ID: 231 (Draft, Accepted for publication)

A design case study: Transferring design processes and prototyping principles into industry for rapid response and user impact

Karen Hui En Sng, Sujithra Raviselvam, David Anderson, Luciënne Theresia Maria Blessing, Bradley Camburn, Kristin L. Wood

Singapore University of Technology and Design, Singapore

ICED17: 21st International Conference on Engineering Design
University of British Columbia, Vancouver, Canada
Aug. 21-25, 2017

Full Paper Submission - DesResApp
Topics: Design methods and tools, Design processes, Design research applications and case studies, Design to embrace resource limitations
Keywords: User need identification, Design process, User centred design, Experience Design

Abstract

Process models and design principles play a major role in the development of a product. With every process and principle having their own benefits, deciding the right combination is a challenging task. In this case study, existing design methods and design principles were tailored through a Design Innovation (DI) process to achieve rapid response system critical for project completion. This paper explores in detail how the DI process was formally made instrumental for an industrial development. Pohlmeyer's ContinUE model was used as a systematic guide on the critical stages along the DI process to capture user needs. The success of the project and implementation of the DI process was tested via the user satisfaction recorded towards the end of the process. With a total of 326 target users, the analysis showed that the diverse user needs identification methods results in different insights. Design theory and other methodologies such as prototyping principles were also demonstrated to be valuable and practical in developing and delivering design solutions. The combination of design theories and process can lead to successful implementation at an industrial level.

1 INTRODUCTION

A design process can be defined as a sequence of steps which utilize design methods and principles to produce a solution, for a given design opportunity. A design process model guides the design practitioners through a basic set of approaches that can be adapted to different design requirements (IDEO, 2015; Kett and Wartzack, 2015; Norton and Pine, 2013). A variety of design process models are available to address the demands of designers from different disciplines, and many of these models exhibit similarities in their core design stages (K, 2012). By analyzing the existing design processes in mechanical engineering, Howard et al., 2008 highlighted the potential use of the divergent-convergent models in design creativity. The 'Double Diamond' design process model by the UK Design Council (Design Council, 2005) uses the divergent-convergent model to execute the design process through four different phases. Although the four phases guide a designer in creating and refining the ideas during the design process, a design process that manages interactions between different disciplines is still needed to gather insights from different perspectives (Howard et al., 2008). Over the years, design processes have evolved based on the domains and the design contexts in which they are applied. Following this trend, the Design Innovation (DI) process used in this study is inspired by the divergent-convergent model of the Double Diamond process adopted into a 'Rapid Response System' (defined in section 4) which incorporates perspectives from multiple disciplines such as business design and systems engineering.

This study analyzes the effect of capturing user needs through the evolution of a product. Previous studies (Kujala et al., 2013 and Pohlmeyer et al., 2015) proposed that user needs can be captured as they evolve over time by collecting user experience at six different points of the design process, specifically anticipated experience, experience, reflective experience, retrospective experience and prospective experience. The proposed approach by Pohlmeyer et al. is implemented in this study to evaluate the design process and to analyze the impact of capturing such needs.

This case study is built on a design project by the SUTD-MIT International Design Centre for an industry client to improve the user experience of unassigned office seating. Due to the short timeframe, the team had to adapt existing methods and principles into the Rapid Response System following the DI process. This design opportunity was also used to study how user needs evolve after experiencing a product over a period of time. This was done to address the following research questions:

1. How do user needs change over a period of time after experiencing a product? To what extent does this affect the user satisfaction?
2. How effective are the adapted design methods and principles in the proposed Rapid Response System when designing under an extremely short timeframe?

1.1 Case study setting

In recent years, workspaces have been adapted by companies to make use of the space in an efficient and interactive way through "hot-desking" (Inamizu, 2013). GIC, a leading global investment firm managing over US$100 billion in assets, hired the SUTD-MIT International Design Center (IDC, idc.sutd.edu.sg) to help them transition to an activity based workspace. The workspace transformation entails having a total of 326 employees to move from assigned to unassigned seating. Employees were told they would be provided with individual lockers and a portable desk kit that would maximize the benefits of their new unassigned workspaces. The IDC's Design Innovation (DI) Team's task was to develop design concepts and prototypes, and to deliver a final product in the form of a compact modular portable desk kit for the employees. There was limited opportunity to improve the locker design as the locker frames were already in production. As such, design concepts for the lockers were limited to the given frame dimension.

While the new, unassigned workspace was under construction, most of the 326 employees remained in traditional, assigned workspaces. A small fraction of the employees worked in a temporary unassigned seating area called the Swing Space. It acted as a pop-up area to house employees while the final workspace was under construction. Employees in the Swing Space used movable office pedestals from their previous assigned seats as storage space to hold their day-to-day desk materials.

