Design Thinking for Human Centric Research Data Systems Engineering

Victoria Lyczak
University of Notre Dame
USA
vlyczak@nd.edu

Scott Hampton
University of Notre Dame
USA

Paul Brenner
University of Notre Dame
USA

Wendy Angst
University of Notre Dame
USA

ABSTRACT

Design thinking research has emphasized the collaborative and iterative nature of design thinking, grounded in user empathy. In addition to divergent and convergent thinking, ethnographic interviewing enables a full landscape of a user's holistic needs to be considered, ultimately allowing those who use the technology to openly explore their unmet needs, future scenarios, and ideal states; enabling it to answer complex questions and technological needs in a human-centric process. In this paper, we aim to advance both the research data and design thinking literature as well as promote greater collaboration between the two by asking "How might we involve a design thinking approach to understand user needs, collect data, and ultimately develop research data storage solutions that delight our end users?" This subtle shift from "meeting requirements" to "delighting" has allowed us to engineer our research data systems with a focus on human powered computational science.

KEYWORDS

Design Thinking, Research Data, Filesystems, Data Security, Data Transfer

ACM Reference Format:
Victoria Lyczak, Scott Hampton, Paul Brenner, and Wendy Angst. 2024. Design Thinking for Human Centric Research Data Systems Engineering. In *Practice and Experience in Advanced Research Computing (PEARC '24), July 21–25, 2024, Providence, RI, USA.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3626203.3670542

1 INTRODUCTION

Data generation and processing requirements for computationally based research and discovery continue to grow in both highly technical and profoundly social ways. Research computing engineers on university campuses are now routinely asked to provide data solutions that bridge numerous storage platforms and protocols both internal to their organization and between peer organizations. Each of these data platforms (filesystems) has distinct design points relative to a variety of metrics such as security (authentication/authorization/encryption/logging), IOPS performance, reliability/redundancy, concurrent MPI file IO, OS compatibility, and more. Further the unique steps of the research data lifecycle [5, 7, 15] and efforts to enable FAIR data principles throughout [1, 3, 17, 18], mean that many scientist's research data infrastructure requirements will change dynamically over time and across numerous concurrent research projects.

This leads to an overwhelming number of research data infrastructure design and optimization parameters. Our team at the University of Notre Dame's (ND) Center for Research Computing (CRC) has been working through such challenges for nearly twenty years and recognized that we were slowly losing ground in attempts to meet even a subset of the growing data requirements. Our partners in enterprise IT (ND's Office of Information Technology (OIT)) were working in adjacent domains and recognized similar challenges. We jointly sought fresh eyes and ideas for complex problem solving and began work with Design Thinking experts in ND's Mendoza College of Business. We embarked on a Design Thinking journey to re-imagine research data infrastructure from the human-centric view of campus researchers versus a more traditional set of technical performance metrics which govern a design and procurement processes. While the performance metrics and technical features certainly remained part of the design solutions; it was critically and uniquely important to shape our mindset around the question "how would research data infrastructure delight our scientists" versus "what are the costs and performance specifications of available filesystems to meet a specific research application".

In the following sections we provide a case study for leveraging Design Thinking to address the complexity of engineering and operating research data infrastructure across the diverse needs of a university community.

2 DESIGN THINKING

Design thinking is a human-centered design process that involves five primary stages: empathize, define, ideate, prototype, test and an optional sixth stage of implementation as denoted in Fig. 1.

The first stage, empathize, involves ethnographic interviews, meeting the interviewees in the physical location where they engage with the situation you are hoping to address and having them show you how they engage with the product or service rather than

