Knowledge Dissemination In Complex Problem Spaces

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December 2, 2022

Systems Design Engineering, 2023
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Abstract – There are circumstances in which product designers can effectively utilize a top-down approach to understand a problem space. Take the quintessential example of an e-commerce website selling shoes: it is reasonable to assume that a product designer who has purchased shoes in the past could reference that experience when identifying the pain points of their prospective users. Unfortunately, it is often the case that product designers engineers and stakeholders must design a solution to a problem with which they have no prior experience. More complex is the case in which users, be them primary, tertiary or secondary do not know the extent to which the problem space effects each other's user group. This paper discusses the design, analysis and results of the educational framework employed by the product design team at Beacon Biosignals to unlock key knowledge transfer between users and designers and experts alike.

Keywords – Heuristics, Knowledge Transfer, Product Design

I SITUATION OF CONCERN & PROJECT OBJECTIVES

Beacon Biosignals (Beacon) is a biomedical engineering company based in Boston, MA. Beacon identifies and standardizes neurobiomarkers by using machine learning, increasing the probability of successful and scientifically sound drug trials [1]. Beacon provides these and other services to pharmaceutical companies who either do not have the expertise within their organization to perform informative scientific discovery, or lack the resources to analyze results of a late-stage drug trial with statistical significance. To deliver these services, Beacon relies on a team of applied scientists, neurologists, product designers, and engineers to 1) analyze and contextualize project findings for a pharmaceutical drug company, 2) annotate and adjudicate neurobiomarkers generated by machine learning models and 3) develop the software and hardware infrastructure necessary to provide such services [1].

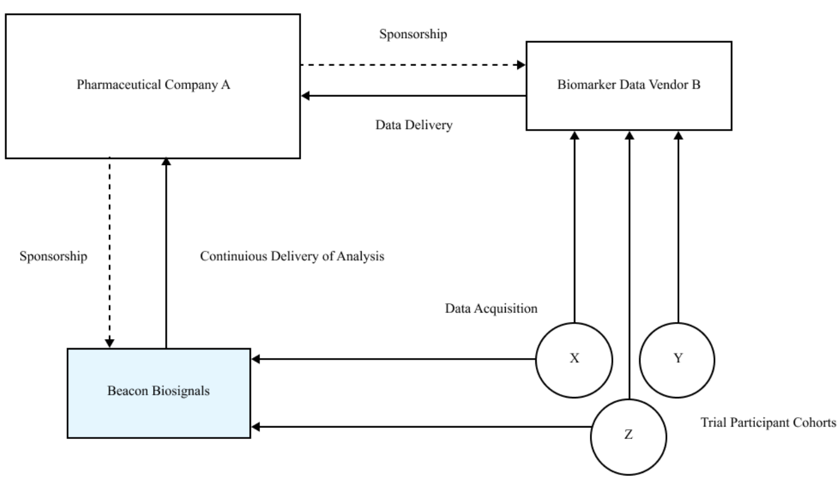

Figure 1: Beacon Biosignals Partnership Model [Image source: SRP, 2022]

Delivering these services requires close, and near continuous collaboration between Beacon and its customers. These customers' teams need to make time-sensitive decisions. They need to know when a trial must be stopped due to safety concerns, or when a particular asset is showing promising trial results. To improve this collaboration between Beacon-teams and customer teams the product design team at Beacon, myself included began a process to design what became known as the *Customer Facing Portal* (CFP).

Early in the design of the CFP it became clear to me and the extended product design team that designing the CFP would present some unexpected challenges. The CFP would facilitate the high bandwidth collaboration between Beacon's applied science teams and pharmaceutical customer teams. The design team initially lacked the knowledge and experience necessary to identify essential boundaries of the problem space at hand. The challenge of complexity is not limited to the bio-pharmaceutical industry and can be addressed by conducting user research, focus groups and employing other methodologies. What is is considerably more unique, and is consequently the focus of this paper, is the challenge that arises in communicating extremely complex solutions to stakeholders and users of a product who do not have the tools or the time necessary to understand the complexity of the problem space of which they are a part.