Most employees in the assigned workspaces had no experience with unassigned seating and had different views and some difficulty expressing their anticipated needs when interviewed. On the

contrary, employees in the Swing Space had a better idea of their behavior and needs when interviewed. These two scenarios allowed for a study that help the team understand the difference in needs and develop unique designs.
The design project had an aggressive two-month timeline, including the manufacturing and delivery of the kits. The successful completion of this workspace transformation project in such a short period of time was made possible by modifications to our Design Innovation (see section 2.1) process to allow for extremely rapid responses. The following sections of this paper further examine the design process and methodologies adopted for this design case study.

2 BACKGROUND

2.1 Design Innovation (DI) process

There are many design processes actively used in professional contexts, and these processes are often segregated by engineering disciplines. The DI process model (Camburn et al., 2017) used in our center synthesizes methods from (1) design thinking (Plattner et al., 2014); (2) organization design (Brown, 2009); (3) systems engineering (INCOSE, 2015); and (4) design engineering (Otto and Wood, 1998; Cross, 2008; Dym et al., 2005). It builds on the 'Double Diamond' Design Process Model developed by the British Design Council in 2005. The Design Innovation process follows four phases: discover, define, develop and deliver. These phases are executed using a suite of individual methods. The conceptual analogy representation can be drawn to the human body, (1) Discover: heart or user-empathy; (2) Define: eyes or representation; (3) Develop: mind or cognition; and (4) Deliver: hands or creative action. The analogy to the human body emphasizes user-centricity and design and an organic relationship between phases. The design innovation framework in Figure 1 shows the four design phases and the conceptual analogy (Hanington and Martin, 2012) associated with it.

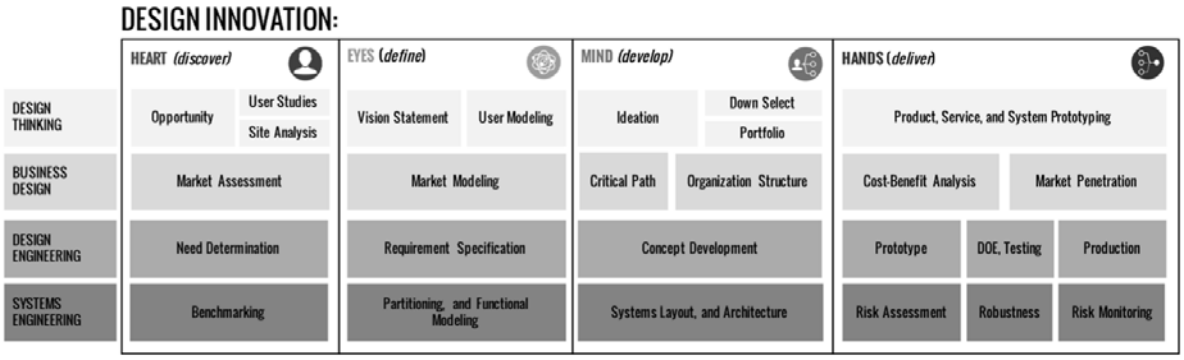


Figure 1: Design Innovation Process (Camburn et al., 2017)

2.2 User Experience Lifecycle Model ContinUE [Continuous User Experience]

The User Experience Lifecycle Model (Figure 2) was introduced for a systematic study of the feedback and needs from users at each stage of the workspace transformation project. Figure 2 illustrates the evolution of the user experience along a series of phases based on user interaction with the product.

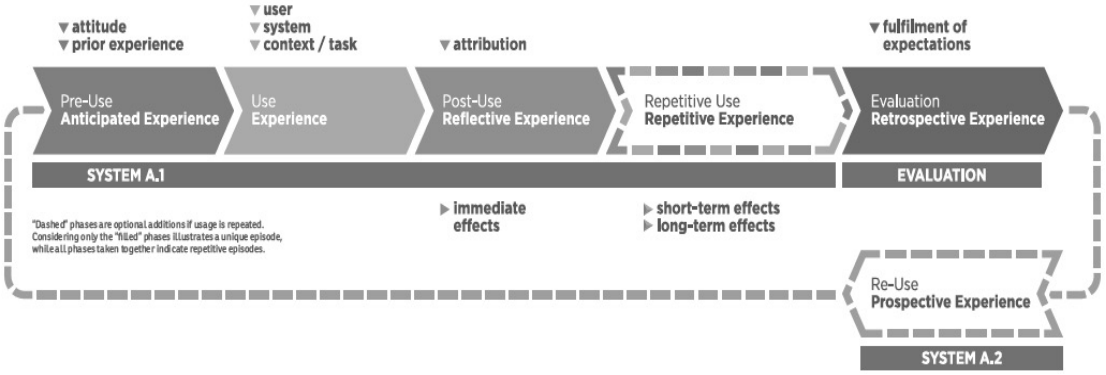


Figure 2: User Experience Lifecycle Model ContinUE (Pohlmeyer et al., 2015)

