YOUR DESIGN JOURNEY

YOUR DESIGN JOURNEY:
A LEARNING DASHBOARD FOR DESIGN THINKING

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Abstract

All teachers faced challenges adapting to teaching during the pandemic. This research was motivated by challenges specific to mentoring students working in teams on design projects for the first time. Using Design Thinking (DT) to design a virtual environment for teaching DT, we conducted a series of interviews and focus groups with our teaching team, and developed four generations of prototypes to solicit increasingly detailed feedback. Our final product is a semi-functional prototype which presents a clear vision of a Progress Widget which can serve multiple purposes for both student teams and their mentors. It is an adaptable map of the design journey, a gateway to a resource library with descriptions of each DT step available when and where students need them, a gauge of progress within the design journey, a communication hub to collect notifications, and an overview tool allowing mentors to see individual contributions to the overall project and to each design step in the journey.

Dedication

I would like to thank my heartfelt appreciation to my esteemed supervisor Dr. Christopher Anand, for his enduring support, invaluable guidance and encouragement throughout my master's journey. I wouldn't be where I am today without his mentorship. I am very grateful for the opportunity he provided me to learn and grow under his guidance.

I would like to thank Dr. Swati Mishra for being on my commitee and providing valuable suggestions throughout this process, especially about Designerly Ways of Knowing and research methods in HCI.

I would like to thank my friends and DT mentors Padma, Akshay, Jamie, Habib, Chris, Sheida, Maryam, Tina, Gurleen, and Gabrielle for their support, and time and for providing invaluable inputs during the interview and focus groups. I especially want to thank Sheida for her support and for providing valuable suggestions.

Lastly, I would like to express my deepest gratitude to my loving mother Parani who has been constantly encouraging and my adorable son Adhidheeran for being the pillars which have enabled me to pursue my degree.

I am blessed to have such extraordinary persons in my life who have been motivating me towards my academic and personal development.

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Abbreviations

DT	Design Thinking
LMS	Learning Management Systems
HCD	Human-Centred Design
UCD	User-Centred Design

Chapter 1

Introduction and Background

Our research lab and student group McMaster Start Coding have developed a practice of teaching Design Thinking (DT) to undergraduate students, graduate students at McMaster, community members, children in Canadian schools and students at international partner institutions. Because of the range of teaching and the demands of teaching during the pandemic, we have developed techniques for teaching virtually. In order to improve and scale up our teaching, we started this design journey, initially focussing on challenges specifically when teaching virtually across borders. In addition to teaching DT, we introduce thousands of children to graphics coding, which is only possible with the support of our web-based development environment, STaBL.Rocks, which includes context-aware chat where children can ask mentors for help. [7] Our experience with the web development environment suggested that web tool support could also help with DT training.

Part of "designerly ways of thinking" is to frame the problem in a general way to allow for more creative solutions, so initial interviews were designed to be open-ended. After those interviews, we discovered that mentors viewed teaching large classes as

their main challenge. This allowed us to shift the focus to tracking team progress and individual contributions.

1.1 Research Questions

Design is a creative process different from most classroom activities. Some university students will never have been asked to make the types of decisions central to the design process. As a result, they are unsure how to proceed and need encouragement to make decisions and help in articulating the reasoning behind their decisions. Interacting with an experienced instructor is a good way to develop the needed skills and self-confidence.

When teaching large classes, with higher student:teacher ratios, teachers have less time to interact or provide feedback to teams and individual students. In for-credit courses, it is also necessary to provide grades in a uniform way. In virtual teaching, teachers also face challenges tracking student progress, but in this case, because they cannot watch the teams interact, and must rely exclusively on their interaction with digital tools.

RQ1. What difficulties did mentors face in providing feedback and tracking team progress when teaching many teams (in person or virtually), and how could those difficulties be mitigated with tool support?

Learning Design Thinking involves doing group activities from problem definition to building a prototype. Each task has a lot of brainstorming and group discussions. Unlike marking other courses, DT courses require a grading mechanism to identify the individual student contribution within group work. What difficulties did instructors face in trying to track the individual progress? In particular, when evaluating the

DT worksheets.

RQ2. What difficulties did the mentors face in tracking individual student contributions and how could those difficulties be mitigated with tool support?

Students after receiving feedback from mentors should modify their work accordingly. This is easy to track in discussions between a mentor and a single project team meeting in person. It is harder for a mentor to keep track of multiple projects, and know which changes are responses to which comments from the mentor or from the user. These are important considerations, but we will not consider them in this phase of the design, which does not involve students.

1.2 Contributions

In this thesis, we have developed a Progress Widget to help mentors track the progress of learning DT and facilitate learning it for student teams. To ground this work, we created a summary of existing tools for design, teaching-learning, and virtual collaboration. Summarized in a comparison chart, it is easy to see how different tools contain different features relevant to teaching DT which we propose combining in a new tool focussed on teaching DT.

This proposed Progress Widget incorporates the visualization of divergent and convergent thinking of the Double Diamond, but unlike the Double Diamond, our Progress Widget makes every task visible so it can be used as a navigation to the DT steps for both Design teams and the mentors.

Furthermore, this design was based on the detailed insights from 6 DT mentors captured in three rounds of interviews, three focus groups and two written interviews.

A table collecting the results of a Thematic Analysis of this feedback presents the three identified themes and nine sub-themes based on the mentor feedback. This thesis also describes the four iterations of the Progress Widget including multiple alternatives. It details the features, mentor feedback for each version and the Action Plan developed at each stage. These plans were designed to incorporate mentor suggestions and to gather more specific feedback, particularly for features where there was agreement on the need but no clear consensus on the best approach to address it.

1.3 Structure of the Thesis

The rest of the thesis is organized as follows: Chapter 2 provides a literature review, discusses various techniques, features for a virtual environment, challenges faced in teaching virtually, and also the British Design Council's Double Diamond. Chapter 3 provides a detailed summary of the existing tools such as Miro, Mural, Github, Learning Management Systems (LMSs), and Google Slides which also includes a description of existing worksheets that are used by our team to teach DT. Chapter 4, where the Progres Widget has evolved, describes the prototypes and experiences used to solicit feedback via interviews, focus groups, and written interviews, and also includes representative quotes and Action Plans developed. This is presented in chronological order and includes initial interviews which led to the focus on the Progress Widget and four versions of the Progress Widget. Chapter 5 concludes the thesis with a high-level summary of the design journey including a tool comparison chart of existing tools and the proposed Progress Widget, answers to the research questions, a table summarizing the results of the thematic analysis of mentor feedback, and future research directions.

Chapter 2

Literature Review

There are three overlapping terms in the literature

- Design Thinking
- Designerly Thinking
- Designerly Ways of Knowing

In this thesis, we will make a distinction between these terms to focus on the more prescriptive Design Thinking, while at the same time acknowledging the critiques of Design Thinking. We then survey the work on online platforms supporting Design Thinking, and creativity in general, but in virtual and hybrid settings. To integrate this theoretical foundation into our design work, we make use of the Grounded Theory.

2.1 Designerly Thinking versus Design Thinking

Lawson [15] says "designerly thinking is a practice-based approach to solving problems, making sense of things, and developing new knowledge." The Interaction Design

Foundation [11] adds that "Design Thinking is a non-linear, iterative process that teams use to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test." Finally, Donaldson and Smith [5] states that "the literature around designerly ways of knowing describes a set of cognitive skills and approaches unique to design experts. This line of research is interested in describing the cognitive strategies and mindsets typical for experts in design." The distinction we observe, is the focus on explicit processes in Design Thinking.

Cross [4] argues that design education should be designed to add educational value rather than focus on technical skills, since design is about a different "way of knowing." Design education should be designed to develop "students intrinsic cognitive processes and abilities." He also lays out three motivations for including design in education:

- "Design develops innate abilities in solving real-world, ill-defined problems."
- "Design sustains cognitive development in the concrete/iconic modes of cognition."
- "Design offers opportunities for the development of a wide range of abilities in nonverbal thought and communication."

2.2 The Critiques of Design Thinking

Laursen and Haase [14] mentioned the differences between Design Thinking and Designerly Thinking. Designerly Thinking is focussed on paradigms and methodological approaches whereas Design Thinking focuses more on "suggestions for actions", tools, and techniques. The second major difference is the mode of communication. Designerly Thinking helps designers to adapt to different problems and ensures situated

actions are taken. Design Thinking uses "suggestions for actions" and is described as a cookbook format for important phases and tools for each phase [14].

The research reveals that Design Thinking lacks the methodological approaches to integrate the actions and to tailor those actions based on the unique challenges of the project. As a result, Design Thinking does not provide the designers with sufficient guidance in selecting, adapting and using design tools and techniques. The implications are that Design Thinking received a lot of criticism as a concept and did not support non-designers who failed to provide guidance on how to engage in situated actions and suggested identifying and unfolding methodological approaches for Design Thinking.

Kimbell [13] raises a different criticism of Design Thinking: that, as practiced, it is too abstract and ignores the specifics of different industries. Her criticism is based on recent recommendations for applying Design Thinking at the level of big businesses. These criticisms do not make sense in the context of teaching beginners (first-year engineering students, or elementary school students).

2.3 Critique of Designerly Ways of Knowing

In contrast, while "designerly ways of knowing" have not faced much direct critique in the literature, they can be criticized for failing to follow the principle of "show, don't tell." The aims expressed by Cross [4] and others are noble, but beginners are likely to forget the abstract motivations promoted by proponents of this approach. Without ample opportunities to apply these concepts, students are also likely to revert to familiar habits. In typical classrooms and large lecture sections, it is difficult to closely monitor multiple project teams and guide them in mastering these new ways of

thinking. Design Thinking, by being more prescriptive, may result in better outcomes by providing clearer guidance on what steps student teams should take next.

2.4 Online Platforms for Teaching Design Thinking

Wang et al. [26] have done research to identify the problems in existing teaching platforms in China. The online platforms in China possess a lot of drawbacks including unstable or congested networks, functional aspects of teaching platforms causing inconvenience to students and the support to the online platforms for effective classroom interaction is not sufficient. A semi-structured questionnaire focussed on the problems that arose when the participants attended online sessions and the user's thoughts on the teaching platform. The main problems include the "inability to discuss and communicate face to face, the inability to interact directly, and poor communication between team members." "A teaching experiment was conducted to explore the problems of the online Design Thinking workshops and they were summarized into 4 categories: Technology, Collaboration between groups, Insufficient interaction between teachers and students, and Lack of atmosphere." [26]

Zaqoot et al. [29] stated that for innovative courses like Design Thinking, Online White Boarding (OWB) provides support and is easy to install. People with creative mindsets understand and use OWB for the first three stages of Design Thinking (Empathize, Define, and Ideate). Students with fixed creative mindsets should avoid using OWB as it is difficult for the Prototyping stage. Students believed OWB was very effective in collaborating and communicating ideas in all the Design Thinking

stages during their design project and provided a structured way to adopt the DT approach. It also supports tertiary education level teaching of Design Thinking.

2.5 Learning Activities for Design Thinking Course

Gan and Ouh [8] observed applying the experiential learning method in a Design Thinking course with a list of learning activities. A survey was conducted on a 13-week course where during the Week 1 and 2 students proposed their projects. Weeks 3 to 6 had the first Iteration. Weeks 7 to 10 had the second Iteration where Week 8 had a break. Finally, Iteration 2.5 continued till Week 13 and there was a presentation at the end of Week 13. A survey was conducted after the last presentation with 104 students focussing on individual learning activities and the overall design of learning activities. The goal was to find an effective learning activity to achieve their learning outcomes, considering their instructional guidance and time spent on these learning activities. "Are the learning activities effective for the students to achieve their learning outcomes?" [8]

The findings include the students preferred to put more effort into a smaller number of iterations. Coding of the design improves their learning outcomes, but there were comments about the workload that it is getting increased. Instructional guidance has an impact on novice students. The complexity of the course increases later in the semester as the students use prototyping tools for high-fidelity prototypes.

2.6 Double Diamond

Baker III and Moukhliss [3] stated Design Thinking is a problem-solving approach

and a package of simplified design practices that fit in a ready framework to address the potential challenges in a broader setting. Design Thinking also addresses real-world challenges and is considered a rigorous practice utilizing creative and innovative approaches to solve the problem.

Zhang and Dong [30] defined Human-Centred Design (HCD) as "People-Centred Design"[30], "User-Centred Design (UCD)"[30], "Person-Centred Design"[30], and "Client/User-Centred Design"[30]. ISO 13407 states a formal definition as "A systematic approach to interactive systems development that focuses especially on making systems usable."[30] "The characteristics of HCD in the field of product design are summarised as:

- The central place for human beings
- Understanding people
- Multi-disciplinary collaboration
- Involving users throughout the design process
- Making products or services useful, usable and desirable

"[30]

Melles et al. [17] mentioned that "Human-Centered Design (HCD) is an approach to interactive systems development that aims to make systems usable and useful by focussing on the users, their needs and requirements, and by applying human factors/ergonomics, usability knowledge, and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability, and counteracts possible adverse effects of use on human health, safety, and performance." [17] Human Centred Design ensures that the designed product is understandable and usable, meets the user's needs and accomplishes the desired

tasks. A good design should overcome many constraints such as usability, understandability, quality, cost efficiency, reliability, and effectiveness. HCD addresses these requirements and ensures the right problem is solved by meeting human needs. The Double Diamond approach was effective for the designers in clearing distractions and focussing on the actual problem and solution. Designers usually begin by questioning the given problem, expanding the scope of the problem to find the underlying issues and converging on one problem statement. In the solutions phase, they explore the space of solutions and finally converge to a single proposal. [17]

"The Double Diamond features two regions of divergence and two regions of convergence. The divergence phases involve research and exploration while the convergence phases involve narrowing down ideas and determining which ideas are most important to the problem being addressed." as mentioned by Anand et al. [2].

It has four phases: Discover, Define, Develop, and Deliver. According to Anand et al. [2], the convergence phase involves research and exploration and the divergence involves narrowing down the ideas and choosing the important idea to address the problem. The divergence phase involves the online search, reading books and interviews. The first phase of divergence starts by choosing a group of people to whom we might have access throughout the Design Thinking process. They are the target audience and the interview data and the solution feedback would be collected from them throughout the DT process. The next quarter of the Double Diamond is the Develop phase which develops the chosen solution. To develop the solution, various DT tools such as brainstorming, sketching, and prototyping. The final Double Diamond is the Deliver stage, where the final solution is launched and tested.