PEARC '24, July 21–25, 2024, Providence, RI, USA

ACM ISBN 979-8-4007-0419-2/24/07
https://doi.org/10.1145/3626203.3670542

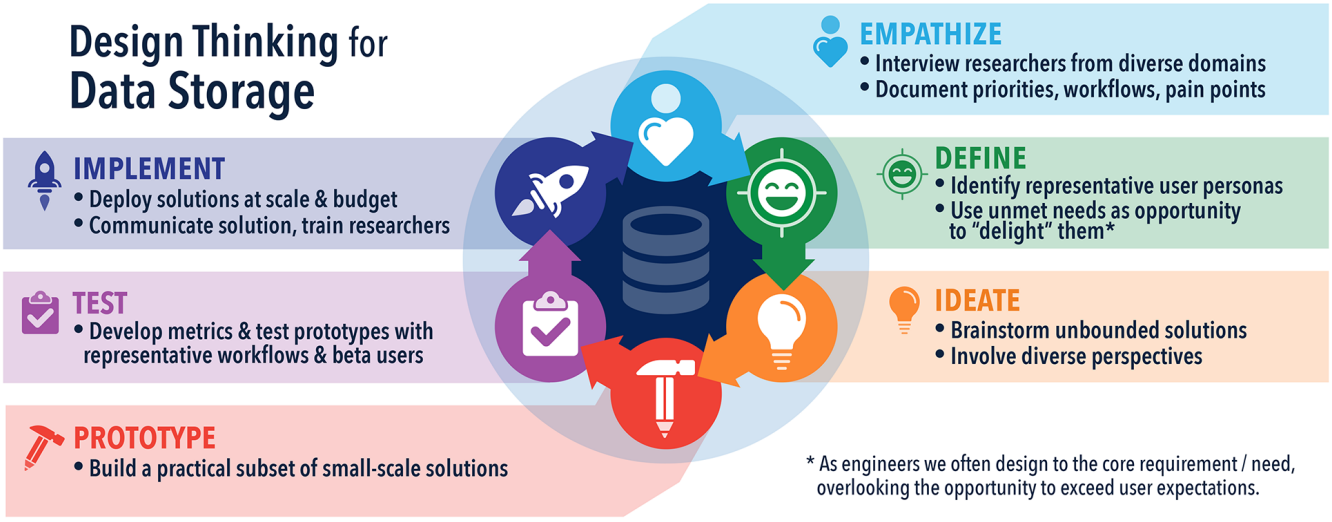

Figure 1: Stages of the Design Thinking Process Applied to Research Data Storage

just having them tell you about it. Doing so helps to uncover pain points and unmet needs of the users. Further, these interviews help identify the emotions and create a deeper level of understanding among the researchers of the user's unmet needs. Ultimately, this process allows for the possibility of identifying insights that define opportunities for innovation. A "beginner's mindset" is welcomed in the early stages of this process; doing so promotes curiosity and ensures researchers do not fill in missing pieces with their own personal answers instead of the user's.

In general, these interviews tend to follow a script to guide the discussion, focused on building empathy, by first asking high-level questions about the user's work, then asking for descriptions and examples of how he or she uses the product or service, what his or her problems are by walking through specific examples when the user experienced a challenge, and alternatively a time when his or her expectations were exceeded, and ultimately, what the ideal state would be if anything were possible for the user to accomplish the specific "job" he or she is looking to get done.

Design thinking makes use of a "double diamond design process," which means using divergent thinking followed by convergent thinking to identify the problem, and then divergent thinking followed by convergent thinking again to develop viable solutions. During the empathize phase, divergent thinking dominates. As the define phase of design thinking begins, convergent thinking takes over. In the ideate and prototype phases, divergent thinking rises, while convergent thinking closes the project with the test phase.

As the research team closes the ideate phase and begins the prototype phase, it is important to acknowledge feasibility as a crucial part of the project's success, though removing this constraint in the early stages of the process is crucial to ensure no potential solutions are left undiscovered.

Throughout the entire design thinking process, there is a strong emphasis on collaboration and sometimes even co-developing the product or service with the very users it is meant to serve. Doing so means it will almost certainly better meet the needs of the users because of clearer insight from the users themselves about their pain points and goals to get a specific task or job done, rather than guessing what these may be. It is important to re-involve the users after the initial empathize and data gathering parts of the process; by involving the users in the prototyping process, the researchers are able to see firsthand the users' experience and truly understand what they would think, feel, and experience overall when using the product or service and to identify any misguided assumptions. Thus, applying this human-centric design approach to research data problems is a particularly valuable approach and one we are advocating for a greater use of in this field.

Existing literature in the research data space has focused on delivering solutions that meet customer needs, even using divergent and convergent thinking in the process. Research data literature has focused less on following an explicitly collaborative development process that involves high contextual contact with their users.

2.1 Key Design Thinking Advances

Design thinking is particularly well-suited for the complex questions and business problems that arise with technological developments and needs, particularly because it makes use of reframing, the iterative process, and accurately understanding user needs [16]. Design thinking is known for its power in effective "wicked problem" solving via its learning and reflective practices [2], where there is not one right answer, and the perfect solution rarely exists. Emphasis on empathy and collaboration have been shown to be successful in design, like with a traffic congestion problem [19]. In this paper, in typical design thinking fashion, the research team utilized personas, an affinity diagram, "how might we" questions, minimum viable product (MVP), and high-fidelity design. In the prototyping and testing stages, the research team made use of usability testing and single ease questions, which assessed the ease experienced by users of a certain task, on a scale from 1 to 7.