The model differentiates between these phases to correctly interpret the needs expressed by users and develop products that provide greater user satisfaction. It distinguishes the following phases: 1) anticipated experience - based on a user's prior experience and attitude before using the product; 2) experience – based on the actual use in a particular context; 3) reflective experience - based on the first interaction with the product, revealing the immediate effects; 4) repetitive experience - based on repeated interaction with the product, revealing short and long term effects; 5) retrospective experience – based on an overall evaluation of whether expectations are fulfilled after repeated interaction; 6) prospective experience – based on experiences with further versions of the product. All these experiences feed into the anticipated experience when confronted with new products. We implemented the model in the case study to systematically evaluate our product and inform the DI process. This is based on the presumption that repeated experience is not the same as the first experience.

2.3 Prototyping strategies, principles and methods

A functional prototype that represents the product being tested, when used at the right time, complements the design process by enabling the users' to express uncaptured needs (Camburn et al., 2015;Häggman et al., 2013; Isa et al., 2015). Camburn et al., in their work proved that providing designers with a set of five design principles significantly increases the efficiency of the resulting prototypes. Leveraging these five principles, this study used prototyping as a key method that enabled the testing of potential solutions with users (Camburn et al., 2015; Walsh et al., 2015). The five design principles introduced by Camburn et al., are as follows: Hack commercial products, Employ basic crafting, Prepare fabrication blueprints, Repeat fabrication process and Include structural voids. These prototyping principles were not only used as a testing strategy for this project, but are also implemented in the final design solutions.

3 METHODOLOGY

The project included ten different stages that were structured around the discover, define, develop and deliver phases of the DI process. Here, stages refer to the execution stages of this particular project and phases refer to the four phases of the divergent-convergent model. User comments were collected during three stages (Stage 1, Stage 6 and Stage 9) from 51, 260 and 134 users respectively. Stage 1 included design methods such as user journey maps and articulated need interviews while the Stages 6 and 9 used online surveys to capture the user needs. The high number of responses to stage 6 can be attributed to the same survey being used to register for the kits. The ContinUE model was later used to evaluate the way in which the collected user needs evolve through the design process. From this point on, 'assigned seating' will be referred to as AS and 'unassigned seating' will be referred to as UA. The methodology and principles implemented during each stage will be elaborated in the following sections.

3.1 Rapid Response System Implementation

The DI process model was adapted for this workspace transformation project to accommodate the very short lead time. This modified DI process is referred to as the Rapid Response System. Figure 3 illustrates the system. The User Experience Lifecycle Model ContinUE (section 2.2) was used as a sub-process to guide the analysis of user needs and experiences during the process. Users from both AS and UA were involved throughout the project. The following section provides a detailed description of each stage followed during the workspace transformation project.

Stage 1: As a part of the discover phase, this stage aimed at understanding the state of art, the worksite of interest and the user needs, using the following methods: benchmarking, journey maps (Hanington and Martin, 2012), site analysis (Francis et al., 1991) and user interviews. 21 journey maps were produced and 30 articulated interviews were conducted over a period of three days. This allowed capturing needs and likes and dislikes(Green et al., 2006) related to 'Pre-Use Anticipated Experience' and 'Re-use Prospective Experience' from the ContinUE model in Figure 2.

Stage 2: Based on the insights derived from the data collected in Stage 1, six personas were created, representing three AS users and three UA users. The three types were decided based on the different

user types observed during Stage 1. With the given timeframe, these personas served as a fast method to categorise and define needs according to different groups of users.

Stage 3: This stage involved developing potential solutions based on the interpreted needs through brainstorming sessions. As mentioned in section 1.1, with the locker frames already in production, this stage developed and suggested locker designs for the given frame size and did not proceed through any further stages. With regards to the work kits, eight candidate design were developed and prototyped. This stage was executed within a week by customising commercially available products. Customisation involved using basic crafting techniques (using office stationary) over existing commercial products as proposed by Camburn et al.

