GlucoMaker: Enabling Collaborative Customization of Glucose Monitors

Sabrina Lakhdhir
sabrinalakhdhir@uvic.ca
University of Victoria
Victoria, BC, Canada

Chehak Nayar
chehaknayar@uvic.ca
University of Victoria
Victoria, BC, Canada

Fraser Anderson
fraser.anderson@autodesk.com
Autodesk Research
Toronto, Ontario, Canada

Hélène Fournier
helene.fournier@nrc-cnrc.gc.ca
National Research Council Canada
Moncton, New Brunswick, Canada

Liisa Holsti
liisa.holsti@ubc.ca
University of British Columbia
Vancouver, BC, Canada

Irina Kondratova
irina.kondratova@nrc-cnrc.gc.ca
National Research Council Canada
Fredericton, New Brunswick, Canada

Charles Perin
cperin@uvic.ca
University of Victoria
Victoria, BC, Canada

Sowmya Somanath
sowmyasomanath@uvic.ca
University of Victoria
Victoria, BC, Canada

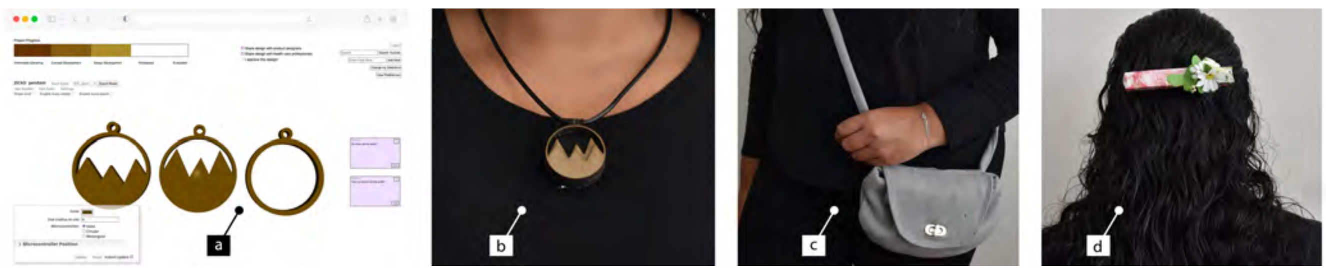


Figure 1: *GlucoMaker* enables (a) designing in collaboration with healthcare professionals and product designers bespoke glucose monitors such as (b) a vibrating pendant, (c) a visual and audio-alerting purse, and (d) a vibrating hairclip.

ABSTRACT

Millions of individuals with diabetes use glucose monitors to track blood sugar levels. Research shows that such individuals seek to customize different aspects of their interactions with these devices, including how they engage with, decorate, and wear them. However, it remains challenging to tailor both device form and function to accommodate individual needs. To address this challenge, we introduce *GlucoMaker*, a system for collaboratively customizing physical design aspects of glucose monitors. Prior to designing *GlucoMaker*, we conducted a prototyping and focus group study to understand customization preferences and collaboration benefits. *GlucoMaker* provides individuals with the ability to a) select monitor form and function preferences, b) alter predefined and downloadable digital model files, c) receive feedback on monitor designs from stakeholders, and d) learn technical design aspects. We further demonstrate the versatility and design space of *GlucoMaker* with three examples of different form and function use cases.

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05
https://doi.org/10.1145/3613904.3642435

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in HCI*; **Interactive systems and tools**.

KEYWORDS

customization, collaboration, glucose monitors, design, fabrication, design for health

ACM Reference Format:
Sabrina Lakhdhir, Chehak Nayar, Fraser Anderson, Hélène Fournier, Liisa Holsti, Irina Kondratova, Charles Perin, and Sowmya Somanath. 2024. *GlucoMaker*: Enabling Collaborative Customization of Glucose Monitors. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), May 11–16, 2024, Honolulu, HI, USA*. ACM, New York, NY, USA, 21 pages. https://doi.org/10.1145/3613904.3642435

1 INTRODUCTION

Healthcare devices such as glucose monitors are used by more than 8 million people around the world to monitor their blood glucose levels [38]. These cases could double in the next 30 years due to lifestyle changes and environmental factors [39]. An important tool that many individuals use for managing their diabetes is a continuous glucose monitor (CGM), which is composed of two parts: a sensor and monitoring device. The monitoring device consists of a specialized hardware device and/or a companion software app [5, 6, 11]. Diabetes, being a predominantly self-managed health condition [33, 59, 75, 87, 110], prompts individuals to seek more personalized approaches for receiving and responding to their data [28, 29, 33, 58, 58, 71, 104]. In line with the paradigm of personalized medicine [59, 75, 112], there is a growing interest towards tailoring both the physical attributes (shape, appearance, and placement) and the functional aspects (software and interactions) of these monitoring devices [14, 17, 35, 78].