Other recent contributions to the literature have stressed the importance of involving desirability analysis throughout the process

and feasibility analysis by continuing to converse with technology experts throughout the process, so as to avoid developing impractical solutions [8]. Design thinking has been shown to be valuable as a framework for organizations striving to amplify innovative behavior; as a mediator, it influenced the effects of team cohesion and motivation on innovation [20].

The most effective and innovative design thinking in a team setting is done with discipline, careful coordination, having a structure of authority, strong structure in the process overall, and an emphasis on honesty and transparency [11]. Careful attention to implementing a disciplined design thinking methodology is crucial throughout all phases (especially later) of the project [13]. Further, the hallmarks of design thinking like analogies and visual representation are useful in communicating technical knowledge across disciplines and to the public [6], making the use of design thinking in the research data space even more valuable

3 OUR DESIGN THINKING FOR RESEARCH DATA METHODOLOGY

In the following sections we discuss how the Design Thinking process helped us approach a the solution of providing a new storage solution for the CRC from a different perspective.

3.1 Empathize

The research team consisted of a mix of design thinking experts and research data experts on campus. The design thinking literature has shown great benefits to multi-disciplinarity in brainstorming as it increases creativity [10]. This initial stage, empathize, was used to help identify users across campus whose data storage and processing needs vary and to ensure we viewed user needs from a broad lens as we went through the design thinking process. The research team conducted seven ethnographic interviews. Three or more members of the research team were always present, following the traditional design thinking roles. One of the team members led the interview, asking questions and following leads that arose throughout each individual interview, another team member served as the videographer, capturing reactions to phenomena discussed during the interview. The third team member served as the primary notetaker during the interview, capturing key quotes, insights, and questions for follow-up.

These ethnographic interviews followed a standardized script developed by the research team, but interviewers were permitted and encouraged to go off-script to gain additional insights or follow-up on any interesting things said by the interviewees. All interviewees gave explicit consent for a recording of the interview. Closing the interviews, interviewees were invited to offer any additional thoughts or sentiments, and then key takeaways were shared with interviewees to confirm what was heard. Interviewees were asked if they would be willing to offer feedback on ideas and prototypes of solutions. All interviewees responded positively. Immediately following the interview the research team debriefed noting anything we found surprising and discussing areas we would like to learn more. The research team then uploaded all notes and digital files and sentiment analysis was performed. Beyond the research team's notes, the team used AI tools to generate interview transcripts and insights, ensuring accurate understanding of each interview.

One key distillation that arose after conducting a number of these ethnographic interviews as a difference in why users do not delete old data, with about a third of our interviewed users falling into the camp of "it's not worth my time" and the other two-thirds fearing the loss of data they might need some day. Similarly, the research team began to see a pattern of concerns and priorities voiced by interviewees: security of data, clarity of the data storage and processing procedures, and processing speed. Particular attention was paid to the interviewees network, within the walls of the institution and beyond, that might add additional layers of complexity to data storage and access.

3.1.1 Research Storage Requirements Survey. The research team complemented the deep-dive ethnographic interviews with a campus-wide survey sent to the audience of the existing Center for Research Computing's user base, which includes students, faculty, and staff. The survey generated 99 completed responses. The survey enabled the CRC to get a broader picture of more users across campus and see if they mapped onto the same user groups evidenced by the ethnographic interviews. It is important to note that discussions within the Design Thinking team had a distinct influence on the style and types of questions. In particular, we went from focusing on specific technical details to more open ended questions with a hope of capturing what usability factors are important to the end-user.

Respondents were asked questions regarding their use of computational research methods, data analysis and management tools, collaboration with users internal and external to the University, the amount of data they need and the nature of that data, and some hypothetical preferences regarding potential options the research team was initially considering as part of the solution as a form of early prototyping.

The survey revealed that only 27.3% of respondents need to transfer data with collaborators or storage locations internal to Notre Dame that are not directly affiliated with the CRC, and only 25.3% of respondents need to share data with collaborators external to Notre Dame on a monthly basis frequently. This means many respondents are working with other Notre Dame researchers who are using CRC's existing resources. Further, most respondents do not work with data that has special security or compliance needs, with this only applying frequently to 15.6% of survey respondents.

Most respondents also expected their data storage needs to grow over the coming year; 24.2% expect an increase of 100GB, 21.2% expect an increase of 500GB, and 27.3% expect an increase of 1,000GB. A few respondents reported needing drastically larger quantities of data storage in the coming year (10TB+, 100TB, even 200TB), while 13.1% do not expect an increase in their needs.