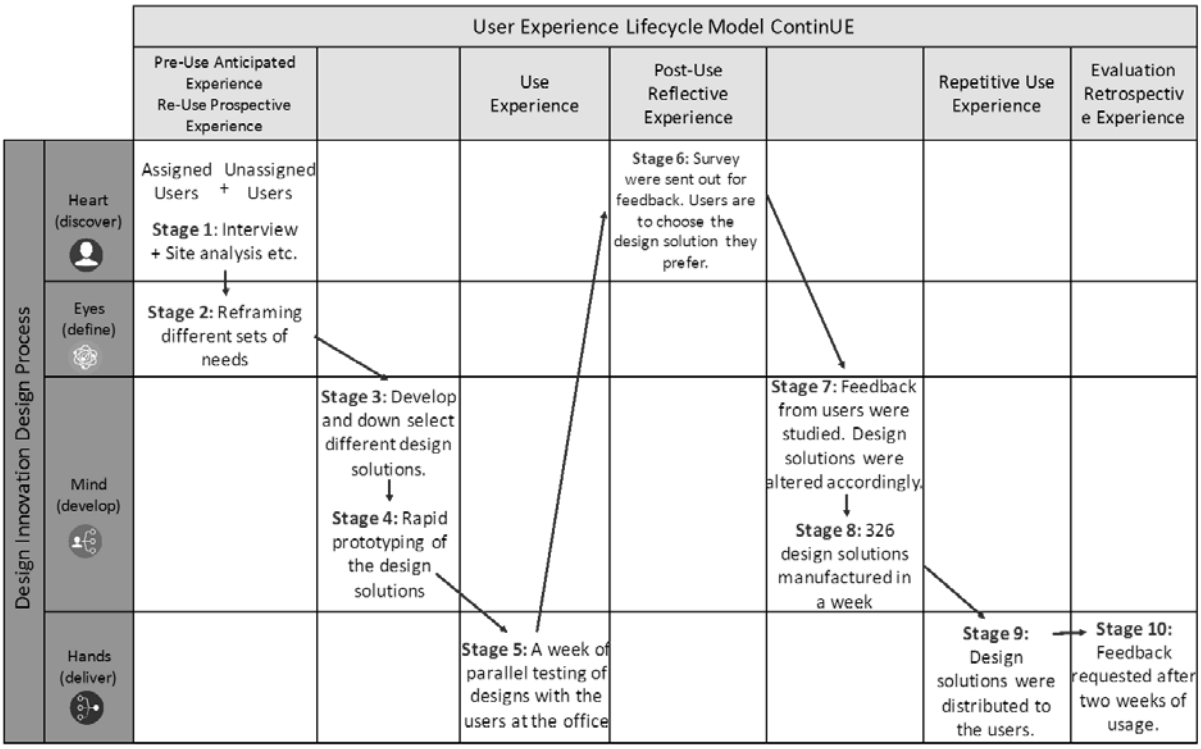


Figure 3: Stages of the rapid response system for the workspace transformation project, mapped to the Design Innovation and ContinUE processes

Stage 4: An isolated subsystem that mimicked the locker was prototyped at the IDC's design space to determine the space and handling (shifting the kit from the locker to workspace and vice versa) of the work kits developed earlier in Stage 3. Using a Pugh chart(Pugh, 1991), designs were down selected from eight to four candidate solutions. The selection criteria were based on the needs of four primary user types ranging from minimalist users to complex users. Three of the four design solutions needed additional construction. Laser cutters enabled rapid prototyping of those solutions. This approach embodied the prototyping principle of using templates or stencils to reduce complexity involved in prototyping. For example, one of the kits used acrylic partitions that made the kit modular for the users.

Stage 5: Prototypes of the four design solutions were delivered to the client's workspace for users to test. The kits remained at a test space along with a model locker for seven days, during which the users tested the kits and provided their preferences and feedback for the next design iteration. This allowed evaluation of the complete user experience with the work kits by including all the related systems involved while using the kits.

Stage 6: The users provided feedback on the kits and selected the kits they preferred through an online survey. The needs interpreted based on feedback from 260 respondents were used to iterate and refine the developed solutions. This reflective stage was analysed as the 'Post-Use Reflective Experience' as per the ContinUE model.

Stage 7: The rediscovered needs from the previous stage were used to iterate further on the developed solutions. During this stage, due to timeline constraints, developments to the current designs were

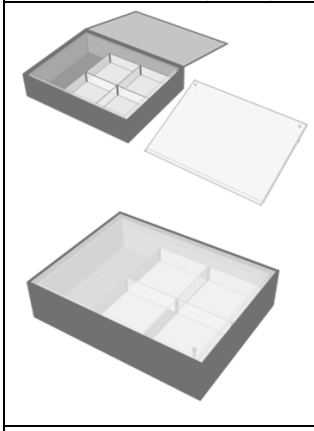
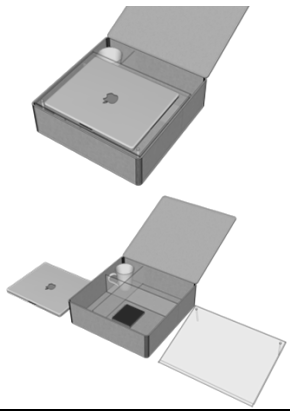
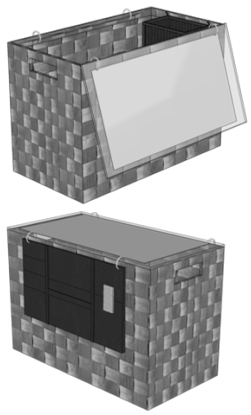
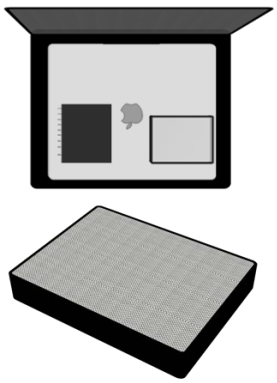
made by adapting the previously used fabrication processes to serve different functions. The process here took prototyping principles a step further by using them to implement the final design solutions as well. Using previous fabrication processes for different functionality also helped reduce the time and cost associated with fabricating the design solutions (Camburn et al., 2015). For example, laser cutters that were initially used to create partitions and lids, were now used to create multi-functional lids that served as a laptop stand and a picture holder.