Tschimmel [23] stated that the British Design Council created a Double Diamond

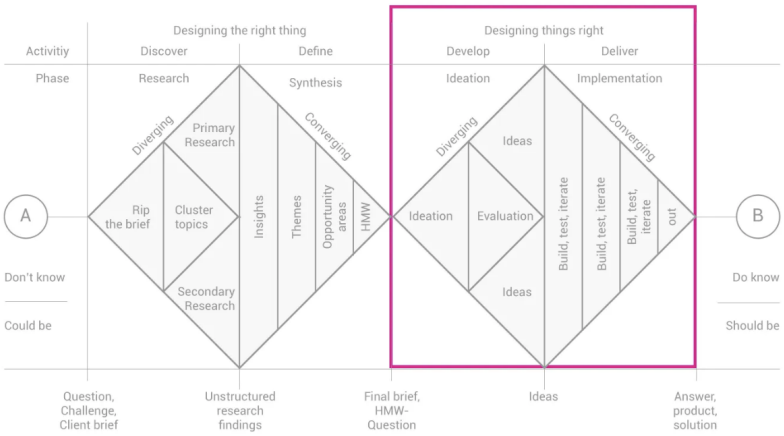

Figure 2.1: Double Diamond approach

in 2005.

- Discover
- Define
- Develop
- Deliver

2.6.1 Discover

United Kingdom Design Council [24] mentions that this phase is the beginning of the project, which starts by identifying the target users, gathering insights about the end users, and their needs and creating initial ideas. The first half of the Double Diamond allows the designers to gather insights, develop opinions on what they see and decide on interesting and inspiring new ideas. In this DT stage, the designers identify the target audience and gather insights from them. Interviewing is done at this stage followed by the Research.

2.6.2 Define

This represents the second half of the first Double Diamond. During this phase, the designers understand the gathered information in the Discover phase. They also try to realize what is important, and what would be the first step to do. The final objective of this phase is to develop a creative design challenge. This phase involves the task of transferring the Interview notes to the Empathy Map and defining the problem.

2.6.3 Develop

The third half of the Double Diamond focuses on creating the solution for the identified problem. Then the created solution is prototyped, tested, and iterated. This iterative process helps the designers to enhance their ideas and create better solutions. This phase has the tasks of updating the Game Generator table, plotting the Desirability Feasibility matrix, using a drawing tool to sketch the prototype and finally updating the prototype based on the user feedback using the Feedback Grid and the Action Plan.

2.6.4 Deliver

The final half of the Double Diamond is the phase where the final product is finalized and launched. This involves the final testing of the prototype, evaluation, and feedback.

2.7 Creating Virtual Environment for Design Thinking

Gebbing et al. [9] conducted a virtual Design Thinking workshop at German International University. A qualitative thematic analysis evaluated user feedback from 38 International students from Asia, Africa, America, and Europe. The analysis involves a grounded theory approach followed by thematic analysis. The first level coding scheme has five dimensions:

- Functionality
- Process
- Affordances
- Collaboration
- Mood

Design Features and Design Principles were identified as a result of the Design Science Research approach. Seven Design Principles were prioritized for virtual collaboration:

- Providing rich resources for creative thinking.
- Technical problems and connectivity issues must be rectified.
- Environment should foster social presence and interaction.
- Effective communication and visualization.
- Methods and technologies must be adapted to the creative process and individual needs.
- The group work benefits from structured but flexible tasks and time management support.

- Provide space for individual work.

These Design Principles were implemented in a prototypical environment for online Design Thinking workshops. The implementation of the virtual environment for an online Design Thinking workshop has the following five features:

- Design Thinking Process: The Design Thinking process was visualized with six iterative phases.
- Creative methods and templates - Experienced supervisor provided instructions, mentoring and support to their learning experience.
- Digital whiteboards - Online collaboration platforms for creative interactions, following each other or creating polls.
- Communication - MS Teams for video conferencing, screen sharing, chat, and breakout rooms. (Private breakout room to discuss how they feel, what they feel, and how they want to collaborate.)
- Supervision - Qualified Design Thinking coaches who facilitated the workshop can be contacted via chat and video call.

Potthoff et al. [20] examined the capability of digitalizing DT methods using the example of Service Blueprinting. A DT method is translated into a digital application and that prototype is evaluated in terms of mindset, motivation and collaboration. This article evaluates a self-developed prototype with its ability to digitalize utilizing web-based collaboration tools. Design Science Research approach is used and evaluated as a web-based prototype. In-depth user tests were conducted with DT experts as a first step and the second evaluation included the user acceptance and motivational aspects. The studies confirm that the digital tool encourages the mindset for the Blueprinting and it has acceptance and suitable for collaboration.

2.8 Motivating Creativity in Hybrid Teams

Gebbing et al. [10] explains how creativity can be embedded in a hybrid environment. A study was conducted with a one-week hybrid Design Thinking workshop to record the experience and behaviour of the participants. The primary objective was to gather and use insights in a creative hybrid collaborative environment. 3 themes emerged out of this study that regulate creativity in a hybrid environment: Functionality, Satisfaction through Progress, and Satisfaction through Collaboration.

The findings confirmed the importance of a hybrid setting which gives the participants freedom and flexibility by enhancing creative collaboration with technical and physical functionality. There were also suggestions to enhance the effectiveness of hybrid teams through communication tools and there can be alternates between the hybrid and remote work for the convergent and divergent activities for successful creative collaboration. Suggestions were also added that team collaboration was positive when the participants established a connection, social presence, explicit facilitation, and effective communication tools. As a result, this study confirms that a hybrid environment for convergent and divergent tasks with the above 3 themes can enhance creativity.

2.9 Using Grounded Theory Analysis to Understand How Design Thinking is Used in Industry

Grounded theory analysis is productive in Learning Management Systems (LMS) to understand user requirements clearly and for building collaborative user interfaces.

Venkatesh et al. [25] state in their literature that the data samples involved detailed case studies of in-depth interviews, company brochures and websites, and design work of 12 companies with very high design profiles. Semi-structured Interviews were conducted with managers between 90 to 120 minutes to capture what design is from a design professional perspective and what criteria they use to identify which products can be launched into the market. The author has used grounded theory analysis and coding techniques to extract central themes from 400 pages of narrative text. 6 analytical themes were extracted along with 3 sub-themes for each theme along with 6 propositions. The findings are Design Thinking with aesthetic vision including notions of creativity, customer-oriented, integrating organizational goals, and winning customer hearts rather than minds could be the driving force for the organization.

Yi and Li [27] stated that Grounded Theory Coding could help the designers in accurately gathering user requirements, build directions for visual design and provide improvement ideas in increasing product competitiveness. Semi-structured interviews were used to collect the data from first-year Physics undergraduates who were using WebCT and Blackboard. An investigation was done to identify how the interface differences have affected the system's usability for students. Grounded Theory was chosen to gather students' feedback, i.e., to collect their approaches to using the LMS

independently from the views of the other stakeholders.

Students were tasked to describe an account with as much information they knew about the LMS and the next step was to summarize the information as one phrase or word. Then the gathered information is grouped based on similarities and coded from the recordings of notes and commentary. Cases with no results are re-examined to come up with a new valid code. In Grounded theory, data collection and theory building are dependent on each other till a solid 'theory' is formed. Grounded theory analysis is productive in Learning Management Systems (LMS), to understand user requirements clearly and for building collaborative user interfaces.

Chapter 3

Existing Tools

This chapter explains the existing tools in detail. Based on research, Miro, Mural, Github, LMS, and Google Slides are considered the existing tools. Each tool is explained in detail, along with its features, advantages, and current limitations, which can be utilized as a Design Thinking teaching tool.

3.1 Miro

Johnson [12] stated that Miro is an Online Whiteboard and Virtual Collaboration Platform where teams can work together synchronously and asynchronously. It provides a shared space where users can share and modify shapes, text, images, gifs, virtual sticky notes, and comments editable by all team members.

The key features of Miro include:

- Templates - Provides various templates such as Mindmap, Empathymap, Personas, Online Sketching, Storyboard, Customer Journey map, etc., that can be utilized based on user needs to depict their visual ideas.

- Sticky notes and Comments - Virtual sticky notes or add a comment box to add any idea or comment which can be easily moved around the whiteboard.
- Drawing tools - Tools to create diagrams, pencil sketching, smart drawing, highlighter, etc., which the user can utilize to draw prototypes or any hand drawings based on their needs.
- Export - It provides various options to export the document as a PDF, image, template, save to Google Drive or embed the Miro board into another application.
- Presentation mode - Miro also offers different ways to present either a specific activity, frame, or the entire board.
- Alerts new changes - Alerts users of new changes to their posts, unseen posts since they logged in, comments and posts are numbered and display the username of who commented on which post.

As per the feedback discussed in Johnson [12], Miro was coded as "classmate interaction," "communication," "encourage students to interact with one another," "got to know my classmates, which doesn't happen in an asynchronous online course," "enjoyed Miro discussion board," and "loved that we could incorporate videos, images, and links as it helped to inspire creativity."

Allah [1] mentioned the advantages of Miro as it supports student interaction and collaboration in online learning. It can be used for brainstorming and icebreaker sessions before a speaking task, and it has efficient student-teacher interaction by utilizing the board. Moreover, it is useful to evaluate students' performance and advantageous for group activities, as the group members can collaborate and work together on the same tasks. Additionally, the teachers can monitor the students'

progress and assist whenever needed. It is also useful for individual student assignments, allowing the inclusion of videos, links, and pictures as needed. It can be easily shared with teachers for feedback as well.

Though Miro has a lot of features, it potentially offers some disadvantages. The limitations mentioned by Johnson [12] were it has an undefined marker board, making it more difficult to monitor the flow of conversation in asynchronous discussion. It also lacks the feeling of human interaction and it has trouble locating specific posts or one's own posts when boards keep adding on as the course progresses. Sometimes students were uncertain about open-ended assignments like initiating the discussion board and there was a lack of organizational structure. The spacing of boards could be improved and it is not accessible to people with special needs. It also lacks a chat feature so it is difficult to communicate with the teacher and get feedback on their assignments. It also doesn't support voting and video chat options are unavailable in the free version. The new users find it challenging to use all the features effectively as there were too many features and making it difficult to navigate between the whiteboards. When multiple users use the whiteboard simultaneously or when the whiteboard has many elements, it causes lag resulting in performance issues.

With these disadvantages, it is concluded that Miro is challenging to use for a complete Design Thinking Project. The features are so enormous that users get confused about which one to choose for each phase of Design Thinking. As most of the learners are students, it would be vital to have selected tools and templates for each step so that the students could utilize them better and easier to finish their projects.

One template found in Miro is the Zendesk Triple diamond, as in Figure 3.1 which

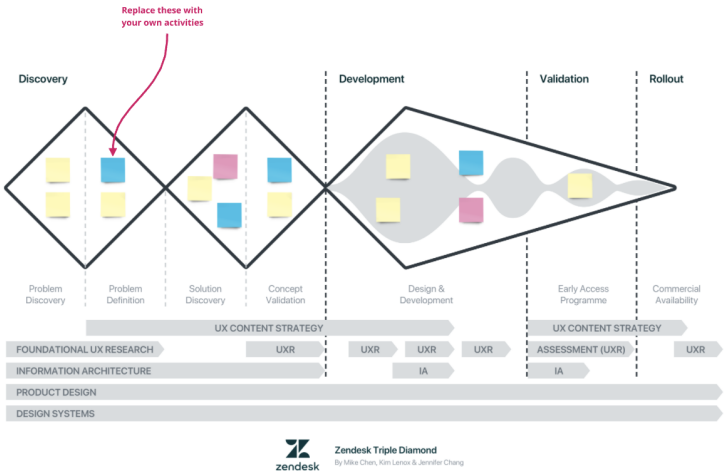

Figure 3.1: Triple diamond

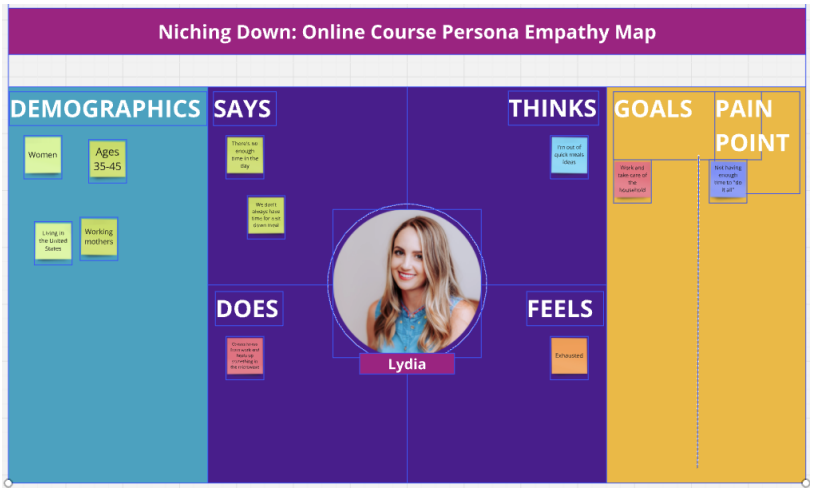

Figure 3.2: Empathy Map

has three diamonds. The first diamond focuses on problem discovery and problem definition. The second diamond focuses on solution discovery and concept validation. The third diamond is to visualize the iterative Agile cycle. In this template, the users can utilize a different version other than the usual double diamond. However, this doesn't have a working environment where the users perform tasks. Sticky notes, shapes, add templates, embedding with apps like Google Images, Wireframe library, charts, diagramming shapes, voting, polling, etc. can be added to this template.

This is another example template in Miro for an Empathy Map as in Figure 3.2. This template has an option to fill in what the user says, thinks, does and feels on a sticky note. It also provides space to mention their demographics, goals, and pain points.

3.2 Mural

Redlich et al. [21] stated that "Mural is a web-based software that allows real-time collaboration, communication, and visualization with multiple users." The mural provides many functionalities for adding notes, shapes, text, and photos and it has many predefined templates. It also supports real-time chat and offers functionality for collaborative voting.

Mural is another Online Whiteboard and Collaboration tool to visualize ideas virtually with real teams. This also provides a shared space to create and modify visualizations, simultaneously. The features of the Mural include:

- User-Friendly Interface - Easy for the new users to learn quickly and access features easily.

