).

Another theory of innovative design is Design Thinking. The concept of ‘Design Thinking’ was first introduced by Rowe in 1987, but has been over- simplified in many industry realms, leaving behind a trail of design thinking experts and a frustrated design research community (Dorst, 2011). More attention is paid nowadays to Design thinking by Tim Brown and the Stanford Design School. They let a large companies and businesses adopt design thinking to solve their complex problems in innovative ways (Brown, 2008). As a result of the link between design thinking and business innovation, many countries are investing in education that integrates design thinking processes, skills and mindsets across curricula, uniting the academic and vocational (Koh & Chai, 2015). Consequently, design thinking is increasingly regarded as an avenue to develop 21st century student capabilities, equipping them with the tools to effectively address the ever-evolving challenges facing global society in the future (Wright &Wrigley, 2017). An individual’s design thinking capability is best acquired through practice, application and experience (Howard, 2012). Expanded from Dreyfus’s (2004) general model of expertise, Dorst represents different ways of design thinking through seven levels of design expertise or practice, with each level having its own method, critical skill set and mode of reflection (Dorst, 2011). Facilitation of design thinking has gained traction in recent years particularly through industry workshops, with many facilitators being from a non-design trained background. As such, the value of design thinking in practice and academia can be diluted by those who have minimal design understanding and expertise. As suggested by Yilmaz and Daly (2016), the success of instruction relies partly upon the facilitator’s ability to provide guidance and feedback on design paths and processes, in order to facilitate a practice where students can learn strategies to fully explore and define problems. It is a systematized process to create new user experiences and opportunities by utilizing the tools and a thinking process that designers use. It’s a significant way of problem-solving, rather than just coloring a product.

2.2 Cooperative Design Tools and Methods

Online collaboration tools can assist learning and practical projects both. In recent years, there are many studies on the learning performance for online tools, while the research about practical projects application are also beginning to increase. Collaboration and product innovation using network platform have become a hotspot. More and more designers, researchers and individuals join in product innovation (Frank, 2009). "Wikinomics" discusses that the large-scale collaboration design can change the world. The book argues that the traditional concept of innovation usually refers to innovation in a closed environment and trying to commercialize it. Today's online collaboration allows small companies or groups to acquire the resources and knowledge they need as large companies without paying a lot.

To discuss appropriate online tools for design collaboration, we need to understand the characteristics of design problems and design activities. The synchronous collaboration is necessary for innovation design like a face-to-face collaboration. Collaborators can directly see each other and obtain rapid feedback. Moreover, there is access to a shared physical environment, which means that other types of visible information are available, such as shared information about physical objects and events (Whittaker, 2002). Olson also addressed one of key characteristics of face-to-face collaboration, called "spatiality of reference." "Spatiality of reference" indicates that "people and work objects are located in space" (Olson, 2000), and as a result, collaborators can communicate with each other by referencing objects in the shared environment. Given the importance of communication based on visual representations (e.g., visual images and hand-drawn sketches) for design problem-solving, a shared physical environment in face-to-face collaboration plays a critical role, especially for visual communication among designers. Because of the merits of face-to-face collaboration, designers in practice come together and conduct problem-solving activities in a project room (Brown, 2009).

Recently, the field of computer science has acknowledged the idea that findings from the domains of psychology and sociology matter to the design of group systems. The design of group systems that support Computer Supported Collaborative Learning and Working integrates knowledge of how people work and learn in groups with knowledge of enabling technologies (Schümmer & Lukosch, 2007). This had led to several requirements for task-related functionality, such as facilities for communication, file-sharing, calendaring and scheduling. However, there are other, often less-obvious requirements (Vick, 1998). These relate to the support of psychological and social processes, which impact group cohesion and team performance, such as group dynamics and people's perceptions of each other. These processes have traditionally been studied in social sciences. As they are essential corner stones for team performance and interaction, they are thus also relevant for team performance in mediated environments. Indeed, according to Ackerman (2000), the main problem in group systems nowadays is the discrepancy between the social needs and expectations of the user and the computer system functionality.