We (the design team) needed to devise a method of knowledge dissemination to educate applied science and engineering teams that would ensure they understood: 1) the needs of pharmaceutical drug companies that the CFP would address, 2) the needs that the CFP would not address, 3) the development process that the product design team would follow to deliver the CFP, 4) how the CFP would change their workflow, and 5,) the timeline associated with the design and development of the CFP. These requirements were developed in accordance to Norman's Principles of Good Design [2]. In doing so the design team would increase the likelihood of success of CFP, which the design team believed would rely heavily on internal adoption.

To ensure that these requirements were met, we established benchmarks by which we could evaluate the performance of our education system. We used these benchmarks to answer the question as to whether our education system and its supportive framework met its initial design requirements. To provide these findings we established an evaluation framework consisting of six Likert-Scale questions measuring the participants' levels of agreement with the design requirements [3]. Participants were asked to respond to the questions outlined in Table 1 before and two weeks after participating in an education session.

Table 1: Likert Evaluation Framework [Source: SRP, 2022]

Question	Likert Response Anchor (1-5 or 1-7)	Norman's Principle
I understand the needs of pharmaceutical drug companies that the CFP would address	Level of Agreement	Conceptual Model
I understand the needs that the CFP would not address	Level of Agreement	Constraints
How concerned are you with the success of the development process the product design team will follow to deliver the CFP?	Level of Concern	Conceptual Model
I understand how, and why the CFP will change my workflow	Level of Agreement	Feedback
How aware are you about when the CFP will affect your workflow?	Level of Awareness	Signifiers
How important is the Customer Facing Portal to you?	Level of Importance	Feedback

II DESIGN METHODS

To construct our education system we explored several methods. We were constrained to a 1.5 hour sessions for each team. As a result, we hypothesized that a cognitive learning approach would deliver the highest knowledge retention amongst participants relative to effort and time. This is because a cognitive learning approach provides a framework in which comprehension, memory and application of knowledge can be effectively facilitated [4]. We deemed this to be critical to the design of the education system because in order to meet our requirements we needed participants to understand the reasoning behind the customer facing portal and why they are being educated about it (comprehension). They also needed to be able to recall the limitations of the CFP as well as the problems that it would solve (memory). Finally, participants needed to understand how they could leverage and apply tools available within the CFP to meet needs of customers and Beacon (application).

To construct the cognitive learning approach, the design team evaluated the performance of three possible education tools that Beacon Biosignals utilized in various parts of the company using a weighted bench marking system. The decision not to introduce additional tools was done intentionally in an effort to limit the time required in building the design system. Using tooling already familiar to the design team and participants limited the cognitive workload required to feel comfortable in the educational environment and begin learning. The three possible education methods were: Microsoft PowerPoint, a presentation program with an editor and slide-style presentation functionality [5], GitHub Markdown, a web application rendering engine for documentation, often for software [6], and Figma Jam, an online browser-based infinite whiteboard for teams to iterate and collaborate together [7].

The frameworks were evaluated on their ability to support a cognitive learning approach. We assessed the tools' ability to make information discover-able (comprehension), facilitate collaboration (application), and encourage information recall (memory). To determine the appropriate tool for the problem space, each tool was ranked on a 5-point scale of range [-2,2] where 0 indicated that the impact was negligible, "+" indicated a positive relationship and "-" indicated a negative relationship. The three tools were ranked against weighted categories derived from a needs-assessment meeting with stakeholders. Each metric was given a weight range [1,3] where 3 was of the most importance, and 1 the least. Weightings were determined through rapid prototyping and experimental usage of the tools. Results are shown in Table 2.