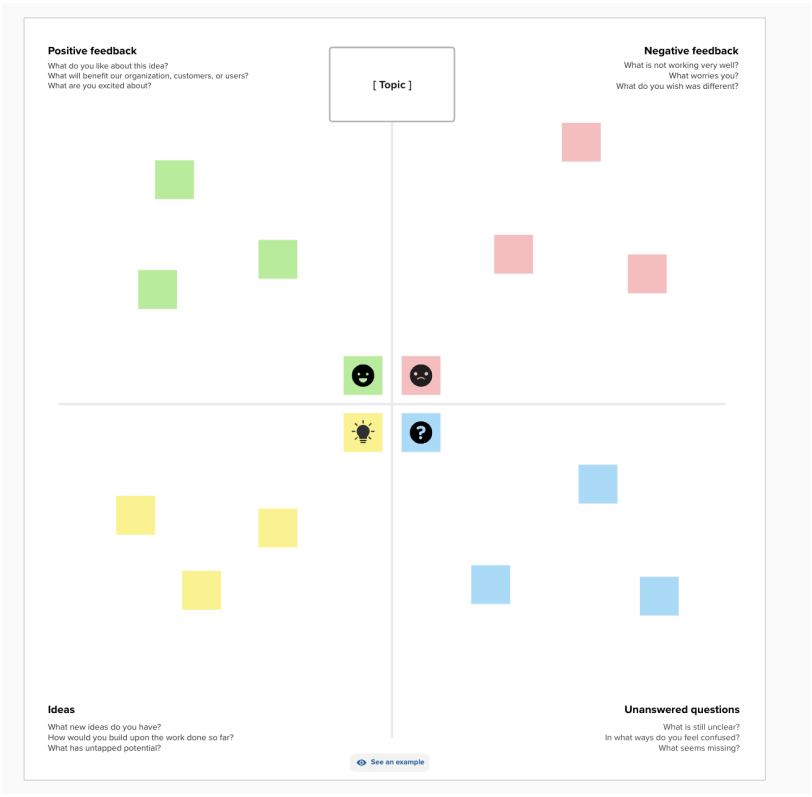

Figure 3.3: Empathy Map

- Templates - It offers enormous templates for various use cases such as Strategize, Plan, Brainstorm, Research, Design, Prsesent, Reflect, Connect and three ways of working (Agile, Design Thinking, and LUMA methods).
- Facilitation Tools - Includes various features such as timer, voting, private mode, laser pointer, customize, toolbar, chat, and track activity.
- Import - Import pictures or documents from Google Drive, One Drive, Dropbox, and Computer.
- Collaboration - Collaborates with multiple users at the same time.

The drawbacks of Mural include:

- Performance Issues - For large or complex boards with many elements it causes performance issues, resulting in delayed response time.
- Cost Expensive - Similar to Miro, Mural is cost expensive despite an individual or a team.
- Export Options - It has limited export options which might not satisfy all the user's needs.

For another viewpoint on Miro and Mural, Duško et al. [6] compared them and listed their similarities and differences.

3.3 GitHub

Zagalsky et al. [28] mentioned "GitHub is a popular web-based social code sharing service that utilizes the Git distributed version control system. It has become an essential tool in technology areas that require collaboration, such as software development and technical writing." A repository has the files, folders, and data relevant

to the project and stores every revision history.

GitHub repositories collaborate among multiple team members and developers with centralized storage to share their project details and code. GitHub makes it easy for people to keep track of the different version histories of the changes that are made to the repository. Version control is used to manage students and their progress. This helped the instructors to manage student work easily as it has their history. Github has access control features which can help the instructors choose the version and share them with specific people.

3.4 Learning Management Systems

Sardjono and Perdana [22] stated that a "Learning Management System (LMS) is an application that provides broad sets of tools for teachers to administer the learning process outside and inside the study room." The paper also discussed that LMS is defined as delivering courses, acquiring knowledge and controlling learning and has become the major tool in monitoring the learning of students in universities and schools, exams, grading, online assignments, and enrollment of the courses.

The author also describes different modes of learning:

- Computer Managed Learning- This learning uses a database that "collects, observes, and manages information" to help in student learning.
- Computer Assisted Instruction - Uses computers to help the regular teaching and utilizes graphics, images, and videos.
- Fixed E-Learning - Uses technology to access educational materials irrespective of location and time with the internet.

- Synchronous Online Learning - This learning is attending classes virtually from any location, provided the instructors help the students if they have any questions and provide support during the learning.
- Asynchronous Online Learning - This type of learning involves the students accessing the learning materials, collaborating with peers, and interacting with instructors without being in the classroom environment.
- Adaptive E-Learning - This is an innovative E-learning where the course is designed based on specific student interests, capability, progress, and learning style.
- Linear E-Learning - This type of learning follows a specific sequence of teaching materials followed by activities and this learning can be used for both physical and virtual environments.
- Interactive Online Learning - This learning enables students to complete their educational tasks by collaborating with instructors and peers and by utilizing multimedia resources.
- Individual Online Learning - This type of learning helps students access courses independently where they can take control and provides flexibility in learning.
- Collaborative Online Learning - This type of learning helps the students to work as a team to develop problem-solving skills. It also can be used for both virtual and physical environments.

Based on the accessibility, LMS is categorized into Built-in LMS and Web-based LMS. Built-in LMS requires software to be installed and the users are required to have their own devices to use this system. Web-based LMS needs the internet and a browser to be accessed and does not require any software to be installed on the

computer. This is the easier method and also can be accessed offline using localhost.

The types of LMS are Open Source and Closed Source LMS. The developers develop Open-Source LMS where the source code is publicly disclosed and private developers develop Closed-Source LMS where the source code is kept private.

When the LMS is being implemented, five dimensions are considered:

- Technology Dimension - The technology support that is required for e-learning considering the hardware, software, and networking.
- Human Resource Dimension - E-learning actors are Administrators, Lecturers, and students. Each actor performs different tasks based on their roles. The administrator performs user management, course management, creating, updating, deleting databases, data backup, uploading, and downloading. The lecturer performs virtual class management, student management, assignment, and quiz management, evaluation, and upload and download documents. The student takes up the virtual class and does online assignments and other virtual activities.
- Environment Dimension - The three important elements necessary to implement e-learning are organization, leadership, and policy.
- Financial dimension - It is important to adjust the organization's financial budget with the plan for the e-learning setup.
- Dimensions of Learning Content - Quality of the learning content is vital. It can have multimedia or text-based content but the goal is to ensure the overall quality is good.

3.4.1 Factors to be Considered in Building LMS

Many factors can be considered when building LMS to avoid failure when implementing LMS:

Nolasco and Hernandez [18] referred to the challenges of LMS as

- Errors caused during online quizzes, assignments or any other online activity cause learning disruptions.
- Limited storage spaces reduce the learning quality.
- Lack of instruction about the features prevented students from using LMS effectively.
- Increased economic burden to students as stronger signals were required to access LMS.
- LMS lacks the interactions between students and teachers.
- LMS lacks real-time instruction and immediate feedback on the student's progress, dependent on internet connections.

3.5 DT Worksheets as Google Slides

Leng et al. [16] mentioned that "Presentations can be shared, opened, and edited by multiple users simultaneously and users can see slide-by-slide and character-by-character changes as other collaborators make edits. It allows instant feedback and collaboration on text and image form when lecturers and students are online at the same time." Meanwhile, students can find the mistakes and revise based on the lecturer's feedback promptly.

Google Slides has the advantage of being robust when collaborating with multiple

users. This has helped the mentors track the students' involvement in the tasks. The Google Sheets also help to identify who is editing the slide with the avatar that is displayed on the slide. The mentors can also easily track if the group members are working on a particular slide or if they are stuck on any specific slide.

The worksheets utilized by Anand et al. [2] will guide the learners through the Design Process. "The purpose of worksheets is:

- The Design Thinking process is broken down into steps, where the users can learn one step at a time.
- Utilized tables and graphs for each stage focussing on finer details.
- A map is included at the top right corner of the worksheet to indicate the stage of Design Thinking. [2]"

The tasks involved in the worksheets utilizing the DT process are elaborated in detail. The worksheets also have a map at the top-right corner to let the users know where they are in the process. This map highlights each DT stage on every page of the worksheet. The first step of the DT process is to Research and Identify the target audience. Then interview is done with them to collect the relevant details of the problem area and their associated problems. Research continues to identify the potential problems that the target users might face and a possible project idea. Based on the possible project area and the preliminary research the target users and the general problem area are identified. The next step is the Interview process with the target user group. The interview questions should be more focussed to get good results out of the interview process. The next task is to frame the open-ended questions for the target users. Open-ended questions give a chance to the interviewee to elaborate on their answers and describe them in detail rather than answering them

with 'yes' or 'no'.

Once the interview questions are framed, then a practice interview is done with their peer team before the actual interview. This allows them to know how the actual interview takes place. During the interview, the team members could take up any of the four roles mentioned in the Interview guide [19]:

- Interviewer
- Notetaker
- Producer
- Observer

Each team member can take up all the roles for an interview to have better insights from the interview.

- The interviewer is the one who does the actual interview.
- The notetaker takes notes of the interviewee's responses.
- The producer has the role of helping the interviewer update the questions based on the interviewees' responses, by eliminating redundancies and assisting the notetaker with updating the interviewees' responses.
- Observer, as the name suggests observes the entire Interview process.

Each team member fills up the Interview raw notes after the Interview and as a team, the Empathy Map is filled out. An Empathy Map helps to empathize with and synthesize the information gathered from the ideate stage. The Empathy Map has four sections Say, Think, Do and Feel. The Say part has what the user says during the interview. The Think part of the Empathy Map is filled with the users' knowledge or opinions, such as if they are surprised by any questions or trying to ignore a topic

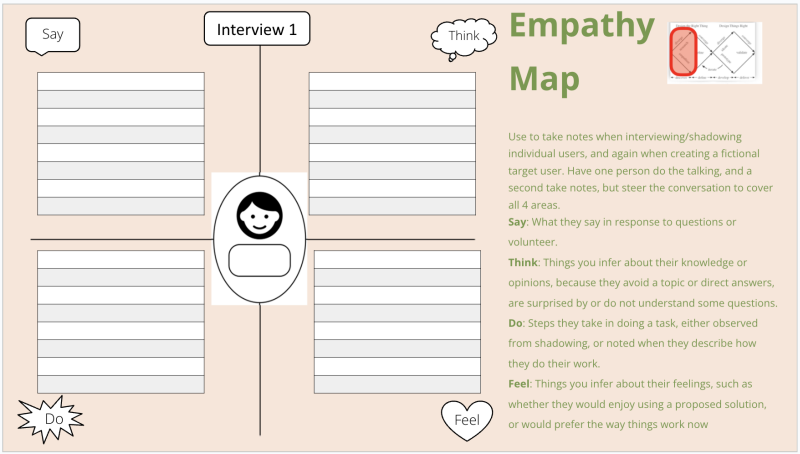

Figure 3.4: Empathy Map in the Design Thinking Worksheet

or if they have. The Do section focuses on the task that they do either by observing or shadowing and recording when they explain how they did the work. The Feel part explains how they would feel about the proposed solution in comparison with the existing environment. After the Practice interview, an evaluation of the interview is done to identify the shortcomings and to resolve any discrepancies that occurred during the interview and to be prepared for the actual interview. Before heading into the actual interview, the interview questions are revised based on the feedback from the practice interview. The next step is the actual interviews with the target users. The interview takes place as mentioned in the Interview guide. Each team member should take up all the roles and interview with as many people to gather insights. When the interviewees are not interested in the interviewed area, the problem area can be slightly modified and aligned based on their interests which could provide a better solution. The target user's interests are identified from the Interview data and they are brainstormed within their team to come up with a general problem area. The brainstormed problems should be linkable to a painpoint and all the problems

should be noted down irrespective of whether they are achievable or not. This involves plotting the Impact Novelty graph. Novelty refers to how new the problem is and impact refers to how the target user is affected by the problem. The problems are plotted after discussing with the group members and if new problems are generated at this discussion they are added to the list and plotted. The solutions are then generated for the defined problem and listed in the Solutions table. The Solutions are plotted in the Feasibility Desirability graph to find a desirable and feasible solution from the list of solutions. Desirability is defined as the product that meets the criteria and is required or needed by the users. Feasibility refers to the product that can be built with the current resources. The graph can be plotted by filling in the most feasible and desirable solution as the highest score considering their time, tools and group contribution. The solution with the highest score is chosen as the best idea and highlighted below the graph. The solutions are then used to build the Game Generator table. The Game Generator table has the symptoms and interests, where the table has a solution for each symptom and interest pair filling up the entire table with game ideas by brainstorming.

Following this, the two best game ideas are created as paper prototypes utilizing any drawing tools or by freehand drawing as the initial prototypes. Initial prototypes can be created using any drawings, sketches or PowerPoint slides with shapes and text boxes. The prototypes should convey the idea of the solution. This gives the user an idea of the prototype's appearance, and what features could be added, removed or modified. One prototype which suits the problem best is finally chosen and that prototype will be continued as the best solution. The prototype is refined with many iterations based on Target user feedback, till the users are satisfied with the final