The strong majority of respondents expressed importance in having recoverable data, with 53.5% expressing that it is very important that some portion of their data be recoverable and 20.2% indicating that their data is very expensive to generate and/or very hard to reproduce or that they are mandated by a grant to keep the data. This 20.2% was also willing to trade total capacity for data security and recoverability. 22.2% of respondents agreed that a recoverable option would be nice to have but not necessary, as their data can be regenerated or downloaded from elsewhere.

Delving deeper into the recovering data recovery preferences, respondents wanted fairly frequent snapshots or backups. 32.7% of respondents expressed a desire for nightly backups where they could retrieve a file only as it existed yesterday and 41.8% expressed a desire for a couple of snapshots taken across different days to track file changes and provide recovery from the last week. 18.4% of respondents wanted recovery options kept for a longer period of time, desiring multiple weeks worth of snapshots to track file changes and provide recovery from the last month, willing to make a trade-off of total capacity in exchange.

3.2 Define and Ideate

After the completion of the ethnographic interviews and user survey, the research team met to engage in the define and ideate stages of the design thinking process. The research team developed four user personas with the goal of clarifying the differing needs of these different user types. Personas are created to represent groups of users that arise from research rather than from stereotypical assumptions [9]. All interviewees were sorted into four categories on two axes: low or high demand on the amount of storage needed and low or high on needed storage performance. During the ideation session, the team revised the storage performance axis which was previously assumed to be the number of collaborators, which was not as relevant to determining how different user groups act and what their distinct needs are.

3.2.1 Personas. The four personas that emerged were: the Laptop Warrior, the Collector, the Grappling Grad Student, and the Rockstar as seen in Fig. 2.

The Laptop Warrior. falls into the low data storage and low storage performance quadrant. This user is able to conduct most all of his or her research on his or her individual laptop, without need for greater processing power from the University. Similarly, the amount of data storage this individual has is not a concern to the individual. His or her primary concerns include relatively fast data processing, secure access to data, and ease of sharing his or her data. During one of our interviews, a Laptop Warrior shared, "We have access to great tools, they work very well. I can access them from anywhere on any device."

The Collector. falls into the high data storage and low storage performance quadrant. This user has mass amounts of data, requiring additional storage beyond his or her laptop, but does not need greater processing power from the University. This type of user often conducts research that is particularly unique and irreplicable, in the form of large sets of data. This user tends to fear losing that data and wants to be ensured that his or her data will always be there and be accessible. During one of our interviews, a Collector shared, "The most important thing is to reliably pull down data and upload data and know that corruption is not going to be an issue…when that [corruption] happened, we haven't been able to replicate that video that we lost ever again."

The Grappling Grad Student. falls into the low data storage and high storage performance quadrant. This user does not typically have massive quantities of data, but often requires advanced processing power beyond a laptop computer. This is especially true for users doing machine learning or big data research tasks. For these users, primary concerns include ensuring data access with appropriate permissions for all collaborators who also need access to the data as well as clarity around how to access and use resources. During one of our interviews, a Grappling Grad Student shared, "Someone's like 'oh, you just do this to do that,' and someone's like 'wait, you can do that? I've been here for four years and didn't know you can do that,' so it would be nice to have some consolidation of knowledge or onboarding."

The Rockstar. falls into the high data storage and high storage performance quadrant. This user often has large quantities of data, in part from years of successful and productive research, and requires advanced processing power for his or her data analysis. The primary concern of this user is processing large quantities of data quickly, with an attitude of eagerness or impatience and high expectations for the process working correctly and efficiently. During one of our interviews, a Rockstar shared, "And then that's when it's like, all right, well, now you're kind of in a time crunch [when submitting a paper with your results] because you have to respond to the review in a timely manner. Essentially, at that rate, then it becomes, all right, you can only work at the speed of the resources that are available."

3.2.2 Other Design Thinking Tools. The research team also considered the framework of an Empathy Map, which marked the pressures of working with collaborators and publishing demands that graduate students and assistant professors in particular are facing. Similarly, the team utilized "Point of Views" using our personas, filling in the blanks of the following sentence: "[persona] needs to [user's needs] in a way that makes them feel [emotive]." For example, the Laptop Warrior needs to seamlessly collaborate with coauthors in a way that makes them feel both nimble and in control.

3.2.3 Brainstorming. As the research team finished building out the personas, we defined a number of "how might we…" questions to guide our process to ensure we approached the unmet needs with a broad mindset to explore what might be possible:

- How might we ensure that users have what they need to do their best work and be productive collaborators and researchers?
- How might we simplify the process of accessing files when needed?
- How might we ensure security requirements for data are being met with minimal to no effort by the user?
- How might we simplify users getting immediate and personalized help when needed?
- How might we work toward optimizing the most efficient use of the storage and processing ecosystem [for the individual] in a way that delights and surprises them?