Stage 8: A total of 326 kits were manufactured for the users as final designs for their day to day usage. Manufacturers from industry were approached and given the requirements. Polycarbonate frames were used instead of acrylic to increase the strength and durability of the product. Metal joints that were easy to attach were used to hasten the manufacturing process. Table 1 illustrates the four work kit designs that were delivered based on the user preferences from stage 6. All 326 work kits were delivered by the end of the two-month design process.

Stage 9: To evaluate the overall design process, users were approached two weeks after they shifted to the UA space. A second set of online surveys captured the user feedback based on the response from 134 users, for the 'Retrospective Use Experience' of the ContinUE model. This was complemented by user journey maps to observe the user interaction with their selected kits.

Stage 10: The results were mapped back to the original needs obtained from Stage 1, and the post-use reflective experience needs obtained from Stage 6. Needs obtained from different stages were used to evaluate the overall DI process.

Table 1: 4 Final design solutions

Kit 1: Black (n=36)	Kit 2: White (n=34)	Kit 3: Basket (165)	Kit 4: Bag (n=91)
			
39.5cm x 27cm x 11cm	39.5cm x 27cm x 11cm	36cm x 20cm x 26cm	36cm x 26cm x 5.5cm
Hard acyclic box with a multipurpose laptop stand	Soft cloth bag with a multipurpose laptop stand	Basket holder with white board/ sticky board	Flexible cloth bag with minimal organizer

4 RESULTS AND ANALYSIS

4.1 Gathering needs based on Anticipated Experience, Prospective Experience, Reflective Experience and Retrospective Experience

To analyse the effectiveness of the Rapid Response System for a given limited timeframe, needs were captured, interpreted and evaluated at different stages based on the ContinUE model by Pohlmeyer et al. (Figure 2).

4.1.1 Anticipated Experience VS Prospective Experience (Stage 1&2)

AS users were categorized as having anticipated experience and UA users were categorized as having prospective experience as per the ContinUE Model. An initial set of needs were interpreted through journey maps and interactions with 13 users from the 'temporary UA' space and 17 users from the 'AS' space, based on the availability of the users during their office hours.

Users who were already experiencing UA provided more feedback on the potential challenges that could occur in UA. They also shared potential features of an efficient locker and kit system that could ease the challenges they faced at the temporary UA space. Similarly, users currently at the AS space

provided comparatively more feedback on the positive aspect of AS. They also shared their thoughts about the positive aspects of AS that they hoped would be maintained by the locker and kit system. Based on this feedback, locker and kit designs were created to make the UA experience seamless and pleasant for the users.

Some positive quotes from the users include:

"Aesthetic design and transparency allows a quick view of what items are in the kit."

"Spacious and there is a handle to carry with one hand."

Some negative quotes:

"Does not meet my needs, better handles would be best."

"Wondering if I can mix 2 or more design options."

Based on the data collected during Stages 1 and 2 of the DI process, four different designs were developed to address permutations of the interpreted functional requirements of the kits (stage 3). Table 2 lists the four designs with certain key structural and functional requirements.

Table 2: Kits Features and Functions

	Color	Sturdy	Weight	Handle	Storage Capacity	Structure & materials	Customizable compartment	Additional features	Kit seal
Kit 1	Black	Yes	Heavy	1 hand	Middle	Rigid plastic	Yes	Laptop stand	Mesh + zip
Kit 2	White	No	Heavy	2hands	Big	Flexible cloth	Yes	Laptop stand	Cloth + zip
Kit 3	5 colors	No	Light	2hands	Big	Rigid weaved basket	Yes	White & notice board	Plastic cover
Kit 4	Black	Yes	Light	1 hand	Small	Wired mesh bag	No	Nil	Mesh + zip

4.1.2 Reflective Experience (Stage 6) VS Retrospective Experience (Stage 9)

Reflective experience as per the ContinUE model captures the user feedback from their first interaction with all four proposed product designs (Stage 6). Retrospective experience, contrary to the reflective experience, captures the overall user feedback after repetitive interaction (two weeks for the case study) with the specific design selected by each user (Stage 9). Feedback from 260 users was collected based on their reflective experience (Stage 6) and feedback from 134 users was collected based on their retrospective experience (Stage 9) via online surveys. 105 users replied to both surveys. Responses from the later group was analysed to capture the differences in needs during the two stages. Needs interpreted from these two periods helped track how user needs evolved through the DI process.