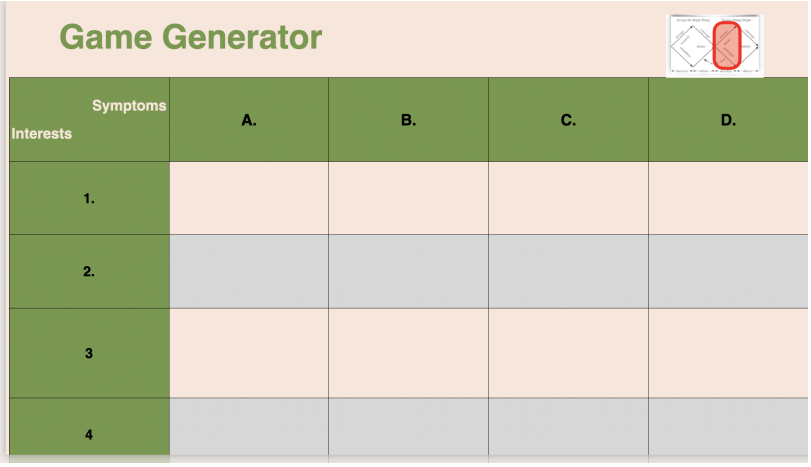

Figure 3.5: Game Generator table in the Design Thinking Worksheet

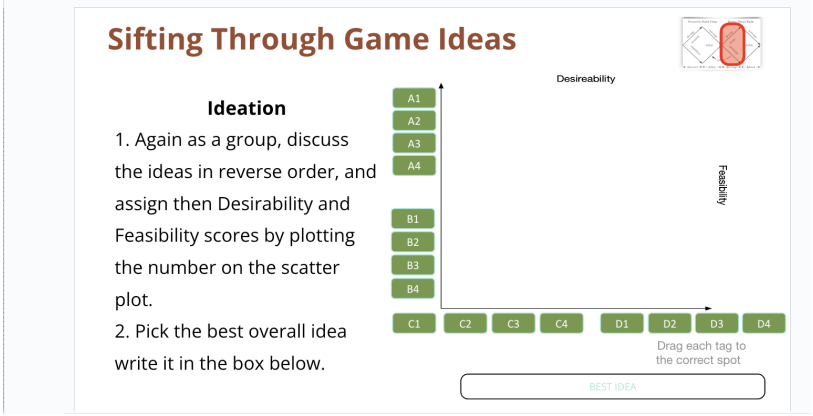

Figure 3.6: Feasibility Desirability Graph in the Design Thinking Worksheet

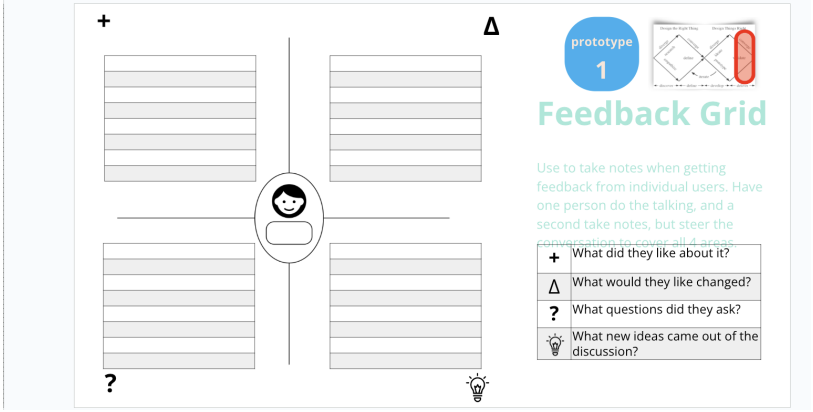

Figure 3.7: Feedback Grid in the Design Thinking Worksheet

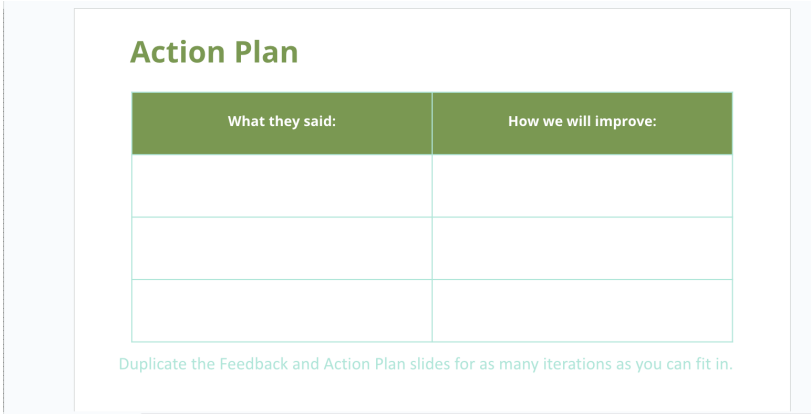

Figure 3.8: Action Plan in the Design Thinking Worksheet

prototype. After getting feedback for each iteration there is a feedback grid slide that the participants can fill in with what the users liked, what they would like to be changed, questions they asked and new ideas that came out of discussion. After various iterations of getting feedback from the users and updating the prototype and refining it continuously the final prototype is developed.

An Action Plan is created for each prototype version/iteration to address the Feedback grid. This highlights the changes that are made in the prototype after each iteration and what prompted them to make these changes.

One example was Parkinson's disease which was chosen to be the problem area for SNS students' DT workshop. The worksheets utilized at the Design Thinking workshops were Google Slides because of their familiarity and effectiveness. The slide covers an introduction to Design Thinking with the Double diamond approach, followed by an introduction to Parkinson's disease. Students were tasked with interviewing their grandparents to identify their hobbies and difficulties related to Parkinson's disease that they face in their day-to-day lives and to come up with a prototype for a game that can help them overcome their health issues.

To effectively teach Design Thinking to Graduates and Undergraduates, Anand et al. [2] have developed Design Thinking Worksheets that share resources about Design Thinking combined with various group and independent tasks for the students to acquire knowledge in Design Thinking. The Worksheet begins with an introductory video explanation of each stage in Double Diamond. Each stage of the double diamond is highlighted in the top right corner of all the slides as they progress through the slides. This helps them to identify which tasks correspond to each Design Thinking stage. The tasks begin by interviewing the users, followed by the Empathy Map through the Game Generator and finally building the prototype and refining it based on the user's feedback.

The interview raw notes gathered during the interview process can be updated in the interview raw notes slide on the worksheet. Each team member will have their interview raw notes and they can fill in the Empathy Map from their raw notes.

Following the Empathy Map, the subsequent slide gathers insights on the participant's interview experience focusing on how they set up the interview, provided any context to the interview, ensured that users were comfortable, utilized open-ended questions and follow-up questions, asked any stories or to narrate any specific question. The next slide of the worksheet is to visualize the user interests using a sticky note. The slide has many sticky notes where the participants can drag and drop the sticky notes and come up with the interests of the users that they have gathered so far. After the Interview process, the gathered raw notes are transferred into the Empathy Map filing out the Say, Think, Do and Feel sections based on the grandparents' perspectives. Then the Elder's interests are listed individually based on the gathered data for each member of the team. Based on the gathered data, the Game Generator

table is filled with the columns being the elder's symptoms and the row being the elder's interests. Each of the cells is filled up with a game idea after brainstorming.

3.6 SNS Worksheets

The Worksheets utilized at the SNS Design Thinking Workshop were Google slides to track the students' progress efficiently.

The students' first task was brainstorming with their team and developing practice interview questions as they had to interview their grandparents. The practice interview questions gave them an idea about the interview questions before they moved into the actual task. The mentors gave their opinions on the interview questions to ensure they have a mix of open and closed-ended questions with follow-up questions wherever applicable. The interview questions should aim to gather good information about their grandparents' interests so that it can help them build a good Empathy Map. Each student has to come up with Interview questions about the grandparents' interests, hobbies, day-to-day activities and challenges for the interview and get the help of the team to finish the interview process.

The team members could take up different roles of Interviewer, Note-taker, Producer and Observer for the Interview process. Each member has to have their interview questions, do the interview and come up with Interview raw notes. The Interview process can be recorded after getting consent from the Interviewees. Interview raw notes can be transferred to the Interview Notes section after the Interview process. The interview guide was helpful for the whole team to get involved with their team members' interviews and get insights into the interview process.

Chapter 4

Prototyping

In this chapter, we have discussed feedback from various DT mentors regarding the Progress Widget. Four different versions of the Progress Widget have been reviewed, focusing on its features, detailed descriptions, mentor feedback, and the Action Plans that led to each subsequent iteration.

4.1 Feedback from the Mentors of the SNS Workshop

The major challenge faced during the workshop was network failure for a few students in remote locations. This made it difficult for them to access the worksheets, participate in the workshop and collaborate with their teammates on various tasks. Another challenge was the different time zones for the mentors and the students, which was quite challenging for the mentors to accommodate the teaching. 3 mentors were interviewed at the end to identify the improvement areas. The questions and

the summary of responses are given below:

Q1. What was the feedback given to different people within the team? Could we measure those significant changes before and after the feedback? The mentors provided tips and examples to frame interview questions and questions related to Parkinson's disease. One mentor utilized the interview guide techniques for a better understanding of the Interview process. The mentor measured their progress by looking at the final interview questions and Empathy Map.

Q2. What did the students learn after the feedback in each DT stage?

The mentors mentioned that the students got clarity about the DT process. The students acquired knowledge about their project, and interview process and weren't allowed to proceed with the next tasks till the current task was fully finished. A few students were confused in say, think, do, and feel part of the Empathy Map and the feedback was helpful here.

Q3. What role does giving feedback play in framing the interview questions, building the Empathy Maps, Game Generator, and final prototype?

The mentors mentioned that feedback played a " huge role because they help students navigate through each stage of design." For a few students, the feedback helped fill the Empathy Map as some students had different Empathy Maps within their teams. It also helped write interview notes and in the game, generator to come up with keywords from the answers during the interview.

Q4. Did the students have good progress after each feedback or did they face challenges in any specific part of the given tasks?

The mentors mentioned that the students had "good progress after feedback." Initially it "didn't go well and they had understanding issues on Empathy Map, but

in a short time they were able to pick up."

Q5. How did the students adapt to the feedback given? Rate it

The mentors rated between 4 to 5 on a scale of 5 for understanding and following better after explaining and following instructions.

Q6. Were there enough feedback cycles?

Two mentors mentioned that there were adequate feedback cycles and one mentioned that it was not sufficient. They also stated that the students had the DT concept in mind but they had to perform the tasks which just needed a push. When the students are new to DT concepts, extra time should be spent on feedback. The mentors also mentioned that three practice interviews are good before the actual interview and we need to monitor for any issues within the team.

Q7. How effectively did practice interviews work? Could practice interviews be more effective?

The mentors stated "Practice interviews are very important. It gives a good sense of how to ask questions, what kind of follow-up they should ask and how to get as much information in one setting." Two of the mentors mentioned that the practice interviews were not very effective as the workshop was for two hours and suggested spending some more time on the interviews. One mentor suggested using AI models. Another mentor suggested, "Need more practice in an interview, Empathy Map, Game Generator, and every task."

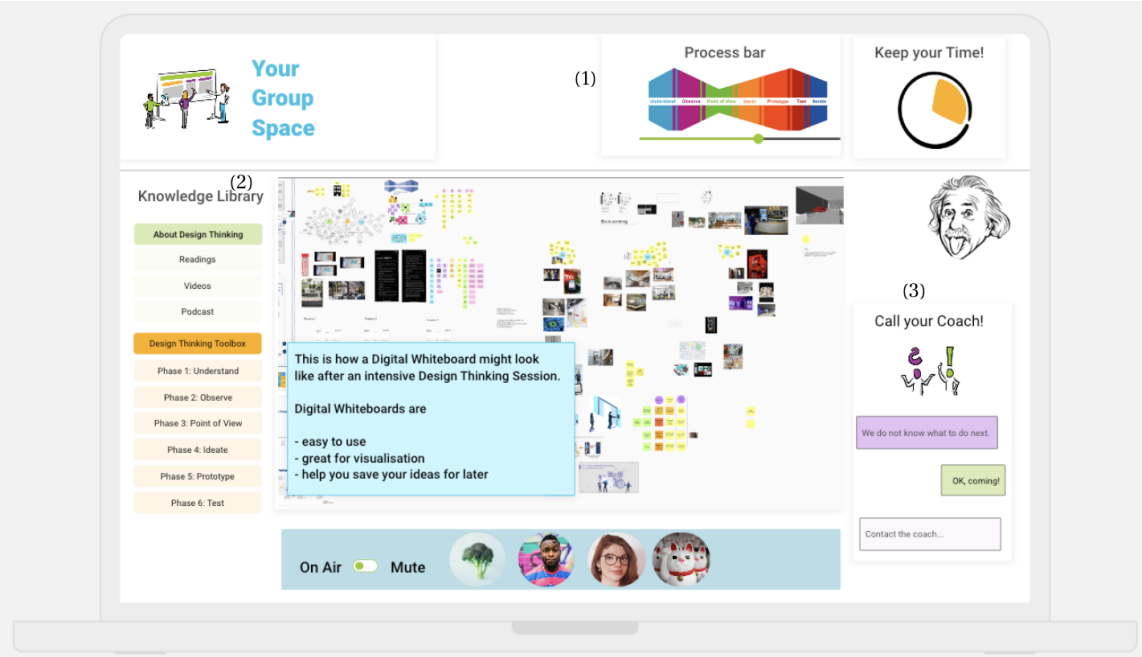

Figure 4.1: Prototype by Gebbing was used to begin the interviews. Mentors strongly recommended Process bar (1), Resource Library (2), and Call Your Coach (3).

4.2 Getting Feedback on the German Paper Prototype

In order to get more concrete feedback from the DT mentors, rather than starting from scratch I have started with the final prototype of [9].

- 6 step Design Thinking innovation process
- Space to display creativity
- Digital whiteboards
- Tools for verbal and visual communication
- Online supervision by a coach

The interview aimed to identify the features of a Design Thinking Teaching tool.

The interview questions and answers are discussed below:

Q1. Are there any specific problems encountered when teaching and evaluating DT?

The mentors mentioned that they faced challenges in matching their accents with the students' accents, and had a communication gap that could be resolved by a tool. One mentor suggested that using a poll could help them come to a conclusion using the best idea. Another mentor suggested using quizzes to differentiate closed and open-ended questions and multiple-choice questions after each DT stage.

Q2. Do you think any evaluation rubrics can be included that could help mentors provide feedback easily?

The mentors mentioned that the rubrics can strongly help, as it can be a standard to teach that the educators can follow. One mentor didn't accept this but mentioned that this may reduce the mistakes and it is synonymous with instructions. Another mentor mentioned that each phase can have a checklist.

Q3. What do you think each of the elements of this tool might be used to improve the practice and especially the teaching of Design Thinking?

One mentor mentioned that the instructions are very important followed by the Progress bar (Double Diamond highlight based on their work), Timer, and Knowledge Library (a short video, typically 1 to 3 minutes, explaining how to do each task at various DT stages). Conversely, other mentors thought Call the Coach, Separate Chats for the Group, and On Air are not necessary.

Q4. Which features would you recommend that we adopt and why?

The mentors recommended a Progress bar, Chat, Knowledge Library, Instructions, Internal chat/ Feedback, unmuting a person and having attractive and catchy images

for icons and instead of a timer, the time spent on each task can be recorded.

Q5. Which features would you not recommend we adopt and why?

The mentors mentioned Timer as it is subjective, Group space is not needed as after a few weeks or months may go unnoticeable.

Q6. Which features do you not understand?

The mentors mentioned the mute button at the bottom and the Group space.

As a result of this discussion, it is clear that a teaching tool with features such as a Progress bar, Knowledge Library, Chat and Instructions can ease the teaching process of Design Thinking.

4.3 Feedback on the Progress Widget I

An interview was conducted with three mentors who instructed the SNS workshop and four teaching assistants of 1XD3 to analyze the design of the Progress Widget I. The interview questions and the responses are discussed below.