Table 2: Education Framework Tool Computational Decision Matrix [Source: SRP, 2022]

Tool	discover-able information	facilitate collaboration	information recall	Results
Weight	2	3	1	-
PowerPoint	+2	-1	0	1
GitHub Markdown	+2	-1	0	+3
Figma Jam	0	+2	0	**6**

the resultant score for each tool was calculated as follows

$$result = \sum weight \times score \tag{1}$$

We see that Figma Jam was scored the highest in the computational decision matrix because of its unmatched ability to facilitate collaborate activities. As a result, Figma Jam was chosen as the tool to deliver the education system.

To meet the engineering requirements of the design system using the cognitive learning approach, the Beacon design team categorized the learning process into three related yet distinct chapters. The first was to establish the reasoning behind the CFP, the second was to encourage collaboration and collect key user-feedback, and the third chapter was to encourage cognition and memory reinforcement amongst participants. These three categories correlated to the requirements outlined in a cognitive learning approach [4].

The first chapter consisted of an educational breakdown introducing the approach that the education system, referred to as the *Roadshow*, would consist of. Chapter 1 introduced a design tool called the *North Star Vision* (NSV) shown in Figure 2. The NSV was a set of idealistic, high fidelity user-interface mock-ups designed by the Beacon design team. The goal of the NSV was to give key stakeholders a shared understanding of what a customer facing portal would do for Beacon's customers. Its purpose was to help the design team answer questions about the needs of pharmaceutical customers and internal applied science users.

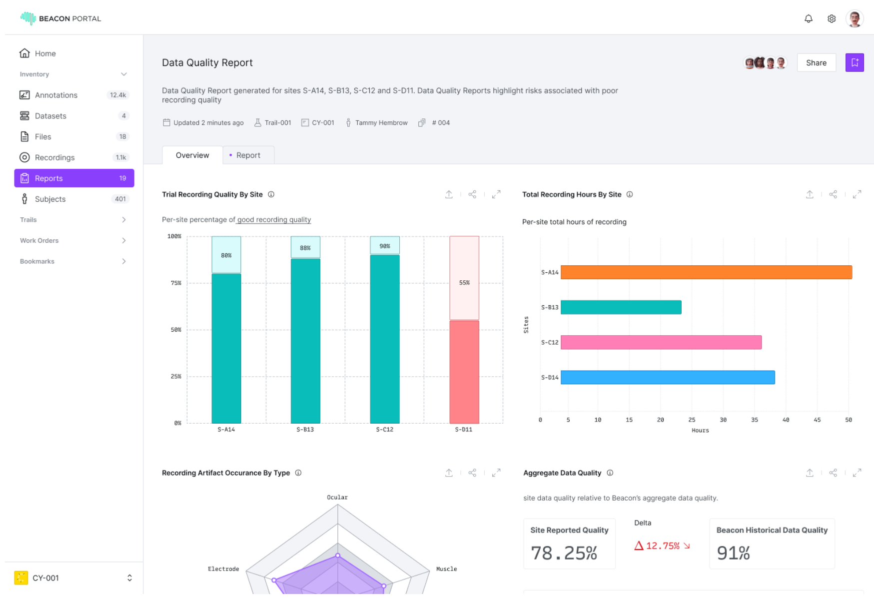

Figure 2: Sample Mock-up from Customer Facing Portal NSV [Image source: SRP, 2022]

During Chapter 1, stakeholders and participants were only given an description of the NSV. They were not shown mock-ups and visual representations. This was intentionally done to reduce the likelihood that decisions made by participants during the collaboration phase of the *Roadshow* would experience bias. Participants were also given a simplified explanation of the iterative design process based on the *Interactive Design Foundation's* applied definition [8].

In the final part of Chapter 1, participants were shown a visual process map outlining the strategy through which the *Customer Facing Portal* would be implemented. Included in this process map were explicit indicators outlining the points at which participant-feedback would influence the design process of the CFP and, when it would not.

The second chapter consisted of a collaborative activity. Participants were given 4 minutes to identify as many pain points for a user persona as possible. This user persona known as *Danny the Director of Translational Medicine* was created by the design team in iterative collaboration with pharmaceutical industry experts and stakeholders to represent the target user for Beacon's *Customer Facing Portal's* first iteration. *Danny the Director* was modeled after the individual who is most-often the interface between pharmaceutical customers and Beacon's applied science teams. They were also chosen because they are most likely to be the linchpin between scientific and strategic initiatives at pharmaceutical enterprises.