3. Conceptual Framework

The research chooses the Design Thinking for the online workshop's learning materials and design method.

3.1 Design thinking

3.1.1 Definition of Design thinking

Tim Brown, the CEO of IDEO, said, "Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success." (Brown, 2008).

Design thinking is a design concept which focuses on a product that can truly integrate into user's life and be relied on by understanding their internal mental model, the environment, and observing the user behavior. Design Thinking is a solution-based design method to solve problems. This method is extremely useful for solving undefined or unknown problems. It mainly involves the following means: understanding the human needs, re-deconstructing the problem in the human-centered approach, creating more ideas in brainstorming, and applying practical methods in prototyping and testing. Design thinking has developed into an innovation design model which for learning and practice. It focuses on the creativity of the professionals from different majors, from different perspectives rather than the creativity of designers, and generates an innovative idea, product or service. Design thinking refers to the use of designers' sensitivity and design methods to meet people's needs on the premise of technical realizability and commercial feasibility (Sheu and Chiu, 2016). Which explores the Designers' three starting points of thinking: Desirability, Feasibility and Viability. This is the same standards with the "three core" concept of design education in Dutch Delft University, which is "people", "commerce" and "science and technology".

3.1.2 Design thinking process

TRIZ method is an important method of innovative design, but the design thinking method is used in this paper and case. Therefore, the specific process of TRIZ is not described. There are five phase or stages for design thinking process. Understanding the five stages of design thinking will enable anyone to use design thinking methods and solve complex problems around us - in our companies, in our countries and even on our planet (Dreyfus, 2004).

Herbert Simon, the Nobel Prize winner, outlined the first formal models of the process of design thinking in his pioneering 1969 article on design methodology. Simon's model consists of seven main stages, each of them contains smaller stages and activities (Howard, 2012). It has a great influence on shaping some of the most widely used design thinking process models. And there are many variations in the design thinking process used today. Although they may vary in number from three to seven stages, they are all based on the same principles in Simon's 1969 model.

According to D. school's research, the five stages of design thinking are as follows: empathize, define, ideate, prototype; and test. In the thinking model, constant divergence and convergence in the process are adopted until the end for practical use (Sheu and Hou, 2015). The five design thinking stages for our innovative design are shown in Figure 1.

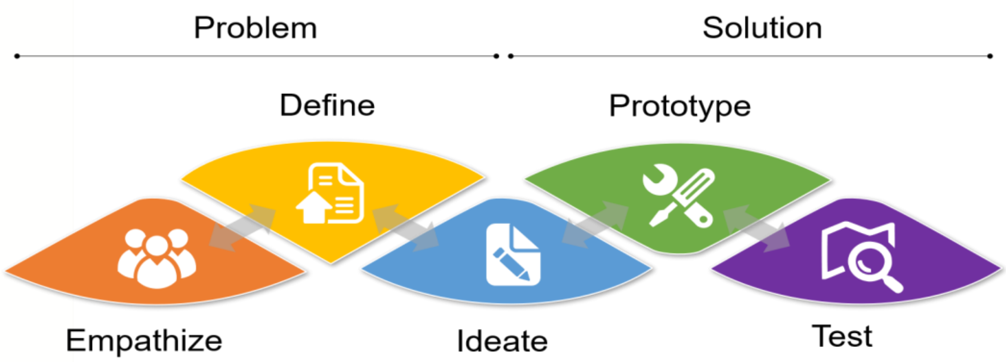


Fig. 1 The five stages of Design Thinking method

(1) Empathize

The first stage of the design thinking process is to gain a sympathetic understanding of the problem you are trying to solve.