4.3.1 Prototype Description

Progress Widget is a key feature that visualizes the progress of different DT stages and makes it easier for the students to understand which stage they are in and how many stages are left to finish the complete process. Seven different versions of the Progress Widget were designed and interviewed for further progress. Each of the DT tasks is indicated by icons on the Progress widget. A monochrome and colored versions is added as different versions of the Progress widget. The different versions are named based on the nature of the design. Three versions of this Progress widget

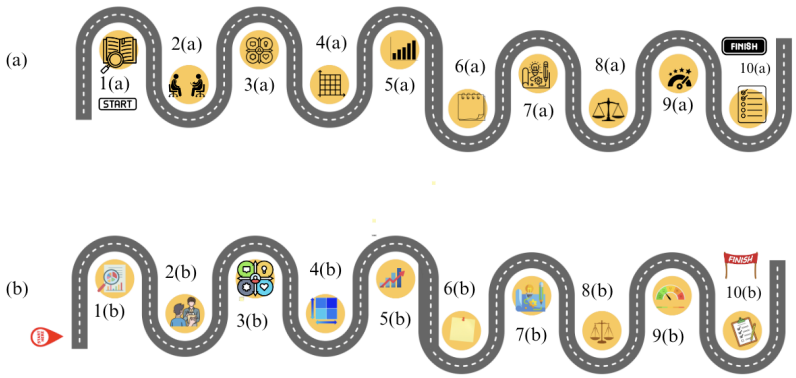

Figure 4.2: Roadmap Monochrome version (a) with monochrome icons and Roadmap Coloured version (b) with coloured icons.

had two versions as monochrome and coloured versions and the last version is the Calendar view version. The different icons on the Progress widget represent the different tasks involved in the DT process, starting from research to the final prototype. Two different sets of icons are used in these seven versions of the Progress widget and they are numbered and described below.

The I.a and I.b are the Roadmap monochrome and coloured versions represented in Figure 4.2 (a) and Figure 4.2 (b). The Roadmap has a start where the DT process begins and a Finish where the process ends.

I.c and I.d are the Arrowdiamond monochrome and coloured versions represented in Figure 4.3 (a) and Figure 4.3 (b). It has 2 diamonds for the entire DT process. When the Research phase is completed, that arrow turns white with the title turned green from Black as shown in Figure 4.3 (a). The other phases are grey in colour which symbolizes the upcoming tasks that need to be completed.

I.e and I.f are the Blockdiamond monochrome and coloured versions represented in Figure 4.4 (a) and Figure 4.4 (b). The different DT stages are named and represented in blocks. The finished stages become dark in colour and the unfinished tasks are very

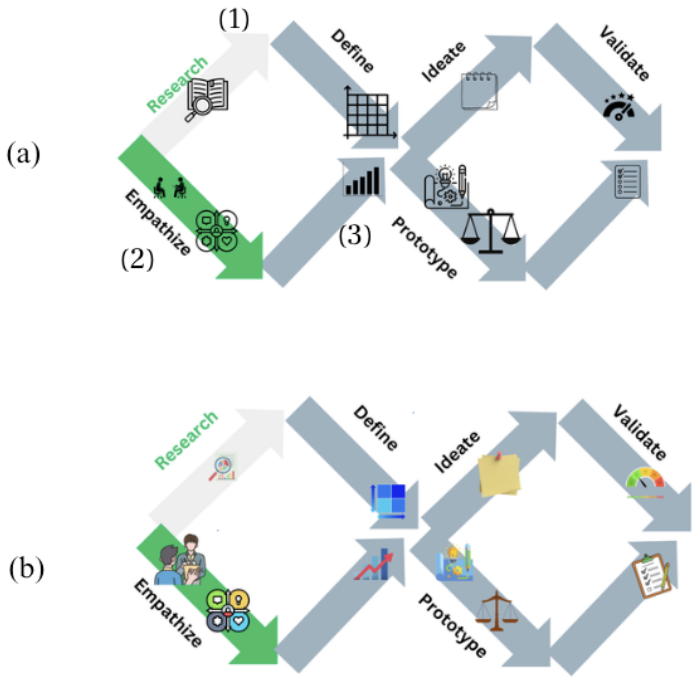

Figure 4.3: Arrowdiamond Monochrome version (a) has the monochrome icons and Arrowdiamond Coloured version (b) has the coloured icons. The completed DT stages (1) turn white, the ongoing task (2) is green, and the upcoming tasks (3) are greyed out.

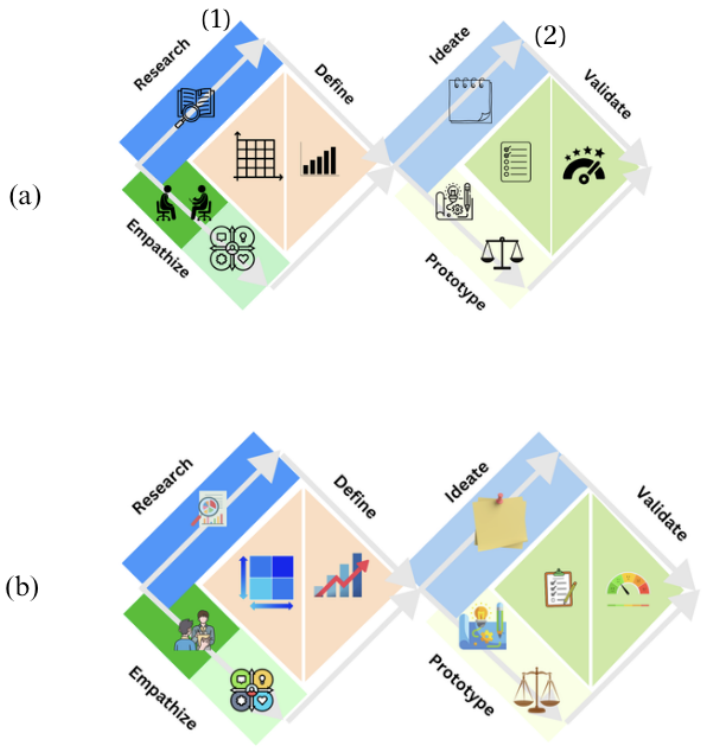

Figure 4.4: Blockdiamond Monochrome version (a) and Blockdiamond Coloured version (b). The completed DT stage (1) is shown in a dark colour, while the upcoming DT stages (2) are displayed in a lighter colour.

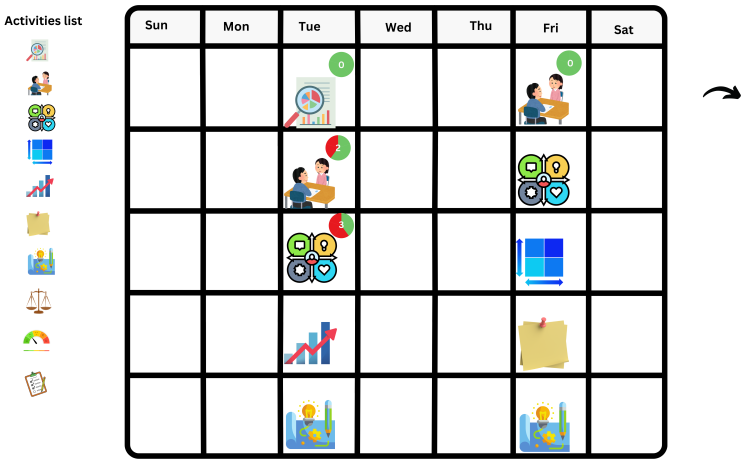

Figure 4.5: The Calendar View includes an activity list that mentors can drag and drop to assign tasks. An arrow on the right allows adjusting deadlines. A green circle with a number shows how many students have completed the task.

light in colour.

I.g is the Calendar view represented in Figure 4.5. It has a Calendar view where the mentors can assign tasks to the student's calendar for the entire course. The mentors can drag and drop the Calendar activities list at the right into the Calendar to assign the task. The arrow on the right side is to move the deadline. The pie chart for each of the finished tasks displays the green and red colours with a number. If the Pie is fully green, all the students of the team have finished the assigned task. When it shows the red colour with the number represents the number of students who didn't finish the assigned task. When the mentor clicks the Pie, then the team members' names are displayed.

- 1(a) and 1(b) - Research icon
- 2(a) and 2(b) - Interview icon
- 3(a) and 3(b) - Empathy Map
- 4(a) and 4(b) - Game Generator table

- 5(a) and 5(b) - Feasibility Desirability graph
- 6(a) and 6(b) - Sticky notes for brainstorming
- 7(a) and 7(b) - Prototyping
- 8(a) and 8(b) - Comparing 2 prototypes and choosing the right one
- 9(a) and 9(b) - Feedback grid
- 10(a) and 10(b) - Action Plan

4.3.2 Mentors' Feedback

Q1. Which of the above designs is good for a Progress widget? Why?

Five mentors out of seven mentioned that the Roadmap is good as it is simple and easy for the students to understand. One mentor mentioned that the road map appears to look linear rather than iterative. Another mentor likes the Double diamond version as it is the usual way to the process of DT. Mentors also mentioned the "Monochrome icon as it is straightforward and easy to read," and "Block diamond - Coloured in a course like 1XD3 will help students to understand the phases well. Additionally, the calendar could be helpful because of the numbers that you put in, i.e., the number of people who are not done with their tasks." There were also suggestions to show the linearity after the Prototyping and the Action Plan.

Q2. Can any other icons be included?

The mentors mentioned that the Prototype comparison icon didn't reflect its meaning and suggested changing it. One mentor mentioned adding reactions that students can use to tell the mentors to say when the given task is easy or hard and requires mentor help or hard and does not require mentor's help. Suggestions were received for adding more icons between the Prototype comparison and Action Plan

to show the prototype iterations.

Q3. Do you think any additional feature can be added to this Progress widget? If yes which feature and why?

The mentors mentioned showing the iterations and having the Roadmap view and the Double diamond view. The Road map view makes it simple and easy to understand and the Double diamond view can have advanced information and methodologically help the learner to know what is Design Thinking and what the learner is currently working on.

Q4. Can this Progress widget be a page navigator in the teaching tool?

Mentors mentioned that the Progress widget can be simple and more details can be added for a clickable view. Mentors also mentioned that Page Navigator is a good option and "I find it very frustrating when the apps, or websites just show the progress, and don't allow you to navigate to different pages when you click on the corresponding icon or name in the progress widget."

One mentor mentioned that the Block diamond monochrome and coloured versions are good because of their simplicity as the pictures in the mentioned phases are next to each other. Another mentor also mentioned that "Coloured Block diamond in a course like 1XD3 will help students to understand the phases well." One mentor also mentioned "Additionally, the calendar could be helpful because of the numbers that you put, i.e., the number of people who are not done with their tasks."

4.3.3 Action Plan for the Prototype

To summarize, the strongest comment was that the Roadmap was easily understandable for a sequence of steps, but it is incorrect as it does not show the iterative nature

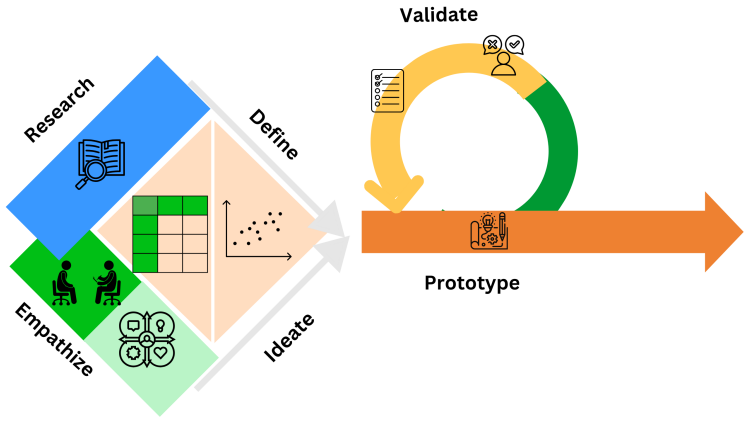

Figure 4.6: Iterative part added to the existing Double Diamond to clearly visualize the iterative stages.

of getting feedback. The DT tasks of Prototyping, Action Plan, and Feedback grid are iterative and they should be shown iterative rather than visualizing linearly. There were also suggestions to include the Agile approach in Double Diamond.

4.4 Feedback on the Progress Widget II

4.4.1 Prototype Description

As a result of this discussion, the Progress Widget is redesigned making changes to bring the iterative nature as shown in Figure 4.6. This new Progress Widget has one diamond and the second part of the diamond is replaced by a circle to show the iterations in the last two stages represented in Figure 4.6. An interview is conducted with 4 experienced mentors in teaching Design Thinking to get their thoughts on the iterative nature. The interview questions and their responses are discussed below:

4.4.2 Mentors' Feedback

Q1. To address the lack of explicit iteration in the different proposals, I have added an iterative version instead of the second Double Diamond. What's your thought on the new version of the iterative Progress "bar"?

The mentors liked the design overall, but the mentors asked "How will progress be shown?" Another mentor mentioned "It is an interesting approach to combine the original Double Diamond with a linear pathway."

Q2. Does it convey the idea of divergent and convergent thinking in the first phase?

The mentors mentioned "It only somewhat conveys the idea. I think adding a label to indicate divergent and convergent is necessary, as there are too many colour schemes within the diamond itself." Another mentioned "Yes, I think so, but if people don't know those terms they might not understand that right away. But as they learn, it should make some sense."

Q3. Does it convey the idea of interactive prototyping, in the second phase, and the need to integrate feedback?

The mentors mentioned that the new design conveys the idea of prototyping as long as the icons and their meanings are clear to the learner. There were also thoughts like "It would be good if you put a little tooltip on top of things when you mouseover. Maybe when they mouse over any of the icons you put up the name of that step as well as a little bit of text saying what it's for. "Another mentor mentioned "Yes, but I think adding the word "Testing" before "Validate" is a good idea as they will have to interview and test their prototype with potential users (i.e. Testing/Validate)."

Q4. Knowing what they mean, do the words "Research", "Empathize",

"Ideate", "Define", "Prototype", and "Validate" occur where you expect them?

The mentors mentioned that "there should be some sort of indication that time flows from left to right, and that anything at the same "x" value or "t" value are things that happen simultaneously (research/empathize and define/ideate)." Another mentor stated "Yes, they are placed in order, accurately. However, it would be difficult to understand the flow of the DT process without any explanation of the diamond." There were suggestions to find a way to show the parallel process in some DT stages.

Q5. Based on your experience as an instructor, what misconceptions will undergraduate students have about these terms, at SNS College, in McMaster CS and Engineering, and in general?

The mentors mentioned that the students might "think that the split arrows in the diamond at the start are two different paths when really they happen together."

4.4.3 Action Plan for the Prototype

As a result of this discussion, the mentors have mentioned that indicating the direction of the progress is something important to consider from the perspective of a Progress Widget. They also highlighted that it is important to show where the divergence and convergence take place, as few DT stages like Research/Empathize and Define/Ideate have the tasks in parallel. There were suggestions to include a way to show the flow of the DT process.

4.5 Focus Group with 1XD3 Teaching Assistants

Another focus group was conducted with 1XD3 Teaching Assistants to gather experience teaching Design Thinking. The interview questions and responses are discussed below:

Q1. Can you share your experience in communicating your feedback on a student's progress?