Following the 4-minute brainstorming session, participants were given 8 minutes to collaboratively group the various pain-points that they created into *k-clusters*, based on what participants deemed to be the pain-points' similar characteristics. This was done virtually with participants editing the Figma Jam and simultaneously participating via audio and video via conferencing software. Following the clustering activity, 8-12 minutes were reserved for discussing the clustering of pain-points for the user persona. The purpose of the clustering and discussion was to provide an opportunity for participants to both collaborate, and grow their comprehension of the problem space in which they, and *Danny the Director* operate. the clustering activity also provided an opportunity for the design team to collect valuable user feedback and gauge participant knowledge. During the third and final chapter, participants were shown curated mock-ups that were part of the NSV. They were then asked to provide informal feedback on the designs. The opportunity for feedback was provided to reinforce the memorable aspects of the ways in which the design team envisions the CFP. It was also done to provide participants with the context of the system that their feedback would influence. The remaining time of the 1.5-hour session was used to answer any remaining questions that participants had.

Finally, two weeks after the education sessions, participants were again asked to fill out the questionnaire outlined in Table 1. To ensure confidentiality, responses were anonymized, and only aggregate data was analyzed. Responses before and after participating in the sessions was compared to evaluate the success of the educational framework against initial engineering requirements of the system. After analysis was conducted, participants were not shown the results of the analysis. This decision was made because the design team felt that it could not adequately predict any downstream effects of revealing such findings to participants and the design team was worried that it could effect the perception participants had on the CFP post-session.

III RESULTS

Survey responses from before and after participation in education sessions were compared. Each question was evaluated based on the count of each type of response shown in Figures 3 to 6. The change in levels

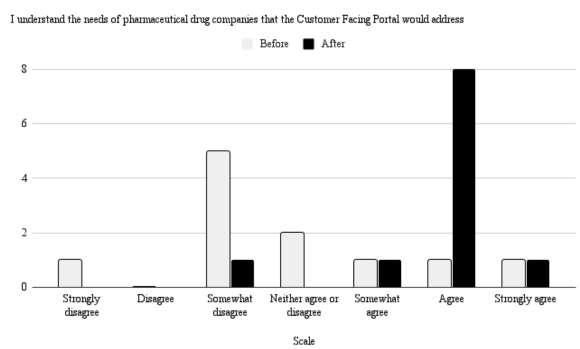

Figure 3: Participant Likert-Scale responses before and after for Question 1 [Image source: SRP, 2022]

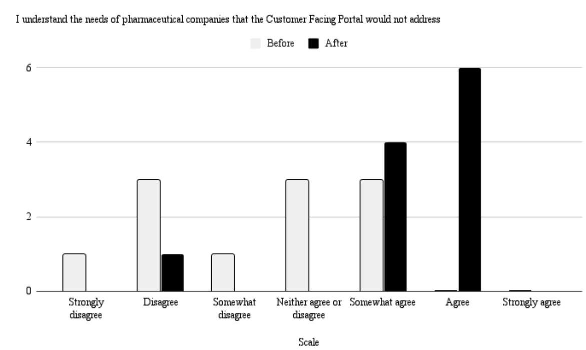

Figure 4: Participant Likert-Scale responses before and after for Question 2 [Image source: SRP, 2022]

of agreement were also calculated. Consider only the extremes of the Likert-Scale indicators, being the case when participants indicated that they strongly agreed, agreed, disagreed or strongly disagreed with a prompt. The sum and mean-count of positive agreement and negative agreement in Tables 3 and 4 increased, and decreased respectively. Only the extremes were considered to be true positive, or negative indicators because the design team felt that the *distance* between Somewhat Disagree and Somewhat Agree was small, and that the selection of Somewhat Agree, or Somewhat Disagree did not represent confidence in a participants level of agreement with the statement.