This stage involves consulting experts, observing, participating, understanding users' experiences and motivations, and immersing oneself in a physical environment to gain a deeper understanding of the issues. Empathize is very important for human-centered design process such as design thinking. Empathize allows a designer to put aside his or her own assumptions about the world in order to gain a deeper understanding of users and their needs (Wright and Wrigley, 2017).

A large amount of information is collected at this stage so that it can be used in the next stages. Researchers can form the best understanding of users' needs and the problems behind the specific product development.

(2) Define

In this stage, designers can aggregate the information created and collected during the empathize stage. Then the team identify the core issues according to the observations and synthesize the information. The members should try to define problems in a "human-centered " way. Specifically, don't define the problem as their own desire or the needs of the team (Brown, 2009).

Defining the problem will help designers team gather great ideas to identify features, functions, and any other elements that can help users solve problems. Let users solve problems themselves with minimal difficulty at least. In this stage, by proposing problems that can help you find solutions, you will begin to gradually move into the third stage, the ideate stage.

(3) Ideate

In the third stage of the design thinking process, designers are ready to start generating ideas. The members have understood their users and needs in the first stage, and members have analyzed and synthesized their observations in the define stage, presenting the problem with a human-centered approach. With this background, the team members can start thinking outside the box, find new solutions to the problem, and they can start looking for alternative ways to solve the problems (Sheu, Hong and Ho, 2017).

Brainstorming is often used to stimulate divergent thinking and expand problem space. It is important to get as many ideas or problem solutions as possible at the beginning of the Ideate stage. At the end of this stage, members should choose other critical methods to help them investigate and test the ideas to find the best way to solve the problem.

(4) Prototype

The design team will now create a Low Fidelity Model which have a part of functions in products so that they can test the solutions to problems identified in the previous stage. Prototypes can be shared and tested among a small group of people outside the team. This is an experimental phase to find the best solution for each problem found in the first three phases (Brown, 2009).

These solutions are hided in the prototype and tested one by one: they may be accepted, optimized and re-tested, and rejected if the experience is not good. By the end of this stage, the team will have a better understanding of the limitations and problems in the product, as well as the behavior, ideas and feelings of real users when interacting with the product.

(5) Test

Designers or evaluators use the final solutions identified at the prototype stage to test the entire product. This is the last stage of the five-stage model while but in the iteration process, the results of the test stage are often used to redefine one or more problems and inform users of their cognition, usage conditions, way of thinking, behavior and feelings. Even at this stage, changes and improvements are ongoing to get the best solution and to get as much insight into the product and its users as possible (Brown, 2009).

3.1.3 The key points of "design thinking"

(1) Visualization and prototype: Designers use mind mapping, design sketch or prototype to visualize their abstract thinking to seek new ideas. Visualization and prototype enable designers to convey ideas faster than words.

(2) Iteration: Repeated the update-test-feedback-update process in the design process. Try to make the prototype better and better.

(3) Interdisciplinary: Design thinking emphasizes cooperation by people from different majors. In IDEO, a design team usually consists of three or five people, who come from various fields such as economics, business, psychology, engineering, design and even medicine. They choose different relevant professionals according to the project need. People from different majors observe and discuss from different perspectives could form a more comprehensive view and creativity.

(4) Divergence and convergence: The contradiction concepts, divergence and convergence, exist at every stage of the design process. First, designers converge the divergent thinking to continue the design process. Second, the divergence of creativity needs the constraints of technology and commerce. Only when these two contradictions are reconciled can the innovation design succeed.

More attention should be paid to users themselves and their environment rather than their behavior. Designers devote too much energy to thinking about how to make the product useful or beautiful and interesting. More and more companies begin to pay attention to the appearance, interface and operation experience of products. It is vital to consider "who will use it", "why they use it", "when and where to use".

(5) The Nonlinearity of Design Thought: The team may have a direct and linear design thinking process, which runs in a logical way. However, the process is more flexible and non-linear.