The mentors mentioned that there were difficulties with some groups since their team members were not coordinating the group tasks. There were also scenarios where some team members were not attending the lab sessions regularly and had difficulty in progressing toward the tasks. One mentor highlighted that "Firstly, there was no way for me to easily record what we talked about or what they told me in terms of their progress. Secondly, I had no way to verify that they did what they said they did. Some way for them to submit reports that are correlated by the app about their progress would be great." Another mentor mentioned that progress trackers could resolve the problem if they gave a clear picture of what each of the team members has accomplished.

Q2. Is it easy to track the student's worksheet version history before and after the deadline for each task?

The mentors found it difficult and frustrating to track their progress as most of the students hadn't filled the worksheets till the deadline. One mentor highlighted that "It wasn't easy to track the student's progress in each DT session (the slides were often empty), and honestly, it was really hard to open the PowerPoint slides on my laptop because it was slow and laggy." The mentors also mentioned that PowerPoint was very slow. Another mentor mentioned "I would say this is the biggest downside

of using Microsoft PowerPoint. Since it is a general-purpose tool, it's not very easy to determine who worked on what or what their progress is. The version history can give you at a glance a general sense of how much they're working on it, but it's hard to tell what each person is working on."

Q3. Is it easy to navigate to different DT stages or the worksheets without a Progress Widget or can a Progress Widget be helpful?

One mentor mentioned "The students will know what stage they are currently in, and if each icon in the Progress Widget navigates you to the exact stage by clicking, that would be a great help." Another highlighted "I would go for having a Progress Widget. And I highly appreciate the Progress Widget supporting navigation to each stage. However, the Progress Widget itself is a big help. You can easily see where you are as you scroll through different slides, and you don't even need to look at the slides' materials." There were also thoughts on having small thumbnails for the PowerPoint along the side of the screen.

Q4. How did you grade the teamwork? Do you think monitoring individual student work for such group activities is needed and can be helpful?

One mentor said "I found that (seemed that) some of the teammates didn't even have any idea about their project (what the game idea was, how they coded that game on Elm, whether they had conducted interviews, or what their teammates wrote in the PowerPoint slides). However, after the worksheets, most of the students who hadn't worked before tried to learn more about their own project and help their teammates, even if only for a small part." Another mentor stated "After we had the report sheets that Dr. Anand designed, it was much easier to track individuals' collaborations. And

it did help a lot. At least after we got the sheets, I could help the groups that were not working well together, by monitoring each group member's contribution. But before that, it was almost impossible with some groups to find out who was not contributing to the project."

Q5. Will the Resource library with all the information about student tasks in the worksheets be helpful for this course?

One mentor mentioned "I will say, one problem with the slides as they are now is that the instructions are mixed together with the team-generated content in the slides. This is good for the team as it's "at a glance" but it also makes things look cluttered. If there was a way to hide the hints behind (i) or (?) icons or something, that would be good. Or at least the ability to toggle the on-screen help."

Q6. Any specific feature is needed in your own experience if there is a tool to teach Design Thinking?

The mentors mentioned that having emojis as reactions for each task can help the TAs track what is challenging for students to understand.

To summarize, the mentors mentioned that there were some challenges with the group tasks in tracking individual contributions. There was no efficient way to track student progress and if they had completed the work that they had mentioned before the deadline. The mentors mentioned that the Progress Tracker could resolve these issues. Embedding the worksheets in Powerpoint slides was used slow and laggy which made it difficult to track student progress even though PowerPoint has a version history feature.

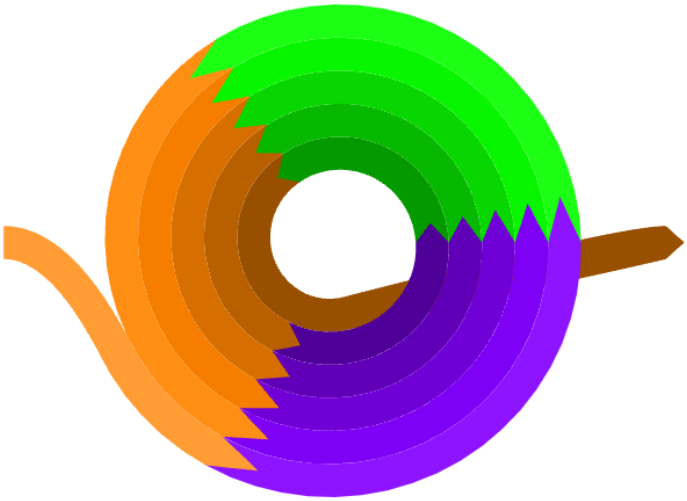

Figure 4.7: Prototyping a design that uses a spiral to visually represent the concept of iteration.

4.6 Focus group for the Progress Widget III

Following the interview with the 1XD3 TAs, a focus group was conducted with a group of 6 DT mentors. This focus group aimed to acquire insights on the updated Progress Widget. In this prototype, we included many unfinished features in order to stimulate discussion. This was most successful in the case of the individual contributions pie chart.

4.6.1 Prototype Description

The Progress Widget was updated with the following features: To capture the idea of convergent and divergent thinking, the Progress Widget includes branching and merging in the flow of tasks as in Figure 4.8. Each of the DT stages in the Progress Widget displays the direction of the progress which is visible as in the arrow in Figure 4.9. Initially, all the DT stages are greyed out with a highlighted border and

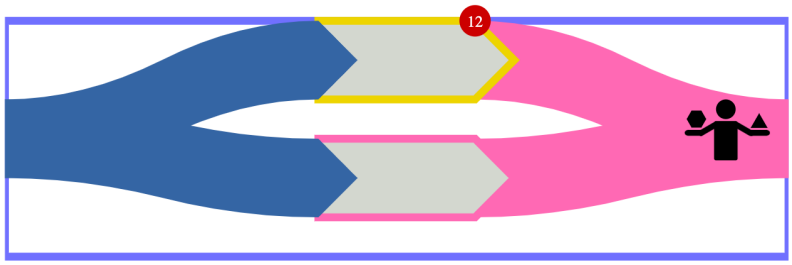

Figure 4.8: Fork path visualizing convergent and divergent thinking and direction of task flow

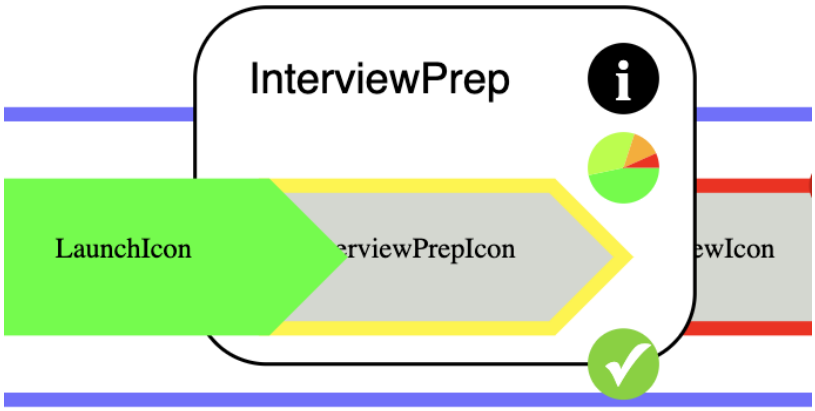

Figure 4.9: Visualization of completed (coloured) DT stage, with the information card for each DT step in the Progress Widget

the completed tasks are filled with a task colour. This makes it easy for the mentors to see how much each team member has contributed to the group work. The spiral in Figure 4.7 shows the iterations taking place in the DT process. The prototyping stage followed by the feedback grid and Action Plan is iterative in a way that the prototype is updated based on the user feedback and the action taken based on each feedback. Pan and zoom are added to zoom in the Progress Widget to see the different DT stages and features that are being added and a hover-over is added to view the contextual information (Info card). It is represented by an information icon  which when clicked opens an empty resource pop-up as represented in Figure 4.13 containing contextual information from the resource library about each DT stage and a task description. The pie on the tooltip has sectors for each member of the group indicating their individual contribution. By using solid colours to indicate completion, team progress should be very visible. There is a notification icon visible as a red circle with numbers mentioned in Figure 4.11 that notifies the student of the count of feedback from the mentors such as feedback on the submitted work or what could be the next step. The feedback will disappear once all the team members read it.

4.6.2 Mentors' Feedback

One mentor mentioned "The idea of a spiral is really great. Initially, there might be some confusion but once they get the explanation it will be clear." Another mentor mentioned "Spiralling out is better as we make bigger things for each prototype and I like this idea of the colour of the road represents what you did and can quickly jump to any part is pretty cool." The mentors also had questions "Is it possible to update

the spiral; on a real-time basis spiral on a real-time basis? Like if we are on the first iteration then we just show one spiral and spiral out and for the second iteration 2 spiral and spiral out and so on." There were suggestions to have a button to add an iteration to the spiral. Mentors also mentioned "It was hard for the mentors to know what the students did from the slides. This tool records the journey that went through." Mentors had questions on "Can the mentors see who has done which part?" The mentors can scroll through to see tiny versions of these tools for all the teams the mentors are assigned. The most important thing is to see if they are coloured or not. The discussions went to identify the different colours for each of the DT tasks and there were future ideas to match the DT task with the associated colour using an app. "Will we be providing a toolkit for students to explain the spiral for the first time?"

There are icons on each DT stage, which could be clickable and take the user to the specific worksheet (in a possible future prototype). When each team member does the interview separately they can be labeled as 1a, 2a, 3a, and so on which can clearly differentiate the different interview processes.

4.6.3 Action Plan for the Prototype

The suggestions were added to hide the pie from the students to make them less stressed and it can be only visible to the mentors who can notify them about the student contribution. There were thoughts to include the due dates so that the students can be notified. Suggestions were also to include a view that the mentor can see the whole contribution of each student for the week. There can be a big pie added next to the Progress Widget which can have each student's detailed contribution to

the whole project and could be visible to the mentor (in a possible future prototype).

Overall, the mentors had positive feedback about the updates of the Progress Widget and there were no disagreements with any specific feature rather they mentioned a few suggestions to add features. The mentor specifically liked the part which can can clearly see the team's progress as the finished and unfinished tasks which were differentiated by different colours.

4.7 Focus Group for the Progress Widget IV

The Progress Widget is updated with additional features based on the inputs from the previous focus group. 6 mentors who participated in the previous focus group gave their suggestions and comments on the new features that were added.

4.7.1 Prototype Description

The Progress Widget is updated with 2 views - mentor view and student view. The Progress Widget has the student view represented in Figure 4.10 (a) and the mentor view represented in Figure 4.10 (b). The difference between the student view and the mentor view is that the mentor view has the capability to see the student's progress and their individual contributions for the whole project and individual contribution for each DT step through smaller and bigger pie. The smaller pie represents the individual contribution for each of the DT steps and the bigger pie visualizes each of the team member's contribution for the whole project.

The student view is represented in Figure 4.10 (a) where the students can see the detailed stages of Design Thinking representing the clickable icons and pointed

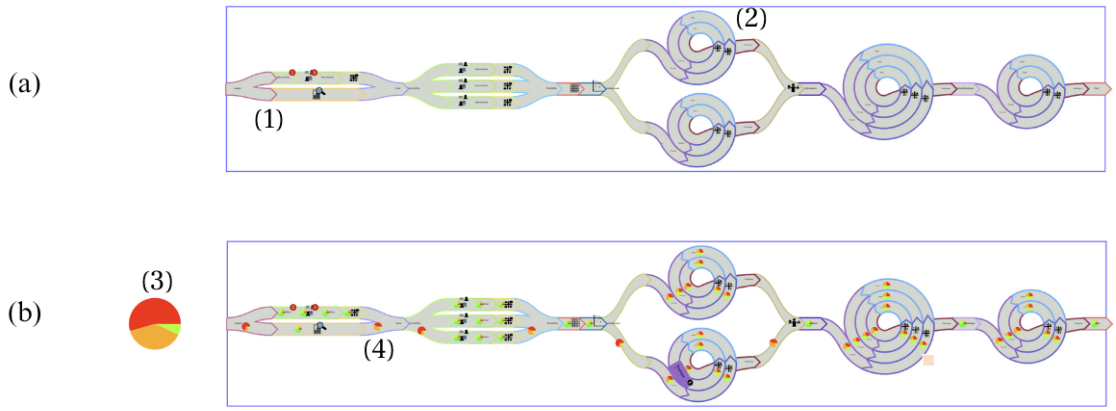

Figure 4.10: (a) Overall Student view of Progress Widget. Branches (1) indicate divergent and convergent thinking. Spirals (2) indicate the iterative nature of prototyping (b) Overall Mentor view of Progress Widget including pie charts for the individual contributions for the whole project (3), and for each DT step (4).

arrows indicating the flow of direction. A red circle with the number indicates the feedback given by the mentor for the respective task represented in Figure 4.11. The feedback will disappear when all the team members have viewed it. The hover-over appears for each of the DT tasks with the respective DT step name, the i icon which displays the contextual information. The contextual information has the task description which has the basic level instructions to perform the task as represented in Figure 4.11. Icons are on each DT step and the DT stage name can be viewed using the hoverover. As a first step, seven icons are added for the DT steps and the other DT steps are on their respective names. The mentor approves the completed tasks and it becomes coloured as represented in Figure 4.12.

Contextual information is expandable. A different icon will represent each step, while the pop-under shown in Figure 4.13 serves to remind the user of the step name, while giving access to the info card from the resource library. The five DT stages in Design Thinking are explaned in the Progress Widget into many DT steps. Our goal

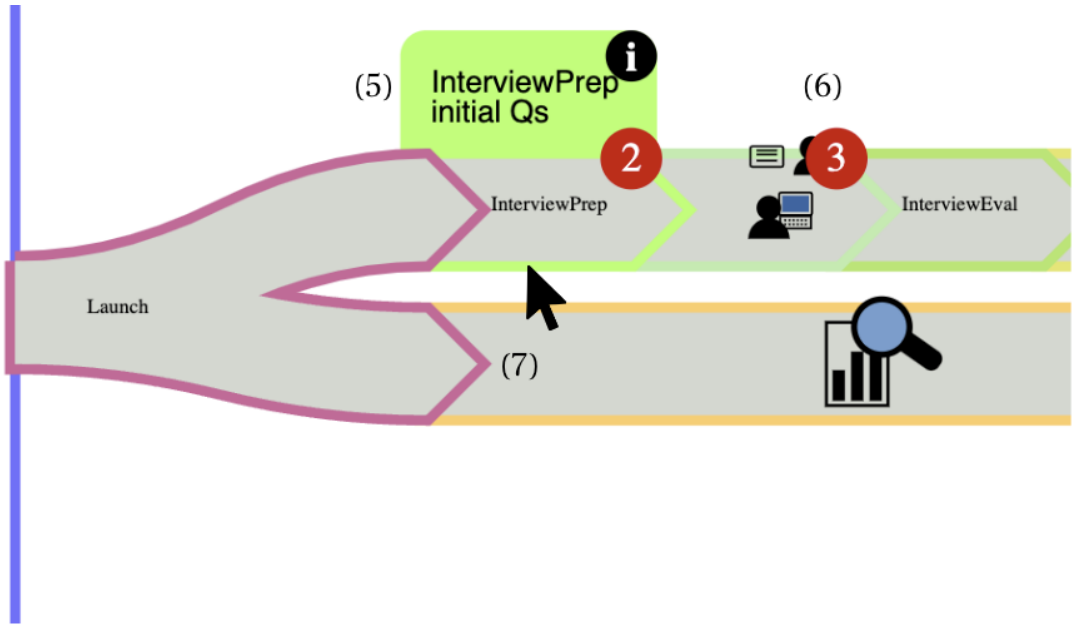

Figure 4.11: Pop-under (5) visible when hovering over each DT step. In the current implementation, the pop-under displays the name of the step, the label, "Initial Qs" of the step to distinguish multiple iterations of the same steps, etc., and an information button to open the card from the resource library for this step. Mentor feedback is represented as a red circle with a number (6) which when clicked will jump to the feedback. (In the case of the mentor view, the same indicators will be used for submittted work, or follow-up commments, awaiting feedback. A directional arrow indicates the flow of DT tasks from left to right (7).