Table 3 and Table 4 shows that the number of participants who showed a positive agreement with questions increased by 17, and those with negative agreement types decreased by 5.

To determine whether observed changes in data were statistically significant, T-Tests were conducted for each question comparing participant responses from before, and after participating in the educational sessions. In

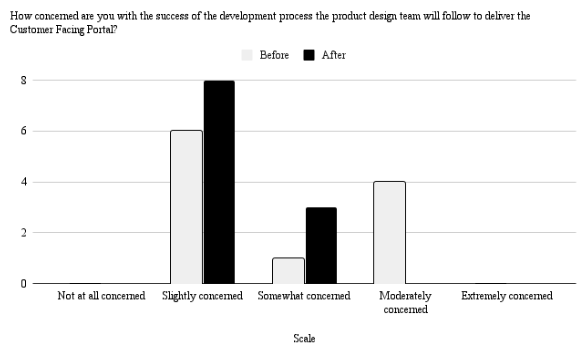

Figure 5: Participant Likert-Scale responses before and after for Question 3 [Image source: SRP, 2022]

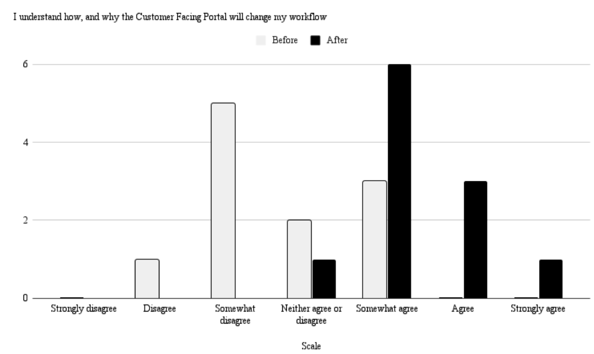

Figure 6: Participant Likert-Scale responses before and after for Question 4 [Image source: SRP, 2022]

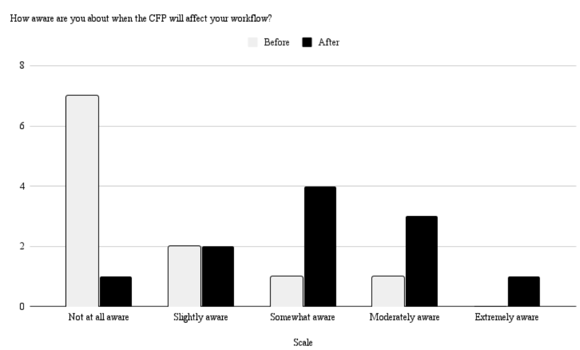

Figure 7: Participant Likert-Scale responses before and after for Question 5 [Image source: SRP, 2022]

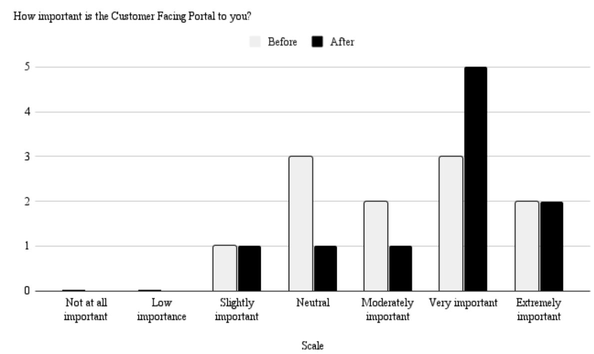

Figure 8: Participant Likert-Scale responses before and after for Question 6 [Image source: SRP, 2022]

accordance with common practice, a *p-value* of less than 0.05 was chosen to indicate that the null hypothesis H_0 could be rejected. This allows us to say with 95% confidence that changes in the agreement type shown in Tables 3, and 4 were not due to random variance, but are rather statistically significant. The *p-values* for each question are shown in Table 5. The *p-values* in Table 5 add statistical rigour to the design team's findings.