These questions served as guideposts for our brainstorming. In design thinking, Osborn's methodology of brainstorming is at play: avoiding criticism, encouraging wild ideas, pursuing quantity over quality, and building on the group's ideas together [14], and this is the brainstorming model the research team employed.

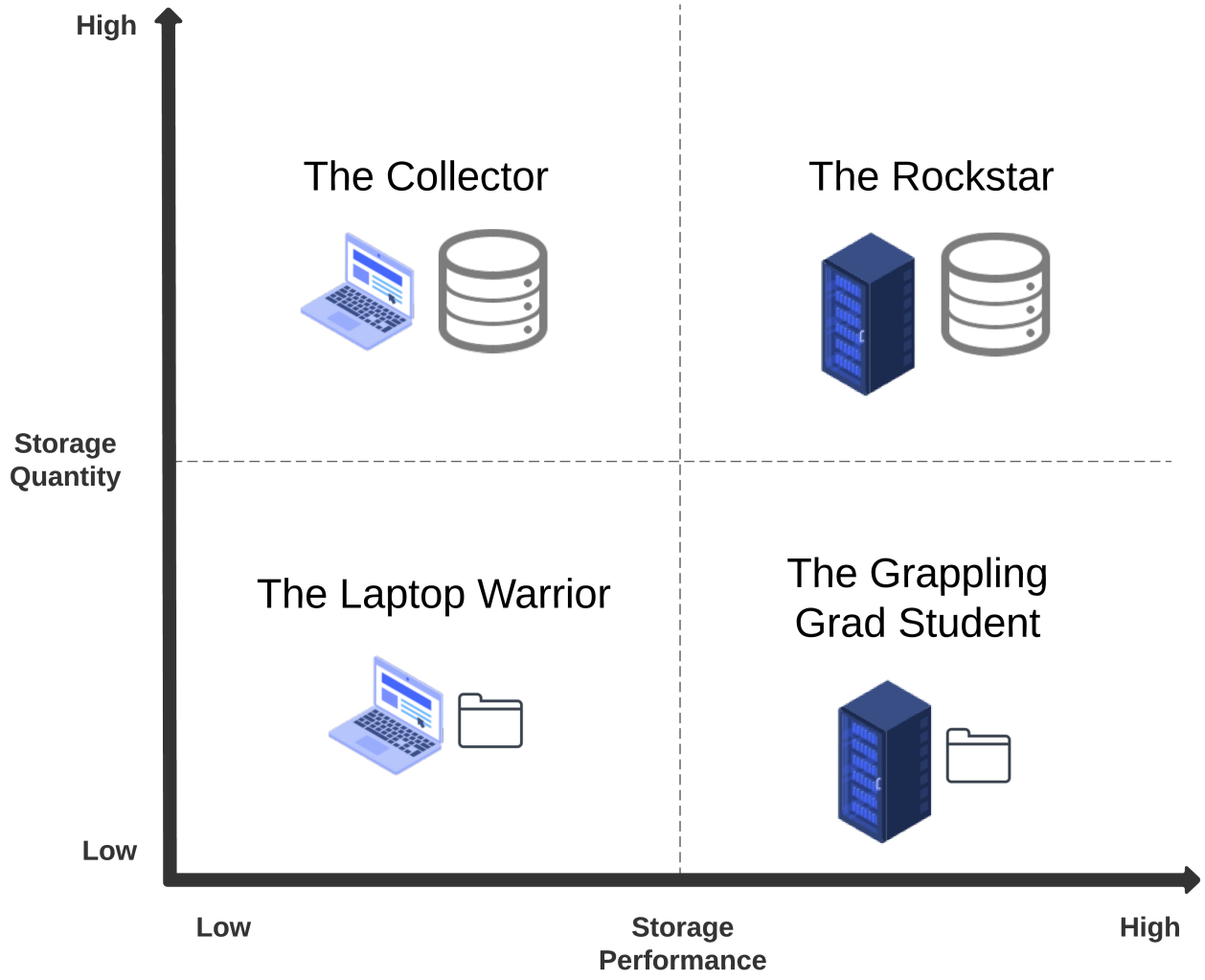

Figure 2: Simplified Research Data User Personas Relative to Two System Design Metrics

The research team engaged in a number of prompts to think about out-of-the-box solutions. Several of these discussions are summarized in the following paragraphs.