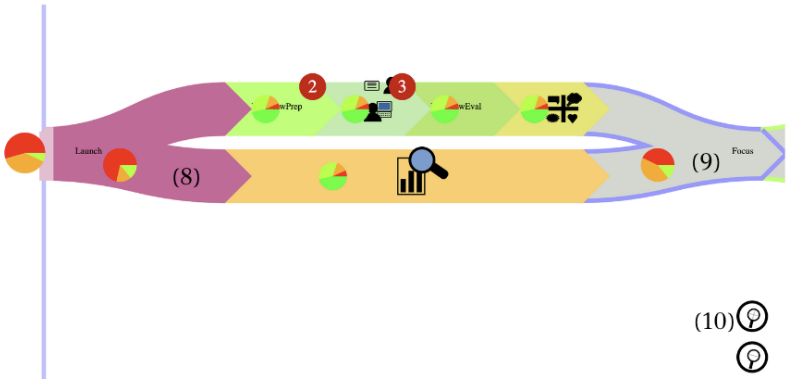

Figure 4.12: Completed DT tasks are highlighted in colour (8) after being approved by mentors, while upcoming tasks remain grey (9). Additionally, there are zoom-in and zoom-out buttons (10) for adjusting the view.

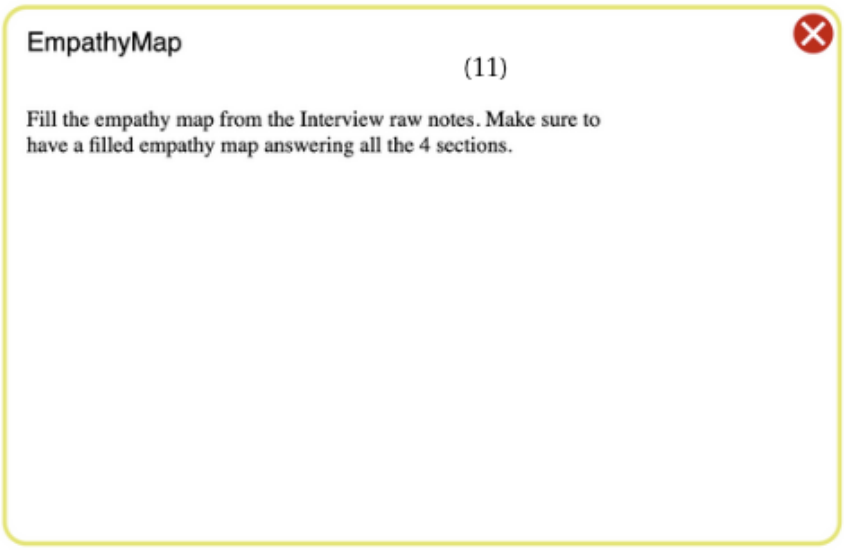

Figure 4.13: Clicking on the info button in the pop-under brings up contextual help (11) in the form of the card from the resrouce library for this DT step.

with this prototype was to make the role of icons clear, rather than to finalize the designs of the icons. Many steps do not yet have icons, and are represented by their names. A full list of the steps available in the current prototype, as well as the info text (which will be expanded in a fully functional prototype), follow:

- Interview - Use your prepared questions to open conversation with your user to learn about their problems, needs, wants and expectations. You will use this information to fill in your Empathy Map.
- InterviewPrep - Create practice interview questions, do a practice interview with the peer group, and make changes to the irrelevant interview questions after the practice interview. Make sure to include open-ended questions and add follow-up questions.
- InterviewEval - Make sure to do an Interview evaluation and share your Interview experience by highlighting your choices in the Interview evaluation table.

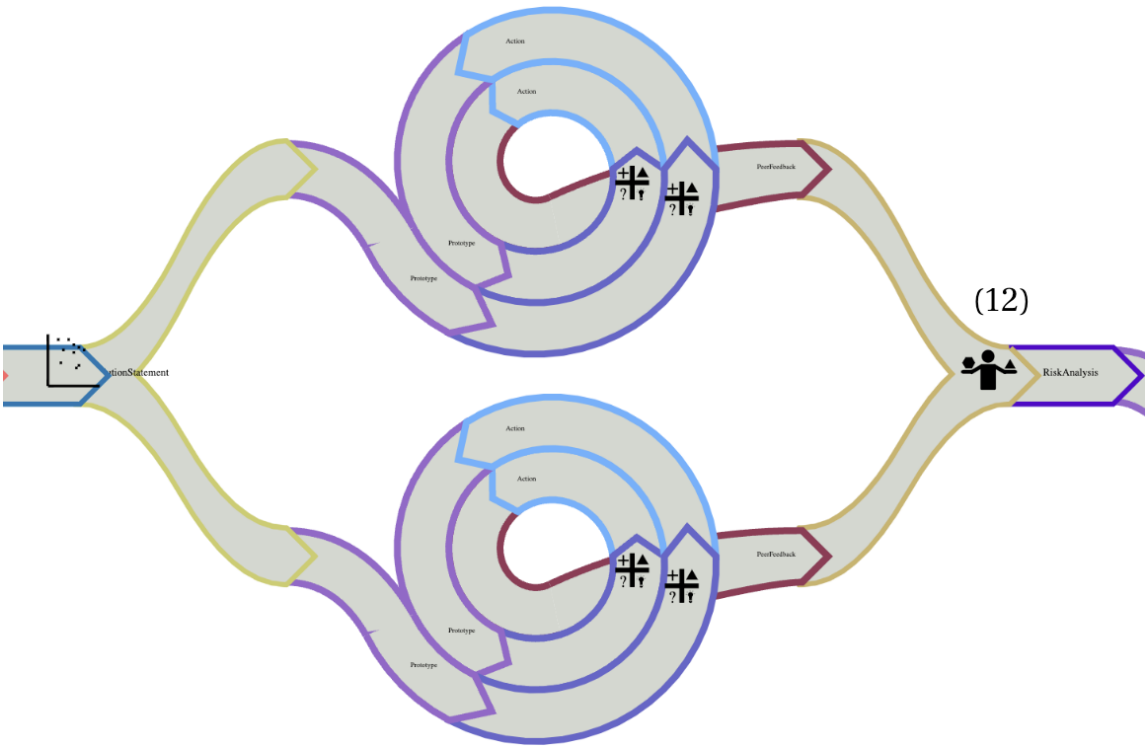

Figure 4.14: Convergent thinking takes different forms, as indicated by the icon (12)—in this case, prototype comparison, where the student teams choose prototype 1 or 2 or combine features of the two.

- EmpathyMap - Fill in the Empathy Map from the Interview raw notes. Make sure to have a filled Empathy Map answering all 4 sections.
- Research - Conduct preliminary research on the problem area, identify the target users, and pinpoint their specific challenges.
- Ideation - Brainstorm solution ideas based on the information gathered during the interviews.
- GameGenerator - Create game ideas in the table for the identified interests and the symptoms of Parkinson's. The Game ideas are created for each interest, and symptom pair for the entire table.
- DesireFeasible - Based on the solutions generated, they are plotted in the Feasibility Desirability graph. The most feasible and desirable solution is chosen.
- ProblemStatement - State the problem that has the highest ranking in terms of impact and novelty.
- TechnicalChallenges - Identify and assess technical challenges that arise while developing your prototype.
- RiskAnalysis - Identify and evaluate possible risks associated with your solution/prototype.
- Focus - Choose a target user group and problem area.
- IdentifyStakeholders - Identify users' needs and how your solution can benefit them.
- Prototype - Use any drawing tool to create a prototype. This prototype will be refined through iterations until it meets the needs of the users.
- Feedback - Conduct interviews with target users about your prototype. Focus on what they like, what needs improvement, questions, and new ideas.

- Action - Use feedback from the users to improve the prototype after each iteration.
- PivotOrNot - Decide whether to continue refining your existing prototype or start a new one based on user feedback.
- ProblemIdentification - Identify problems based on the information gathered during the interviews.
- ImpactNovelty - Rank your problems based on their impact and novelty.
- SolutionIdeation - Utilize traditional brainstorming to identify solutions that circle around the HMW statements.
- SolutionStatement - State the solution corresponding to the problem you want to address.
- PrototypeSelection - Compare the pros and cons of each prototype based on user feedback. Then, select the best prototype to continue refining and improving.
- PeerFeedback - Have a group discussion with peers to identify if any details can be included
- Pitch - Presentation of the design journey and demonstration of the final prototype.
- Launch - Write team charter and set scope if not defined by teacher.

4.7.2 Mentors' feedback

The mentors mentioned some suggestions like adding a circled background to all the icons to make them look similar as all the icons look different based on their purpose. One mentor mentioned that "Instead of having a free form like zooming and movement, I was thinking like a minimap kind of almost like in VS code. The

bigger view at the top and the minimap at the bottom that we can slide along." The discussions were done to ask if we could have the Progress Widget rotate to its side as time flows from top to bottom. However, few mentors strongly recommended that it will be effective if the process flows from left to right. There were suggestions to add the tool at the top so the students can know where they are as they progress through the different stages. They added that it will be clear when we add "You are here" similar to the map which can help the students to know where they are in the DT process. They added that new learners might have difficulty knowing where each DT stage starts and ends, we could have a Double Diamond map that can be added to one end. Another mentor mentioned "I was thinking of also having some other icon that shows this is where you are expected to reach before the next deadline. The deadline icon may also be adjustable by the mentors." The worksheets will appear below the Progress Widget in a single-page view or a split view when there needs to be a reference to a different worksheet. The mentors also mentioned that it is more detailed than the Double Diamond. One mentor said she was happy when there was a pie for tracking the team's progress which was mentioned in the previous focus group. The mentors mentioned this tool with various DT steps as icons might be confusing for someone new to Design Thinking, as all the stages are not listed. So there were comments to visualize the DT stages as a high-level view when zoomed out and the icons can be visible when zoomed in as a detailed view. The instructors can have the ability to drag and drop and the number of iterations required for the spiral.

Based on the last feedback, I conclude that the discussion about the Progres Widget led to a clear vision for a proposed collaborative DT environment using the Progess Widget as a gateway and gauge. The mentors are excited about the next

steps, namely integrating the worksheets into a self-contained tool, and testing it in a real teaching environment.

Chapter 5

Discussion and Conclusion

In this thesis, we have developed a semi-functional prototype of a Progress Widget. In this chapter, we put this prototype into context. First, we collect the key features from existing tools into a comparison chart, adding a column for the future of the imagined tool to be built around the Progress Widget. Next, we're going to summarize the prototyping journey, with an emphasis on lessons learned about soliciting actionable feedback. In the next section, we use thematic analysis to summarize what we learned about the priorities of DT mentors and features they identified which we believe will improve project outcomes and team growth by helping mentors track progress and give timely feedback. All of this contributes to answering our original research questions, and we conclude with a discussion of future development and research directions.

5.1 Tool Comparison

For ease of reference, key features of all tools are summarized in Tables 5.1 and 5.2, with one column for each tool. The final column lists the features of the proposed tool, which is the result of interviews and prototyping described in the remaining chapters of this thesis.

5.2 Lessons from Prototyping

From the

- Three rounds of interviews,
- Three focus groups, and
- Two written interviews,

with six DT mentors, we learned that tracking individual and group contributions in the group tasks was their main pain point. Contrary to our initial expectations, this pain point was felt equally for in-person and virtual teaching. In order to turn this pain point into actionable suggestions, we needed a concrete focus for the discussion. Introducing Gebbing et al. [9]'s paper prototype for a "virtual environment for creative collaboration" was the concrete focus required. Many of the proposed features were clearly appealing to the mentors, but the Progress Widget in the form of a multi-coloured Double Diamond attracted the most attention. So we focussed on this by creating seven paper prototypes to capture a range of design possibilities and prevent premature narrowing of the design space. Specifically, our research group has invested a lot in using the British Design Council's Double Diamond, including as a 'minimap' in the top corner of every DT worksheet, so we already had a paper version of the

Table 5.1: Comparison of Tools (part 1)

	Miro/Mural	GitHub	LMS	DT Worksheets as Google slides	**Proposed Progress Widget**
Interface	Infinite canvas for users to collaborate virtually	Code repositories and has transparent version control	A software application for course/training delivery	Online presentation and user-friendly platform	Online tool for DT course incorporating DT worksheets
Templates	Prebuilt templates for brainstorming, teamwork, mindmapping, etc.	Existing repository can be the Project templates for new repositories	Course contents, templates and assignments	Each slide is a worksheet for a DT step	Mini-apps for each DT step, including Empathy Map, Game Generator, Action Plan, etc.
Integrations	150 applications such as Microsoft Teams, Zoom, Google Drive, Onedrive, Microsoft Outlook, etc.,	Microsoft Teams, Visual Studio Code, Jira cloud	Google Drive, Microsoft Teams, Office, Zoom, Youtube, etc.,	Google sheets, Hubspot, WordPress, Clickup, Miro, Survey Monkey, etc.,	Task-specific tools such as Interviewing, Prototyping, and Coding tool will be integrated.
Features	Sticky notes, Canvas options, Control access, Mapping and diagramming, Create and publish custom templates, Chat, Lock feature, Timer, Summon participants and Private mode.	Code hosting, Version control, Collaboration, Bug fixing, Git repositories hosting, Track and assign tasks, Codespaces	Course content workspace, Quizzes, Grading, adding rubrics and comments, etc.,	Animations, offline access, Accessibility features, Sharing, mobile app access and presenter view	Student progress tracking, Progress bar as page navigator, Chat