IV DISCUSSION

To increase the likelihood of success of the *Customer Facing Portal's* minimum viable product, it was determined that an educational framework was necessary. This educational framework was required to ensure that applied science teams and stakeholders understand: 1) the needs of pharmaceutical drug companies that the CFP would address, 2) the needs that the CFP would not address, 3) the development process the product design team will follow to deliver the CFP, 4) how the CFP will change their workflow, and 5) the timeline associated with the design and development of the CFP. According to the findings from the educational system's evaluation framework, there was a statistically significant improvement in participants conceptual model, understanding of problem space constraints, feedback pathways and key signifiers. Positive agreement indicators were found to have increased by 850%, and negative agreement indicators were found to have decreased by 83.33% after participating in the educational sessions. At the outset, this demonstrates that the educational system met its design requirements and is encouraging for proponents of information dissemination via cognitive learning.

Table 3: Change in Count of Agreement Type Before and After Participation in Education Sessions [Source: SRP, 2022]

Agreement Type	$\sum$ Before	$\sum$ After	Δ Agreement Count	Percentage Change
Positive (Agree/Strongly Agree)	2	19	+17	+850%
Negative (Disagree/Strongly Disagree)	6	1	-5	-83.33%

Table 4: Change in Mean Agreement Type Before and After Participation in Education Sessions [Source: SRP, 2022]

Agreement Type	μ Before	μ After	Δ Agreement μ	Percentage Change
Positive (Agree/Strongly Agree)	0.67	6.33	+5.67	+850%
Negative (Disagree/Strongly Disagree)	2	0.33	-1.67	-83.33%

However, when diving deeper into the results of the evaluation framework we see more nuanced findings. The educational framework showed large swings in a positive direction relating to the understanding participants had in the needs of pharmaceutical customers that the CFP would and would not address. However, results pertaining to the level of concern participants had with the success of the project as well as its importance were less clear cut. While still statistically significant, when participants were asked to rank their agreement related to their concern for the success of the *Customer Facing Portal* the $\Delta\mu$ agreement rank only decreased by 0.54, a minor improvement. Similar was the case with the $\Delta\mu$ agreement rank gauging the importance of the Customer Facing Portal for participants. It improved by only 0.55. These findings indicate that while the cognitive learning approach employed by the educational framework was very successful at disseminating understanding of the problem space, it was less successful at conveying to participants reasoning behind the importance of the Customer Facing Portal and why they should care about it. It was also less successful at quelling anxieties about the success of the project form participants. In fact, more participants indicated that they were slightly concerned about the success of the development process for the CFP after participating in the educational sessions than before as shown in Figure 5. The design team speculates that this phenomenon could be attributed to the fact that participants simply had more information after the sessions and consequently had more to be worried about, but this theory remains unconfirmed.

V. LIMITATIONS OF METHODS USED

There are certainly limitations of the Likert-Scale analysis framework. Most notable is the internal weighting limitations of classical Likert-Scale questionnaires. Implicit in the questions is the assumption that adjacent selections on the Likert-Scale are equidistant. This is of course not necessarily the case. It is entirely possible that the psychometric distance between "Somewhat Agree" and "Agree" is not equal to the distance between "Agree" and "Extremely Agree" [9]. Individuals may also have a tendency to avoid choosing "extremes" due to societal norms that frown upon "extreme" positions in either positive or negative contexts. Human opinion is non-discrete. As a result, during the discretization of thoughts and understanding via the completion of a Likert-Scale questionnaire, it is unavoidable that information will be lost [9].