3.1.4 Summary

Essentially, the process of design thinking is iterative and flexible, focusing on collaboration between designers and users, focusing on turning ideas into reality according to the thinking, feelings and behaviors of users. Design thinking solves complex problems through the following methods:

(1) Empathize: understand the needs of the users involved;

(2) Define: reorganize and redefine issues in a human-centered approach;

(3) Ideate: create many ideas in the creative stage;

(4) Prototype: develop prototype/solution of problems;

(5) Test: constantly test the prototypes.

One of the main advantages of the five-stage model is that the knowledge acquired later can be fed back to the early stage. Information is constantly used to inform understanding of problems and solutions. This creates a permanent cycle in which designers always gain new insights, create new ways of looking and possible uses, develop a better understanding of users and the problems they face.

3.2 Online collaboration tools

The most common conception of design problems is to consider them as “ill-structured” problems (Détienne,2006). Initially, there is no definite criterion to test a proposed solution, much less a specific process to apply the criterion to (Herbert, 1973). To solve this type of problem, designers collaboratively conduct their process with rapid explorations of the problem and solutions in tandem, rather than following linear stages (Andrew, 2010). Accordingly, design activities for the problem and solution (e.g., information gathering, analyzing, idea generating, and evaluating) are also performed in parallel and iteratively. Due to the interrelations of activities, design problems are difficult to decompose into independent sub-problems (Olson, 2000). For this reason, designers work closely together during the whole process rather than working independently and combining the outcomes. According to the standard of synchronous collaboration, we divided the online collaboration tools into the function based on interacting with others and shared resources (graphics, documents and 3D models) in the group. Its application scenarios are divided into four aspects: communication session, resource sharing, process participation and model making according to the five steps of design thinking. We analyzed the common online collaboration tools to explore how online collaboration tools can be applied to innovative design. The figure 2 shows the match between online collaboration tools and design thinking process.

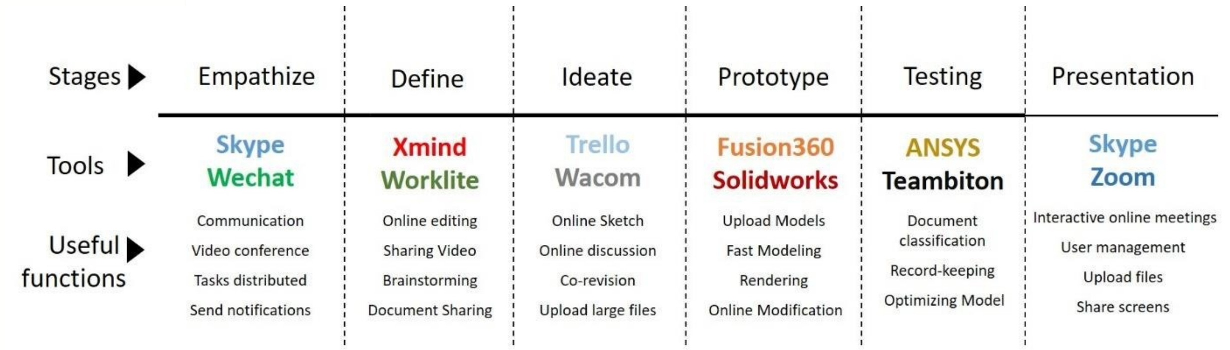


Fig. 2 The useful functions of online collaboration tools to Design Thinking process