Table 5.2: Comparison of Tools (part 2)

	Miro/Mural	GitHub	LMS	DT Worksheets as Google slides	**Proposed Progress Widget**
Collaboration	Synchronous Collaboration with multiple users	Asynchronous collaboration for collaborative coding, Transparent version control, Issue tracking and Pull requests	Discussion forums and Group tasks	Collaborators can have access such as view only or edit access. The presence of the avatar shows which slide is being viewed and edited	The presence of the avatar will be used to see student Progress, the Communication thread for mentors and students, and the Version history of worksheets can be viewed by the mentor.
Target users	Designers	Developers, Managers, Students and Instructors	Students and Instructors	Design students, mentors and Instructors	Design students, mentors and Instructors
Sharing/Feedback	Shareable links (View-only and edit mode), Comment option	Supports external testers, Code reviews, Pull requests	Grades, Rubrics and comments, Progress tracking, Deadline - On-time or late submission	Shareable links (View-only and edit mode), Comment option	Grades, Rubrics and comments, Progress tracking, Deadline - On-time or late submission

progress bar. We didn't want to just reinforce past choices. In addition to different versions of the Double Diamond, including semi-functional software prototypes, we included a "roadmap", in the form of a curvy road, with a start, finish and icons at each curve representing a DT step. In total seven prototypes were presented at this stage. To our surprise, the mentors overwhelmingly liked the fresh approach of the roadmap, even though it did have obvious drawbacks (lack of iteration, lack of divergent and convergent thinking). We made several attempts to combine features of the "roadmap" with the Double Diamond, and to introduce graphical elements to represent iteration. These prototypes created a lot of discussion, identifying several goals:

- representing prototype iteration visually,
- representing parallel tasks visually (which is related to but not the same as divergent and convergent thinking),
- representing the current team's progress in the DT process visually,
- representing the relative contributions of members within a team visually,
- representing the stages in DT each composed of multiple steps,
- using consistent mapping of time and space (e.g., time flows from left to right),
- integrating a resource library (an appealing aspect of Gebbing et al. [9]) via tooltips within the Progress Widget.

Based on the mentors' many concrete suggestions, the Progress Widget was designed. Four generations of prototypes were evolved based on the mentor's feedback. As the prototypes became more detailed, so did the feedback from the mentors. With the final prototype, all of the mentors felt that a clear direction had been established, not only for a Progress Widget, but a tool incorporating the resource library in the form

of tooltips and expanding information cards, and navigation to digital versions of the worksheets. Not every aspect of the prototypes was accepted by the mentors. While the addition of pie charts to indicate relative team contributions was welcome as an oversight tool, mentors strongly disagreed with sharing this indicator in the student view, because it could easily lead to conflicts.

5.3 Themes from Progress Widget Feedback

In addition to iterative analysis of mentor feedback to drive the next prototype iteration, we also used grounded theory to generate a big-picture view of the combined feedback from all iterations. From this analysis, three themes and nine sub-themes emerged. The themes and their relationship to the sub-themes, together with representative mentor quotes are organized in Tables 5.3 and 5.4.

Table 5.3: Themes discovered in feedback (part 1).

Quotes	**Sub-themes**	**Themes**
I would definitely go for having a progress bar. And I highly appreciate the progress bar supporting navigation to each stage. However, the progress bar itself is a big help.	Progress Widget	Visualizing Design Journey
This has always confused me about the Double Diamond: it can feel like you're supposed to take one of the two paths at once, but actually, they're done in parallel. I wonder if there's a way to show this that makes it clear they happen simultaneously.	Visualize parallel tasks	
The roadmap is clear and easy to understand.		
How will progress be shown?	Colour completed tasks	
Try to show iterations somehow	Visualize iteration	
Having explicit sections for each of the iterations/prototypes you need to work on.		
There should be some sort of indication that time flows from left to right	Visualize flow	

Table 5.4: Themes discovered in feedback (part 2).

Quotes	**Sub-themes**	**Themes**
There was no way for me to easily record what we talked about or what they told me in terms of their progress. I could have done it manually but that would have taken more effort and would have been difficult to do while also talking to them.	Facilitate mentor-student communication	Visualizing Student Progress
I would say this is the biggest downside of using Microsoft PowerPoint. Since it is a general-purpose tool, it's not very easy to determine who worked on what or what their progress is.	Visualizing individual student contribution	
We tend to grade the whole group without considering the individual contributions.		
It is a bit complicated by the fact that different iterations have a different number of slides. It can be a little difficult to navigate right to where you want to go.	Navigate to the tasks	Navigation
One problem with the slides as they are now is that the instructions are mixed together with the team-generated content in the slides. If there was a way to hide the hints behind (i) or (?) icons or something, that would be good. Or at least the ability to toggle the on-screen help.	Contextual help	
But it would be good if you put a little tooltip on top of things when you mouse over.		
Maybe when they mouse over any of the icons you put up the name of that step as well as a little bit of text saying what it's for.		

5.4 Research Questions

RQ1. What difficulties did the mentor face in providing feedback and tracking team progress when teaching many teams, and how could those difficulties be mitigated with tool support?

The DT mentors experienced difficulty keeping track of when teams had completed tasks in their PowerPoint worksheets and needed feedback, especially between deadlines, or when teams were late. For each team, they had to open the PowerPoint and check for progress, which was very time-consuming in large classes.

In the final prototype of the **Progress Widget**, mentors can see all of the updates needing feedback for all teams at once by looking for the red circle notifications. They can navigate to the specific worksheet requiring feedback with a single click on the icon representing that step, where they can provide feedback. The combination of overview, quick access, and commenting in place will make mentor feedback timely and efficient. Similarly, students can see when mentors have given feedback using the same red circle indicators and similarly jump to the worksheet in question to see the new comments in context.

RQ2. What difficulties did the mentor face in tracking individual student contributions and how could those difficulties be mitigated with tool support?

The mentors (specifically teaching assistants) mentioned that for a few groups, some teammates some students were not contributing to the group task, but other team members did not want to raise this issue until it was very late in the process. The mentor should have a clear view of every student's contributions to the group tasks. This is a problem for group projects, in general, but for DT projects, each

member brings a different perspective which improves group decision-making.

In the final prototype of the **Progress Widget**, mentors can see each team member's contribution in a pie chart attached to individual DT steps and to the overall project.

In this thesis, we have designed an iterative Progress Widget which will help the mentors to visually see the progress of each team. The Progress Widget acts as a page navigator for various DT stages and worksheets where the students perform their DT tasks. Students can easily track their progress in the Design Thinking process, see which stages they have completed, and identify the remaining stages and tasks to complete. This gives them a clear idea of the entire DT process. The arrow in each stage points to the direction of the process flow. Each arrow contains icons representing tasks, which are clickable and can be used to navigate to the corresponding worksheet when clicked. The fork path is added to show the convergent and divergent tasks similar to a Double Diamond. The Progress Widget can be zoomed in and out. Also, there's a resource pop-up which has the instructions for each task, as well as information about that particular DT stage. Additionally, a pie chart is provided for each stage, displaying the individual team contributions through the chart's segments. The spiral added for the final three steps illustrates the iterative nature of the Design Thinking process during the Prototyping, Feedback Grid, and Action Plan stages.

5.5 Future Work

Future developments of this Progress Widget are to integrate it into a Design Thinking course. One potential direction is to implement it into a course to gather feedback

about the tool being used in the context of education. This could give us a real-time experience of knowing how this iterative Progress Widget helps the students and the mentors throughout the DT course. This can eliminate the discrepancies in tracking student progress and monitoring.

The fork path branches are variable for each team based on the number of people in the team. An add button could be placed near the spiral to add a new iteration. There can be a Mentor view and a student view. The mentor view has the provision to check individual and team progress, provide feedback and instructions and view the student worksheets, assign due dates and tasks. In the student view, the students can see the feedback and comments, chat with mentors and their team members, edit their worksheets before their due date, and opt for a presentation mode to see the entire worksheets. The feedback could disappear once all the team members have viewed the feedback. The students can communicate through the existing chat. An avatar could be assigned to each student to identify the student and to record their individual contributions. A programming environment will be linked to this Progress Widget where the users can code their prototype and make iterations. Throughout the thesis, we have interviewed DT mentors but to have a better understanding of the student's view we have plans to collect the DT student's points of view while they are learning. The descriptions used in the information card are the first level of information and more detailed information will be added in the future prototypes. Another future work is to figure out the best mapping colour for each DT step by surveying with the mentors.

Bibliography

[1] R. K. Allah. The use of miro in teaching practice. *Exchanges: The Interdisciplinary Research Journal*, 10(3):77–91, 2023.

[2] C. K. Anand, G. Dulai, L. Yao, M. Arief, O. D'Mello, S. S. Menon, and C. W. Schankula. *Creating with Code*. Fondation STaBL Foundation, 2023.

[3] F. W. Baker III and S. Moukhliss. Concretising design thinking: A content analysis of systematic and extended literature reviews on design thinking and human-centred design. *Review of Education*, 8(1):305–333, 2020.

[4] N. Cross. *Designerly ways of knowing*. Springer, 2006.

[5] J. P. Donaldson and B. K. Smith. Design thinking, designerly ways of knowing, and engaged learning. *Learning, design, and technology: An international compendium of theory, research, practice, and policy*, pages 1–24, 2017.

[6] L. Duško et al. The visual online tools for collaborative learning and icebreaker activities. *Vestnik of the Russian University of Friendship of Peoples. Series: Informatics Education*, 19(4):351–359, 2022.

[7] C. d'Alves, T. Bouman, C. Schankula, J. Hogg, L. Noronha, E. Horsman, R. Siddiqui, and C. K. Anand. Using elm to introduce algebraic thinking to

k-8 students. *Electronic Proceedings in Theoretical Computer Science*, 270: 18–36, May 2018. ISSN 2075-2180. doi: 10.4204/eptcs.270.2. URL `http://dx.doi.org/10.4204/EPTCS.270.2`.

[8] B. K. S. Gan and E. L. Ouh. Designing learning activities for experiential learning in a design thinking course. In *2019 IEEE International Conference on Engineering, Technology and Education (TALE)*, pages 1–8. IEEE, 2019.

[9] P. Gebbing, C. Lattemann, and E. N. Büdenbender. Towards a creative virtual environment for design thinking. *Pacific Asia Journal of the Association for Information Systems*, 15(4):1, 2023.

[10] P. Gebbing, J. Bosbach, M. Helms, A. Umel, and C. Lattemann. Blending the best? fostering creativity in hybrid teams. *ECIS 2024 proceedings*, 2024.

[11] Interaction Design Foundation. What is Design Thinking (DT)? `https://www.interaction-design.org/literature/topics/design-thinking`, 2016. Accessed: 2024-08-12.

[12] E. K. Johnson. Miro, miro: Student perceptions of a visual discussion board. In *Proceedings of the 40th ACM International Conference on Design of Communication*, pages 96–101, 2022.

[13] L. Kimbell. Rethinking design thinking: Part i. *Design and Culture*, 3:285 – 306, 2011. doi: 10.2752/175470811X13071166525216.

[14] L. N. Laursen and L. M. Haase. The shortcomings of design thinking when compared to designerly thinking. *The Design Journal*, 22(6):813–832, 2019.

[15] B. Lawson. *How Designers Think*. Routledge, 2006.

[16] C. O. Leng, C. Y. Sheng, C. K. Yeap, and C. P. Tan. Students' perceptions towards using Google slides and google classroom as online collaborative tools in Mandarin learning. *Journal of Islamic*, 6(36):81–91, 2021.

[17] M. Melles, A. Albayrak, and R. Goossens. Innovating health care: key characteristics of human-centered design. *International Journal for Quality in Health Care*, 33(Supplement_1):37–44, 2021.

[18] D. P. Nolasco and D. M. P. Hernandez. Learning management system usage: Unwrapping its potentials and drawbacks. *CTU Journal of Innovation and Sustainable Development*, 15(2):92–102, 2023.

[19] S. K. Padma Pasupathi, Jiawen Wang. Interview Guide: Preparing Students to Interview Users. Private Communication, 2021.

[20] T. Potthoff, D. Siemon, K. Wilms, S. Möser, M. Hellmann, S. Stieglitz, and S. Robra-Bissantz. Collaborative service blueprinting for design thinking: evaluation of a digital prototype. *Hawaii International Conference on System Sciences*, 2018.

[21] B. Redlich, D. Dorawa, D. Siemon, and C. Lattemann. Towards semi-virtual design thinking-creativity in dispersed multicultural and multidisciplinary innovation project teams. *Hawaii International Conference on System Sciences*, 2018.

[22] W. Sardjono and W. G. Perdana. Implementation of learning management system towards quality education according to sustainable development goals. In *AIP Conference Proceedings*, volume 3026. AIP Publishing, 2024.

[23] K. Tschimmel. Design thinking as an effective toolkit for innovation. In *ISPIM Conference Proceedings*, page 1. The International Society for Professional Innovation Management (ISPIM), 2012.

[24] United Kingdom Design Council. Design Methods for Developing Services. `https://www.designcouncil.org.uk/fileadmin/uploads/dc/Documents/DesignCouncil_Design%2520methods%2520for%2520developing%2520services.pdf`, 2015. Accessed: 2024-08-12.

[25] A. Venkatesh, T. Digerfeldt-Månsson, F. F. Brunel, and S. Chen. Design orientation: a grounded theory analysis of design thinking and action. *Marketing theory*, 12(3):289–309, 2012.

[26] C. Wang, Y. Sun, Q. Lin, R. Cao, and Y. Che. Online teaching platform of design thinking workshop. *Ergonomics in Design*, 47:22–29, 2022.

[27] Y. Yi and Y. Li. Study on grounded theory-based product design. *2021 3rd International Conference on Artificial Intelligence and Advanced Manufacture*, 2021. doi: 10.1145/3495018.3495026.

[28] A. Zagalsky, J. Feliciano, M.-A. Storey, Y. Zhao, and W. Wang. The emergence of github as a collaborative platform for education. In *Proceedings of the 18th ACM conference on computer supported cooperative work & social computing*, pages 1906–1917, 2015.

[29] W. Zaqoot, L. Oh, et al. Teaching design thinking using online whiteboarding in a graduate-level digital innovation course. In *26th International conference on computers in education, Metro Manila, Philippines*, pages 26–30, 2018.

[30] T. Zhang and H. Dong. Human-centred design: an emergent conceptual model. *Include2009 Proceedings*, 2009.