Statements made by the participants through the online surveys were grouped based on their similarity. For example, if one user stated 'prefers a lighter kit' and another stated 'lighter kits are easier to carry', they both were grouped under the same category 'weight'. This grouping approach followed the variety metric proposed by Shah et al., 2003. Two raters independently categorised an initial set of statements, then discussed the results, and one rater decided on specific definitions for each bin. The process was repeated for a different set of statements using the developed definitions provided, resulting in an agreement of 79.2% between the two raters.

Following the grouping process, a Wilcoxon signed rank test was used to see if there was any significant difference in the number of responses received from the reflective experience (191 responses) and retrospective experience (131 responses) These results show a significant decrease ($p= 0.028$) in the amount of feedback received during the retrospective phase when compared to that of the reflective phase. Another aspect tested between these stages was that, among the 131 responses, 117 pieces of user feedback listed the design modifications they preferred and the rest commented on the aspects they liked the most. 76% of the listed design modifications were unique i.e., the modifications that were not articulated by the users during the reflective experience.

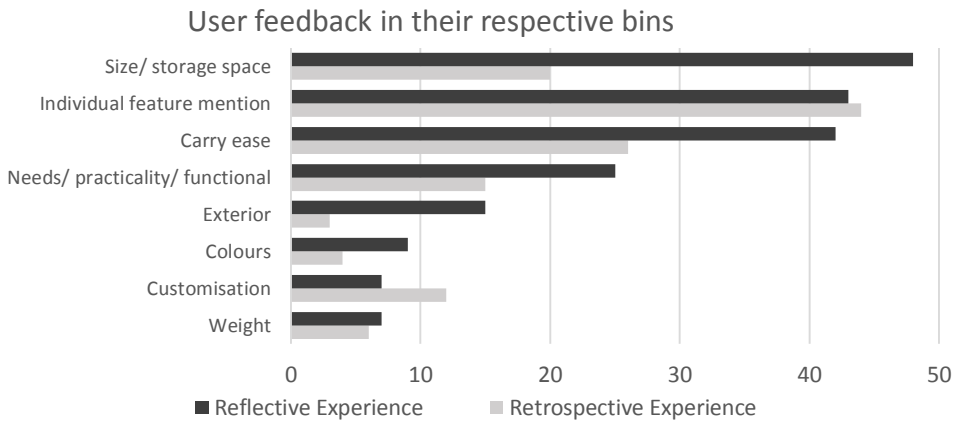


Figure 4: User feedback and their respective bins

To have a deeper understanding of the difference in categories (Bins) the users were concerned about, further analysis was done on the difference in the frequency of the responses captured per category. A Fisher's exact test was used to test this difference. As shown in figure 4, almost all categories showed a decrease in frequency of feedback shared. Kit size was the only category to exhibit a significant difference ($p < 0.05$). These two comparisons were used to capture different needs perceived by the users based on their duration of interaction with the product.

4.2 User satisfaction vs User needs

User needs were interpreted from the responses received during the stages 6 and 9. To understand the evolution in user needs after experiencing the kits over a period of two weeks, the difference (increase or decrease) in needs identified by the users was analysed. This increase or decrease in needs was compared to the satisfaction ratings given by the users. Satisfaction ratings were provided for the respective kits after two weeks of repetitive usage. The users were asked to rate their products on a scale of 0 (not at all satisfied) to 4 (extremely satisfied). On average 71.25% of users were satisfied with the kits provided.

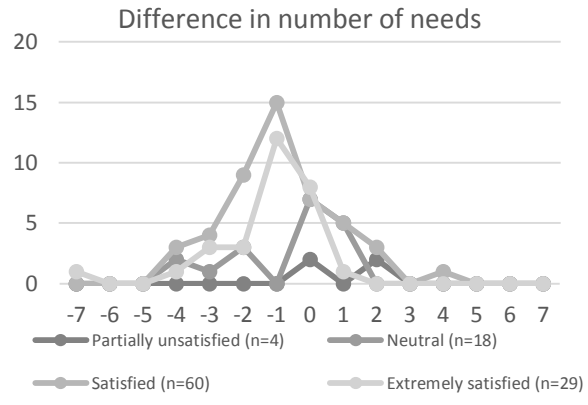


Figure 5: Difference in number of needs shared by users during the two stages with respect to the different levels of user satisfaction