What's the worst that could happen? The research team was first prompted to consider how we could address the problem in a way that ensures the user almost never gets their needs met, as design thinking recognizes that pushing ideas to extremes can result in novel solutions [12]. These ideas included the user never being able to get help, requiring users to figure things out entirely on his or her own, only having one individual capable of solving the problem for the entire university, only having a "one-size-fits-all" storage and processing solution, requiring an excessive amount and frequency of authentication, and automatically deleting files without user permission or notifying users.

Through the Lens of Existing Organizations. The research team next considered how existing organizations might meet the needs of the identified personas, another trigger question posed by Liedtka and Ogilvie (2011). First, the research team considered how to approach the problem through the lens of Disney Studios. Ideas included always having a "character" walking around to interact with who you were excited to interact with, making the experience fun and magical with activities that you were excited to share with others, offering users a limited number of "fast pass" options to quickly bypass cumbersome aspects of the process (like going to the front of the line at Disney), ensuring every contact person has extensive knowledge (who cannot say "I don't know" to questions, like at Disney), or, similar to the "bippity-boppity" makeover by your Disney fairy Godmother, giving users the opportunity to get a full technology ecosystem counsel and makeover to ensure all of your user needs/dreams that can be served with technology come true.

Second, the research team considered how Uber might meet our persona's needs. Ideas that arose included the ability to track how technology jobs are going through a process like the "Your ride's been stopped for awhile. Is everything okay?" feature Uber offers by constant monitoring of how your Uber trip is progressing so that researchers can be notified if things have stalled or don't look right," involving a gig economy model of on-demand workers, perhaps graduate students, that can be called upon as needed to serve during high demand times like popular industry conference paper deadlines or university deadlines for submitting packets for promotions, or the ability to see where your data is, where a job is in process, or the steps in a process to achieve what you are trying to do, including the associated costs. Although, in this instance, rather than the cost for your ride and the ability to have more room or arrive more quickly if you pay more, using this model with data means understanding the storage and processing "cost" with options for basic or advanced based on the task and timing at hand.

Other assorted ideas inspired by other companies included following a Slack model of providing a common chat room where people can pop in and answer others questions, or recreating the casual and inviting experience at the Apple store where you can try out the latest and greatest, chat with an associate, or get assistance when needed.

No Constraints. Next, the research team was prompted to consider how we would meet the personas' needs if we faced no constraints and had to spend as much money as possible. Ideas included hiring an individual who served as each researcher's personal assistant to ensure they always had what they needed when they needed it, a 24/7 direct call service with no wait times to answer all questions, providing free personalized technology makeovers ensuring all data processing and storage needs now and in the future for work and personal use are easy and seamless, providing unlimited storage to all researchers at the university, providing the latest and greatest technology to everyone, and having a greater number of staff at the CRC.

Because the research team is constrained by a budget, an important switch in thinking occurred: how can we get the most value for the most people with our solution, rather than what is the "latest and greatest" service we can afford?

Forming Potential Solutions. As the research team formed potential solutions, we were guided by IDEO's feasibility, desirability, and viability framework. The intersection of these considerations is the "innovation sweet spot." Desirability means considering whether the potential solutions accurately address problems the user is facing. Feasibility means whether pursuing the potential solutions strengthens the organization's business or desired goals. Viability means considering the long-term sustainability of pursuing the potential solution [4].

With these characteristics in mind, the research team then began to form potential solutions that would be provided in addition to changes in data storage or processing systems themselves. These include hiring an individual dedicated to answering questions who could keep all previously asked questions and add all new questions to a book, which is currently happening at the Colleges IT help desk level at the University; or publishing a data storage and processing menu for researchers when they arrive at the University and sharing it with all existing researchers in addition to posting it somewhere permanently that would be easily accessible for all University researchers. All of these additional supporting solutions have the goal of shaping the user experience to be one of surety, ease, and clarity.

Write a future headline. To close the ideation session, the research team was prompted to consider the big-picture view of the implications of this project. If it were 10 years from now, what would the headline of the *New York Times* read? Some of the more popular responses are collected here:

> *"Research productivity at the University of Notre Dame doubles over the last decade"*
> *"Yet another Notre Dame researcher wins Nobel prize"*
> *"Notre Dame tops research productivity rankings"*

A key takeaway from this exercise was that the these headlines have nothing to do with data access and storage, and everything to do with how we support the laptop warrior, the grappling grad student, the collector, and the rockstar to do the best work they can do to make excellent research that serves the University and humanity. When you are boarding a flight you do not want to know the type of engine or fuel being used, you just want to have a stress-free experience, be serviced by helpful and enjoyable flight attendants, and get to your destination ahead of schedule and ready to hit the ground running!