Three major software company, Microsoft, Google and Apple, have launched their own online collaborative work platforms. The Office, Google Docs and iCloud all use cloud technology, which can create, edit, store, synchronize and share files online anytime, anywhere on different devices. People can cooperate with others to edit documents. These three platforms are undoubtedly the most powerful in terms of function. But for various reasons, they also have great limitations. For example, the high cost of Office 365 makes it difficult for ordinary users to bear. The Google Docs is limited by policy, and it is difficult to use it in some place. And iCloud is also difficult to promote in a wide range due to Apple's relatively closed hardware and software environment. In addition, many Internet companies have developed their own online collaboration tools. In recent years, several excellent collaboration tools have emerged, such as Dow Cloud, JingOal, Shimo, Teambition, Worktile, Zoom, Trello, ZOHO, Quip, Show-Document and so on. These collaboration tools are more lightweight and focused on one kind of work. The online tools should be easily upload, download and edit the common document, know when and where members doing for their task. We test the online collaboration tools for our workshop to see the functions of these software. Many online collaboration tools have the potential to be applied to innovative design. We need test them by the workshop to figure out their specific functions and application scenarios.

4. A Case Example

4.1 Case Background

This instructional program is designed to support the IDEEA global project for 2019 in collaborative design and engineering. The program instructional methodology will be to deliver at least one sequential instructional video each week during the program 10-week period. Each video will be delivered via both a dedicated IDEEA website and a YouTube Channel that can be viewed at any place in the world at any time as many times as desired if Internet access is available. The videos directly on the website and the same unlisted videos with YouTube URL links will be provided so that only the IDEEA participants can view them. It is intended that each participating IDEEA student team and mentors will view each video in sequence and apply the content to their project design and development as needed. The website and videos are designed to assist all the participating IDEEA project teams in Design Thinking and product design and development process, principles, skills and tools. The whole process will be online teaching and design without face-to-face communication.

4.2 Participants

There is a collaborative global teamwork on this project with student teams, guided by a team faculty mentor, that will develop, build and simulate a final drone concept. Individual team members will also develop and document their own project work appropriately. Each team will divide the project work up among the team members for developing the final integrated design concept.

The students were divided into 20 groups and there were 6 to 8 members in each project team, 2 from the same school of 4 global universities. Each team member will have specific tasks for the project development as well as general overall design input responsibility. Each student will be expected to do design research and document it, do brainstorming and idea-sketching and document it, do mockup making and CAD modeling and document it, and do user testing and validation and document it. The Design Thinking process works very well, but only if one applies it diligently and thoroughly. For the mentors to know if the process and work is actually done, students must document all their work diligently. The whole collaboration design process is online except the two students from same school can work together.

4.3 Procedure and Tasks

Student project teams and mentors will be introduced to the art, process and practice of physical cyber product design and to the product design process via Design Thinking. Student teams, with guidance and support from their mentors, will each research, develop and mockup a new physical smart cyber product design concept that resolves a human-centered need as a program project within fixed category parameters based on a design brief. All students will learn and execute required Design Thinking empathic research, project definition, brainstorming ideation with sketching, making with mockups and CAD modeling, and testing with design simulations. Students will work as project teams on their project with outside collaborative support teams as needed. Basic instruction via videos will be provided for required program processes, methodologies and skills. A final project and mockup presentation will be required for each student project during a final program event in the summer of 2019. Modern physical smart cyber product design is multidisciplinary and collaborative, integrating designers, engineers, various professionals, customers, users, and stakeholders, all from various disciplines, as well as the integration of smart cyber technologies into physical systems. This program will reflect that approach and will enhance students' collaborative teamwork experience, communication skills, and exposure to the various disciplines. This is a hands-on program that mixes video tutorials, experiential learning, field project research and execution work, and collaborative teamwork. Student teams will conduct a mentor-guided project that will include human need-finding, design research, project definition, concept ideation, mockups/simulations/modeling, testing and validation, and refinement of a final tangible physical smart cyber product system concept in mockup form. There will be a final presentation and display of student project team concepts, mockups, models, and process summary.

This project will follow the standard Design Thinking process of five modes or phases in stepped linear sequence, though several modes may be either utilized at one time or revisited more than once for proper project execution. Instruction for each project process mode/phase, as well as the associated skills and materials, will be provided to the teams online.

(1) Research: Intuitional/Contextual/Discovery empathic research-includes notes, images, media, video, sketches, interviews, etc., of real drones and drone situations, existing drones, components, users and customers, related issues, and data, all researched and developed by the student team.