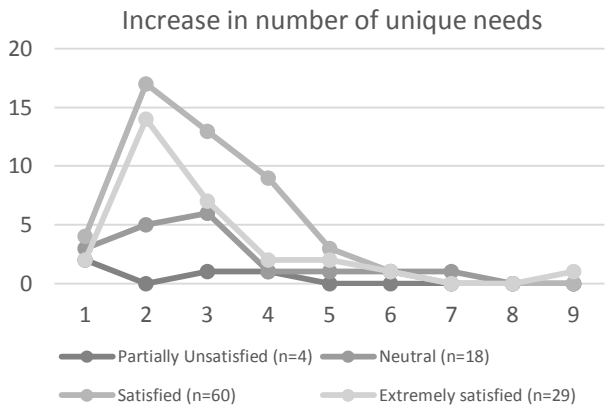


Figure 6: Increase in unique number of needs shared by users during the two stages with respect to the different levels of user satisfaction

Figure 5 illustrates the distribution of difference in needs realized by participants with different levels of satisfaction. The distribution in figure 5 shows that during testing, the majority of users who rated their satisfaction level as 4 (extremely satisfied) and 3 (satisfied) had recognized more number of needs than the users who had rated 2 (neutral) and 1(partially unsatisfied). Following this, the increase in unique number of needs was alone calculated to understand the impact of repetitive use of the kits among users with different level of

satisfaction. Unique needs are the newly identified needs recognized by the participants after repetitive use of the kits. Figure 6 displays the number of unique needs identified after the retrospective phase. The distributions (Figure 5 and Figure 6) provide an interesting insight on how the level of satisfaction might not always imply completely fulfilled needs.

5 DISCUSSION AND CONCLUSION

This case study demonstrates how the design innovation process to a limited timeframe. The 'User Experience Lifecycle Model ContinUE' was integrated to capture user needs efficiently throughout the design process. Based on the results obtained, the research questions raised earlier are answered as follows:

1. How do user needs change over a period after experiencing a product? To what extent does this affect the user satisfaction?
   Results show that user needs evolve with the product and capturing them during the discover and deliver phase alone might not be sufficient to capture the potential needs that are recognized after repeated use of the product. 76% of the needs articulated by the users after repeated use of the product were unique needs that were not recognized during the reflective experience. Figure 7 illustrates the distribution of these unique needs associated with the user satisfaction level. Overall, the repeated use of a product helps the users articulate new needs.
   According to the distribution illustrated in Figure 6 and Figure 7, even the satisfied and extremely satisfied users recognized new needs after repeated use of the product. It is interesting to note that the level of satisfaction could be associated with fulfillment of initially identified needs and not necessarily the fulfilled needs.
   In addition, among the two groups of users, the AS users expressed their needs in terms of the positive aspects of the current AS that they expected the locker and kit system would maintain; the UA users expressed their needs related to the prospective locker and kit system that could ease the challenges they face at the current temporary UA space. This shows the difference in the type of needs articulated by the categories of users. Based on the results obtained, it would be beneficial for a designer to capture not just the pre-use (Anticipated) and post-use (Reflective) experience, but also the re-use (Prospective) and repetitive use (Retrospective) experience.
2. How effective are the adapted design methods and principles in the proposed Rapid Response System during an extremely short timeframe?
   The proposed Rapid Response System catalyzed the design process, satisfied the requirements within a short span and evaluated the outcome. The 71.25% satisfaction rate achieved within the given duration of two months demonstrates the success of the system. This result shows that even with an extremely short timeframe, the DI process provides a framework for designers to capture and iterate on the user needs efficiently by implementing a unique combination of design methods and principle adaptations.

6 IDC DI TEAM REFLECTION

As part of an overall workspace transformation initiative, we developed four designs and delivered 326 functional products in the short span of two months. The continuous application and integration of the design process along with the application of the prototyping principles from Camburn et. al. enabled the team to develop, design, prototype, test and manufacture rapidly while ensuring customer satisfaction. We have made the first steps towards a reasonable mapping of an iterative DI process to the continuous user experience model ContinUE. This case study has also shown a successful application of the prototyping principles. Further, the user feedback from retrospective experience will be probed deeper to provide a single modular solution that caters to the needs of different users.

ACKNOWLEDGMENTS

A sincere thank you to the GIC Singapore for providing such a design opportunity. A special thanks to both the GIC, the SUTD-MIT International Design Centre (IDC) (http://www.sutd.edu.sg/idc.aspx) and Codomo (https://codomo.com.sg/) for the support they provided throughout the project. Any opinions or findings of the authors and do not necessarily reflect the views of the sponsors or collaborators.

REFERENCES

Brown, T., 2009. Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation. HarperBusiness, New York.

Camburn, B.A., Auernhammer, J., Sng, K.H., Mignone, P., Arlitt, R., Perez, K.B., Huang, Z., Blessing, L., Wood, K.L., 2017. Design Innovation: A study of Impact on practice. Proc. 2017 Int. Des. Eng. Tech. Conf. IDETC 2017 Clevel. OH August 6-9.

Camburn, B.A., Sng, K.H., Perez, K.B., Otto, K., Wood, K.L., Jensen, D., Crawford, R., 2015. The Way Makers Prototype: Principles of DIY Design V007T06A004. doi:10.1115/DETC2015-46295

Cross, N., 2008. Engineering design methods: strategies for product design. John Wiley & Sons.