4 DISCUSSION

The key take-away from this exercise has been the insight gained into the services our user base is really interested in for our next storage purchase. As a department that provides for computational research on campus, we are often concerned about performance metrics and new, potentially innovative technologies. While these are important factors to consider, our interviews and preliminary surveys have demonstrated that usability, ease of access, data integrity, and collaborative tools are just as important to many people. So much so that many are more than happy to trade total capacity for these features. In addition, the opportunity to go out and meet users where they work has increased the sense of community for both employees of the CRC and the researchers on campus.

Moving forward into the prototyping and testing stage, the research team aims to involve users again. One design thinking framework we will use is the compelling experience framework, developed by design consultancy IA Collaborative, that considers the AEIOU experience framework where the researchers will consider activities, environments, interactions, objects, and users of the experience, and what this looks like at all stages of the user journey following the 5E model of how a user is enticed to begin engaging with the product or service, what the experience is to enter, what happens as they engage, the process and experience to exit, and the activities what will extend the experience in a productive and meaningful way for the user.

5 CONCLUSION

In this paper, the design thinking process was applied to the research data storage development process in a case study. This

demonstrates the effectiveness of and promotes greater collaboration between the user and the team developing and maintaining the data storage process, and enables the data storage team to suspend any long-held beliefs and assumptions on the user needs by conducting contextual ethnographic interviews with users to better see and feel their experiences. After developing the key user personas, conducting surveys to validate the personas, and ideating ways to better meet the unmet needs of these users, the team was able to broaden the scope of solutions needed beyond the systems themselves, to a more human-centered approach aimed at supporting the personas needs to meet to get their work done in a way that aligns with their personal circumstances and ultimately achieve their research goals. This collaborative approach proved particularly useful in answering the complex, technical questions that the user is often not practiced at communicating by meeting users' needs in a human-centric way. Because of design thinking's adaptability in application, this case study should prove useful in inspiring similar applications to a variety projects in the future. This paper also provides insight into the current solution to the University's research data storage systems.

ACKNOWLEDGMENTS

Partial financial support for the upgrade and evolution of the University of Notre Dame research data storage infrastructure was provided by NSF CC* Award #2232803. We would like to thank a breadth of Notre Dame campus community participants including those from the Office of Information Technology, Center for Research Computing, Mendoza College of Business, and the Graduate School. In addition to participating in the broad-reaching campus research data needs survey, numerous research groups agreed to participate in Design Thinking interviews.

REFERENCES

[1] Rachana Ananthakrishnan, Kyle Chard, Mike D'Arcy, Ian Foster, Carl Kesselman, Brendan McCollam, Jim Pruyne, Philippe Rocca-Serra, Robert Schuler, and Rick Wagner. 2020. An Open Ecosystem for Pervasive Use of Persistent Identifiers. In *Practice and Experience in Advanced Research Computing* (Portland, OR, USA) *(PEARC '20)*. Association for Computing Machinery, New York, NY, USA, 99–105. https://doi.org/10.1145/3311790.3396660

[2] R. Bender-Salazar. 2023. Design thinking as an effective method for problem-setting and needfinding for entrepreneurial teams addressing wicked problems. *Journal of Innovation and Entrepreneurship* 12, 1 (2023), 24.

[3] Katie Chapman, Guangchen Ruan, Esen Tuna, Alan Walsh, and Eric A. Wernert. 2023. Scholarly Data Share 2.0: Granular Access to Research Data. In *Practice and Experience in Advanced Research Computing* (Portland, OR, USA) *(PEARC '23)*. Association for Computing Machinery, New York, NY, USA, 177–180. https://doi.org/10.1145/3569951.3597585

[4] D. Chasanidou, A. A. Gasparini, and E. Lee. 2015. Design Thinking Methods and Tools for Innovation. In *Design, User Experience, and Usability: Design Discourse*, A Marcus (Ed.). Lecture Notes in Computer Science(), vol 9186. Springer, Cham. https://doi.org/10.1007/978-3-319-20886-2_2

[5] Laura Christopherson, Anirban Mandal, Erik Scott, and Ilya Baldin. 2020. Toward a Data Lifecycle Model for NSF Large Facilities. In *Practice and Experience in Advanced Research Computing* (Portland, OR, USA) *(PEARC '20)*. Association for Computing Machinery, New York, NY, USA, 168–175. https://doi.org/10.1145/3311790.3396636

[6] V. Clemente, M. Reis, C. Ezingmüller, K. Tschimmel, and F. (2023 Pombo. [n. d.]. October). In *Design Thinking Meets Academic Research: Science Communication for Design Communities Using Analogies and Illustrations*, In International (Ed.). Springer Nature Switzerland, Conference on Design and Digital Communication . Cham, 569–583.