(2) Define: Team project design a one-page project design brief written by the project team that summarizes their research and found needs, and defines their direction for their project development and target solution.

(3) Ideate: Concept ideation and Innovation-includes team brainstorming of ideas and basic 2D ideasketches of concepts, ideas, processes, charts, diagrams, graphs, etc., based on research findings of issues and needs in the Project Design Brief.

(4) Prototype: Concept simulation via mockups and CAD models-multiple ideas and concepts in physical and digital 3D for possible solutions to overall design, modules, subassemblies, problems and needs.

(5) Test: Concept testing and validation-testing and validation of concepts and ideas using low-fidelity and high-fidelity mockups and CAD models with users and relevant stakeholders and situations to get responses, feedback and critique for the selection of best concepts for a final version.

(6) Presentation: Final refinement and presentation-combination/synthesis/integration of best ideas and concepts based on testing research and finalization of design solution in 2D media and 3D concept form in mockup and CAD model. Preparation of final team design solutions and presentation of research, ideas, sketching, mockups, models, process and design/solution results during a summer 2019 all-team IDEEA event TBA. Table 1 is a general summary of the above tasks. Participants at each stage need to collaborate to complete the following tasks online all the time.

Table 1 The tasks of innovation design at each stage

Tasks of stage	Context Research	Empathize	Definition	Ideation	Prototype	Testing
Task 1	General attributes &considerations	Interviews development	Overall document design	Application idea-sketches	Low-fidelity mockups for early testing	Testing setup & coordination
Task 2	Existing design & features	Personas development	Heading& summary statement	Component idea-sketches	CAD model of components	Early low-Fidelity mockup testing
Task 3	Technologies available	Surveys development	Key points/bullets	Controls idea-sketches	CAD model of overall design	Final mockup/model testing
Task 4	Applications possible	Observational research development	Editing, grammar, terminology	Module idea-sketches	CAD model of structure	Data presentation & analysis

4.4 Analysis

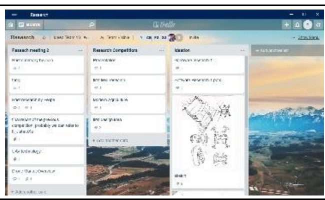
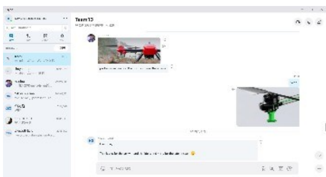
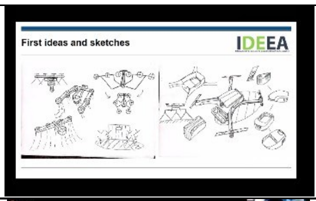
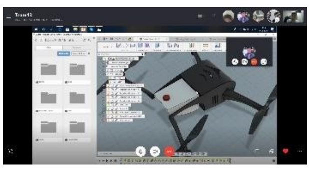
After the IDEEA's innovation design, we choose the Team 13 for a survey which include a questionnaire about the usability evaluation for the online collaboration tools they use and an in-depth interview. They basically use the online collaboration tools throughout the whole design process. The background information about the team members shows them is composed of typical multidisciplinary members with different majors and nationalities, as shown in Table 2.

Table 2 Background information of Team 13 members

Numbers	Region	Major	Online tools level	Design level
Member 1	Germany	Engineering	Skilled	Skilled
Member 2	Germany	Engineering	Ordinary	Skilled
Member 3	Brazil	Art	Skilled	Skilled
Member 4	Brazil	Engineering	Skilled	Ordinary
Member 5	China	Engineering	Ordinary	Ordinary
Member 6	China	Engineering	Ordinary	Ordinary
Member 7	China	Art	Skilled	Skilled
Member 8	China	Business	Skilled	Ordinary

After the IDEEA's innovation design, we choose the Team 13 for a survey which include a questionnaire about the usability evaluation for the online collaboration tools they use and an in-depth interview. The design process of group 13 is relatively successful while the team were composed of students from different cultural backgrounds. Unlike some groups have high percent students with the same cultural background. They basically use the online collaboration tools throughout the whole design process. The background information about the team members shows them is composed of typical multidisciplinary members with different majors and nationalities, as shown in Table 3.