Design Council, 2005. A Study of the Design Process [WWW Document]. URL http://www.designcouncil.org.uk/sites/default/files/asset/document/ElevenLessons_Design_Council%20(2).pdf (accessed 12.19.16).

Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D., Leifer, L.J., 2005. Engineering Design Thinking, Teaching, and Learning. J. Eng. Educ. 94, 103–120. doi:10.1002/j.2168-9830.2005.tb00832.x

Francis, R.L., Jr, F.M., White, J.A., 1991. Facility Layout and Location: An Analytical Approach, 2 edition. ed. Pearson, Englewood Cliffs, N.J.

Green, M.G., Linsey, J.S., Seepersad, C.C., Wood, K.L., Jensen, D.J., 2006. Frontier Design: A Product Usage Context Method 99–113. doi:10.1115/DETC2006-99608

Häggman, A., Honda, T., Yang, M.C., 2013. The Influence of Timing in Exploratory Prototyping and Other Activities in Design Projects V005T06A023. doi:10.1115/DETC2013-12700

Hanington, B., Martin, B., 2012. Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions, 58480th edition. ed. Rockport Publishers, Beverly, MA.

Howard, T.J., Culley, S.J., Dekoninck, E., 2008. Describing the creative design process by the integration of engineering design and cognitive psychology literature. Des. Stud. 29, 160–180. doi:10.1016/j.destud.2008.01.001

IDEO, 2015. The Field Guide to Human-Centered Design, 1st edition. ed. IDEO.org / Design Kit, San Francisco, Calif.

Inamizu, N., 2013. Positive Effect of Non-Territorial Office on Privacy: Allen's Experiment Secret. Ann. Bus. Adm. Sci. 12, 111.

INCOSE, 2015. INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. John Wiley & Sons.

Isa, S.S. (1), Liem, A. (1), Steinert, M. (2), 2015. The Value of Prototypes in the Early Design and Development Process. 80-5 Proc. 20th Int. Conf. Eng. Des. ICED 15 Vol 5 Des. Methods Tools - Part 1 Milan Italy 27-300715.

K, B.L.G., 2012. AN ANALYSIS OF DESIGN PROCESS MODELS ACROSS DISCIPLINES. 70 Proc. Des. 2012 12th Int. Des. Conf. Dubrov. Croat.

Kaplan, S., 1996. An Introduction to TRIZ: The Russian Theory of Inventive Problem Solving. Ideation International.

Kett, S.G., Wartzack, S., 2015. Integration of Universal Design Principles into Early Phases of Product Design- A Case Study. 80-9 Proc. 20th Int. Conf. Eng. Des. ICED 15 Vol 9 User-Centred Des. Des. Socio-Tech. Syst. Milan Italy 27-300715.

Kujala, S., Vogel, M., Pohlmeyer, A.E., Obrist, M., 2013. Lost in Time: The Meaning of Temporal Aspects in User Experience, in: CHI '13 Extended Abstracts on Human Factors in Computing Systems, CHI EA '13. ACM, New York, NY, USA, pp. 559–564. doi:10.1145/2468356.2468455

Norton, D.W., Pine, B.J., 2013. Using the customer journey to road test and refine the business model. Strategy Leadersh. 41, 12–17. doi:10.1108/10878571311318196

Otto, K.N., Wood, K.L., 1998. Product Evolution: A Reverse Engineering and Redesign Methodology. Res. Eng. Des. 10, 226–243. doi:10.1007/s001639870003

Plattner, H., Meinel, C., Leifer, L., 2014. Design Thinking Research: Building Innovators. Springer.

Pohlmeyer, A.E., Hecht, M., Blessing, L., 2015. User Experience Lifecycle Model ContinUE [Continuous User Experience]. ResearchGate.

Pugh, S., 1991. Total Design: Integrated Methods for Successful Product Engineering. Addison-Wesley Pub, Wokingham, England ; Reading, Mass.

Raviselvam, S., Hölttä-Otto, K., Wood, K.L., 2016. User Extreme Conditions to Enhance Designer Empathy and Creativity: Applications Using Visual Impairment V007T06A005. doi:10.1115/DETC2016-59602

Shah, J.J., Vargas-Hernandez, N., Smith, S.M., 2003. Metrics for measuring ideation effectiveness. Des. Stud. 24, 111–134. doi:10.1016/S0142-694X(02)00034-0

Walsh, E.P., Daems, W., Steckel, J., Peremans, H., Baelus, C., 2015. Design for Assistive Technology Applications: Usefulness of Re-Use? 80-9 Proc. 20th Int. Conf. Eng. Des. ICED 15 Vol 9 User-Centred Des. Des. Socio-Tech. Syst. Milan Italy 27-300715.