[7] Sean B. Cleveland, Jennifer Geis, and Gwen A. Jacobs Cleveland. 2020. Scientific Data Annotation and Dissemination: Using the 'Ike Wai Gateway to Manage Research Data. In *Practice and Experience in Advanced Research Computing* (Portland, OR, USA) *(PEARC '20)*. Association for Computing Machinery, New York, NY, USA, 188–197. https://doi.org/10.1145/3311790.3396661

[8] Nicolò Cocchi, Clio Dosi, and Matteo Vignoli. 2023. TECH TO MARKET. FINDING AND DESIGNING SUITABLE TECHNOLOGY APPLICATIONS WITH DESIGN THINKING. *Proceedings of the Design Society* 3 (2023), 3315–3324. https://doi.org/10.1017/pds.2023.332

[9] A. Cooper, R. Reimann, D. Cronin, and C. Noessel. 2014. *About face: the essentials of interaction design*. Wiley, John & Sons.

[10] Doris Fay, Carol Borrill, Ziv Amir, Robert Haward, and Michael A West. 2006. Getting the most out of multidisciplinary teams: A multi-sample study of team innovation in health care. *Journal of Occupational and Organizational Psychology* 79, 4 (2006), 553–567.

[11] F. Heldal. 2023. Design thinking teams and team innovation performance. *Journal of Innovation and Entrepreneurship* 12, 1 (2023), 85.

[12] J. Liedtka and T. Ogilvie. 2011. *Designing for growth: A design thinking tool kit for managers*. Columbia University Press.

[13] L. Lorusso, J. H. Lee, and E. A. Worden. 2021. Design thinking for healthcare: Transliterating the creative problem-solving method into architectural practice. *HERD: Health Environments Research & Design Journal* 14, 2 (2021), 16–29.

[14] A. Osborn. 1942. *How to Think Up*. McGraw-Hill.

[15] Dylan Perkins, Shelley Knuth, Thea Lindquist, Andrew Johnson, Nickoal Eichmann-Kalwara, and Timothy Dunn. 2022. Challenges and Lessons Learned of Formalizing the Partnership Between Libraries and Research Computing Groups to Support Research: The Center for Research Data and Digital Scholarship. In *Practice and Experience in Advanced Research Computing* (Boston, MA, USA) *(PEARC '22)*. Association for Computing Machinery, New York, NY, USA, Article 71, 4 pages. https://doi.org/10.1145/3491418.3535165

[16] C. T. A. Pham, S. Magistretti, and C. Dell'Era. 2022. The role of design thinking in big data innovations. *Innovation* 24, 2 (2022), 290–314.

[17] Rob Quick, Larry Lannom, Marina Krenz, and Yu Luo. 2019. E-RPID PEARC 2019: The Digital Object Architecture and Enhanced Robust Persistent Identification of Data. In *Proceedings of the Practice and Experience in Advanced Research Computing on Rise of the Machines (Learning)* (Chicago, IL, USA) *(PEARC '19)*. Association for Computing Machinery, New York, NY, USA, Article 123, 4 pages. https://doi.org/10.1145/3332186.3333255

[18] Nickolaus Saint, Ryan Chard, Rafael Vescovi, Jim Pruyne, Ben Blaiszik, Rachana Ananthakrishnan, Mike Papka, Rick Wagner, Kyle Chard, and Ian Foster. 2023. Active Research Data Management with the Django Globus Portal Framework. In *Practice and Experience in Advanced Research Computing* (Portland, OR, USA) *(PEARC '23)*. Association for Computing Machinery, New York, NY, USA, 43–51. https://doi.org/10.1145/3569951.3593597

[19] R. E. Saputro and R. Faturama. 2024. Revolutionizing Sustainable Public Transportation: The Go-Bus Mobile App Journey With Design Thinking. *Sinkron: jurnal dan penelitian teknik informatika* 9, 1 (2024), 230–243.

[20] S. Shiralian, F. Ghodratizadeh, K. Talebi, and E. Chitsaz. 2023. *The Innovation Equation: Understanding the Connection between Team Cohesion, Motivation, and Design Thinking Mindset in Boosting Employee's Innovative Performance*. Journal of Entrepreneurship Development.

Received 8 March 2024