Table 3 Outline of the IDEEA workshop, April 2019

Schedule	Activities		Online tools	Functions used
Week 01 Breaking the ice	Introduction and Overview, Select topic		Skype, WeChat	Real-time editing, Sharing files, Real-time communication,
Week 02 Empathize	Contextual and Discovery Research		Trello, Teambition	Sharing files assigning tasks, Saving dialogues, Progress tracking
Week 03-04 Definition	Identify needs, Definition report		Skype, Shimo	Divergent & Convergent thinking, Document classification
Week 05-06 Ideation	Brainstorming, Sketching, Ideation report		PowerPoint, ProcessOn	Sketch, Visualization Uploading files
Week 07-08 Prototype	Mockup making, CAD modeling, Refinements		Fusion 360	Rapid prototypes, Easy learning, Cloud storage,
Week 09 Testing	Execute testing, Validation		Fusion 360, Skype	Communication, Field research, Personalization
Week 10 Presentation	Deliver presentations		Zoom, Skype	Setting permissions, Speech, Video Conferencing

This paper mainly focuses on the efficiency of online collaboration and the advantages and disadvantages of collaboration tools, providing methods and tool references for future online collaboration. This kind of collaboration among students from different regions and backgrounds is a potential innovative design form in the future. So, we choose five usability items from the research. There are five usability evaluation items for the team members' questionnaire for the online collaboration tools they use. The checklist was based on Jakob Nielsen's traditional usability heuristics and to suggest usability areas that need more investigation (Norman and Nielsen, 2010). Participants evaluated five usability indicators of each software, and 1-5 points represented the degree of poor to excellent. Figure 3 shows the average values of 8 participants' usability evaluation for 6 online collaboration tools.

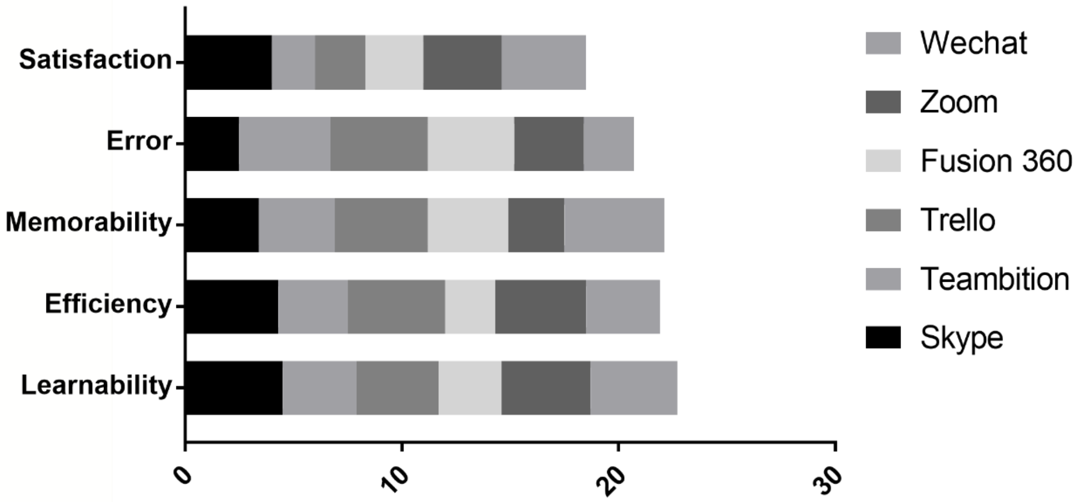


Fig. 3 The Mean of Usability Evaluation for the online collaboration tools

From the data analysis in Table 4, Skype and WeChat have a better overall usability performance. Trello is also quite concise, but it focuses on text work makes someone unsuitable for innovative design. For example, some people mentioned that uploading files is too limited and they cannot have real-time conversations. In addition, Zoom is a software that only suitable for giving speeches or meeting without saving records. Surprisingly, professional teamwork software such as Teambition has been abandoned after trying it out. Maybe its functions are too complex and redundant.