Table 5: Questionnaire Ranges and *p-values* Comparing Responses Before, and After Participating in Educational Sessions [Source: SRP, 2022]

Question	Integer Range	*p-value*
I understand the needs of pharmaceutical drug companies that the CFP would address	[1,7]	$p = 0.00023700$
I understand the needs that the CFP would not address	[1,7]	$p = 0.00000030$
How concerned are you with the success of the development process the product design team will follow to deliver the CFP?	[1,5]	$p = 0.0251115$
I understand how, and why the CFP will change my workflow	[1,7]	$p = 0.00000024$
How aware are you about when the CFP will affect your workflow?	[1,5]	$p = 0.0000364$
How important is the Customer Facing Portal to you?	[1,7]	$p = 0.0251115$

These limitations were known to the design team when the Likert-Scale-based evaluation framework was selected. It was decided that the usability and low overhead of Likert-Scale questionnaires out-weighted the aforementioned limitations. To combat the limitations, the evaluation framework yielded statistically significant results that aligned with feedback collected during informal team discussions with participants about the educational sessions. It was during these sessions that participants were given the ability to freely discuss their non-discrete opinions on the educational framework designed to disseminate information about the *Customer Facing Portal*.

VI. CONCLUSIONS

The design team at Beacon was faced with the unique challenge of communicating extremely complex solutions to stakeholders and users of a product who do not have the necessary tools to understand the complexity of the problem space that they are part of. To address this unique challenge, the design team devised an educational framework designed to disseminate information about the problem space and proposed solutions to applied science and engineering teams alike. To determine whether the educational framework was successful in its goals, an evaluation framework was created using Likert-Scale questions design to evaluate participant comprehension, ability to apply knowledge, and ability to recall information before and after participation in educational sessions.

An analysis of data drawn from the evaluation framework indicated that there was a statistically significant improvement in participants' understanding of the problem space and its constraints, possible changes to their workflow, and their confidence in the projects success and its timelines. As a result, the design team at Beacon Biosignals concluded that the educational framework met its engineering design requirements established at the project's outset. This was demonstrated by a 850% increase in positive agreement indicators and a 83.33% decrease in negative agreement indicators after participating in the education sessions. The sessions provided value to Beacon Biosignals' product development team in the form of product feedback and problem space insights, while simultaneously providing value to those participating in the education sessions.

VII. RECOMMENDATIONS

Recommendation: When product design teams have limited experience with a problem space, or must convey a complex system to stakeholders and users, it is beneficial to employ a quantifiable education framework using a cognitive learning approach to disseminate information to internal user and stakeholders.

Rationale: As shown in the findings of the educational evaluation framework described in this paper, participants indicated with statistical significance that their understanding of the complex problem space, the limitations of proposed solutions as well as timelines had improved after participating in the educational sessions. As a direct result, the design team was able to proceed confidently and quickly with the design and development of the minimum viable product for the *Customer Facing Portal*.

Costs: Calculating the cost of an educational framework as a function of the number of user groups, we can use the following linear equation

$$t_{hours} \approx 4^a + 1.5b : a, b \geq 1 \tag{2}$$

where a is a constant representing the exponential increase in the time required to generate an education framework of increasing complexity, and b is the number of sessions required to educate all required users. In the case discussed in this paper, $a = 1$ and $b = 5$. Thus, the total time cost of education was approximately 11.5 hours.

Benefits: While generalizing the cost of poor understanding of a problem space and users during a design process is out of scope for this paper, it is reasonable to assume that the cost is exponentially greater than that of the development and execution of an educational framework aimed at increasing understanding of a problem space. In Jonathan Shariat and Cynthia Savard Saucier's book *Tragic Design: The Impact of Bad Product Design and How to Fix It*, they describe circumstances in which poor understanding of a problem space, or lack of complete understanding of users resulted in the loss of millions of dollars, lost time, and in some cases the even resulted in the death of users [10]. These losses are as good a case as any for the implementation of low-overhead frameworks constructed to improve design processes, reduce project risk and fortify understanding of a problem space for users and designers alike.

ACKNOWLEDGMENTS

Thank you to Mike Buttery, Sr. front end Engineer at Beacon Biosignals, Ilan Goodman, Vice President of Platform at Beacon Biosignals, Jarrett Revels, CTO and Co-founder at Beacon Biosignals, and the extended team at Beacon for participating in countless project meetings, and the many hours dedicated to the development and creation of the *Customer Facing Portal*.

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