Table 4 Usability Evaluation for the online collaboration tools

	Skype	Teambition	Trello	Fusion 360	Zoom	WeChat
Learnability	4.5	3.4	3.8	2.9	4.1	4
Efficiency	4.3	3.2	4.5	2.3	4.2	3.4
Memorability	3.4	3.5	4.3	3.7	2.6	4.6
Error	2.5	4.2	4.5	4	3.2	2.3
Satisfaction	4	2	2.3	2.7	3.6	3.9

5. Conclusion

Our research revealed that the online collaboration tools may promote innovative design of multi-disciplinary members, though it is not evident that online collaborative tools promote innovation, probably it promotes process efficiency – in terms of cost and time reduction. The implication of the study is that the design tasks of the workshop are completed by each team with almost no traditional offline collaboration with good performance. It is feasible for people in different areas to collaborate and complete design activity online. On the one hand, this case experience can be extended to other kind of collaborative work. Online collaboration tools allow more resources to be integrated, and promote the development of collaborative design for other work like Medicine or Industry work. On the other hand, through the usability evaluation and interview for the members, we can improve the functions of online collaboration tools to make it more suitable for collaboration design rather than just for commercial collaboration. In order to increase the online collaboration tools contribution to innovation design, some suggestions are proposed based on the analyzed results of interview and evaluation.

For the online collaboration tools, we could do the modular design and adjustment according to the requirements of design, commerce or medicine projects. Full-featured online tools can cause too much interference to users. The normal online collaboration tools are inappropriate for other kind of tasks, such as Trello which is inappropriate for design activities. At the same time, online collaboration tools need more personalized settings. People play their own roles in the team. They may need their own setting to expand certain functions. If several tools can't complete the project, users will have to use more online tools at the same time. Too many tools would reduce the efficiency of teamwork badly.

For the online collaborative tools for innovative design, design activities need divergent thinking and multi-dimensional interaction. Designers need to share resources such as text, pictures, voice and video. Online tools should be able to upload and save these resources. Secondly, the design thinking process often needs to tract back to the previous process. It is very important to keep and classify the records. Designers need the multi-equipment communication to support people to communicate anytime, anywhere. And people may use different languages and need images instead of words for information design so that everyone can understand them. In addition, in collaborative design or collaborative learning, it is necessary to add a managerial role in job interviews. There were some members avoid responsibilities and work because of no statistics of their workload in the online collaboration tools. Joining managers or showing the amount of work each person has accomplished can urge everyone to contribute the team and promote the efficiency. In the future study, we should consider these problem and try to make the research more convinced.

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Author Biographies

Zhinan Zhang is an Associate Professor at Shanghai Jiao Tong University since 2013. Zhang received his Ph.D. degree in Shanghai Jiao Tong University.

He is currently an ASME Member and Senior Member of the Chinese Mechanical Engineering Society, Guest Editor of Journal of Shanghai Jiao Tong University. His areas of interests include Design engineering and innovation, Tribo-system design and analysis.

Zhao Yu is a Ph.D. student at Shanghai Jiao Tong University since 2017. Yu received his Master of Engineering from Southeast University. He is Student member for Institute of Electrical and Electronics Engineers (IEEE), Member for The Chinese Society of Academic Degrees and Graduate Education (CSADGE). His areas of interests include Interaction Design, Ergonomics and Social design.