Despite the importance of such systems in people's daily routines and the need for self-management, the design of glucose monitoring devices often challenges the ways in which people can customize them (e.g., [20, 53, 58, 72, 76, 87, 98, 100, 104, 110]). For example, the aesthetics of the physical monitor has an impact on how people use the device and how self conscious they feel during such interactions [14, 20, 76, 100]. Individuals currently have few options to address this challenge. Research has shown that individuals add stickers to decorate their monitors, but cannot easily alter its form or how it may be worn [17, 78]. Similarly, the ways in which people interact with their device has an impact on how comfortable they feel using it in varied contexts such as workplaces or in social settings [14, 20, 76, 100]. While current glucose monitor systems offer users some flexibility to customize when they receive alerts and how they receive the alert (e.g., ringtone and minor customizations to the user interface (UI) [47]), they cannot alter the type of alert or with whom it is shared, which is important for adhering to different social contexts in which individuals find themselves [14, 80]. Lastly, while individuals can attempt to engage in more low-level do-it-yourself (DIY) solutions such as altering the programmed functionality of devices or assemble a monitor using a toolkit of hardware parts to improve its functionality [14, 17, 35, 36], such solutions rely on individual's expertise and can introduce challenges for safety-in-use [17, 35]. To tackle the aforementioned design challenges, researchers have highlighted that new innovative technologies and processes that offer more individualized solutions are critical and must be researched [75, 112]. In the broader domain of healthcare, researchers have suggested that such innovative solutions can provide ways to: 1) engage device users in design processes as is the focus in patient-oriented research [43, 84, 93], and 2) bring in clinical and designer perspectives to asses whether or not certain methods and fabrication techniques will benefit users and guarantee safety in designing [50, 57, 73]. We draw inspiration from such suggestions, and apply them to the domain of diabetes management. Our paper contributes to this space and explores how individuals, with the support of healthcare professionals and product designers, can design and develop more personalized solutions for diabetes management.

We performed a three-phase co-design user study with individuals with type 1 diabetes, product designers, and healthcare professionals to better understand the potential for performing physical customizations (e.g., device appearance, placement, and feedback mechanisms) through collaboration with professionals for offering insights towards safety and technical feasibility in designing (Figure 2). Informed by these findings, we developed *GlucoMaker* (Figure 1a), a tool to facilitate the collaborative design of customized glucose monitors, and demonstrated *GlucoMaker*'s use across the development of three unique monitor examples (Figure 1b,c,d). In our work, we combine customization and collaboration to address our goal of fostering safe, user-centered ways of designing personal healthcare solutions.

In this paper we contribute:

(1) Findings from our co-design user study that elaborate on the types of physical customizations individuals want to perform, what a customization design process entails, where in this process collaboration might be beneficial, and how collaboration might be employed, and
(2) *GlucoMaker*, a novel tool, informed by our study findings, for supporting the collaborative customization of glucose monitors with four novel interactions in the context of healthcare: (i) a scaffolded or guided approach towards selecting form and function preferences of the monitor, (ii) the ability to alter predefined and downloadable digital model files, (iii) a multi-user feedback and approval process to support asynchronous and distributed collaboration, and (iv) access to resources to learn technical design.

2 RELATED WORK

Our work draws from literature on diabetes management, product-design oriented collaborative processes, and prototyping tools.

2.1 Diabetes Management

There is some work in HCI and clinical domains regarding the design and use of CGMs for diabetes management.

In HCI, prior efforts have been focused primarily towards developing new technical solutions for glucose monitoring [18, 30, 37, 70, 90, 103]. These efforts focus on considerations such as non-invasive monitoring [30, 37, 70] and digital approaches, like multi-modal displays, to improve existing monitors [90]. Qualitative studies, like those conducted by Yu et al. and James et al., focus on challenges with current monitoring systems such as the inability to collaboratively monitor glucose levels [114] and how lifestyle factors and transitions such as moving or changes in diet impact monitor usage [53]. Regarding customization of existing glucose monitoring systems, a DIY community has begun emerging within the diabetes community [17, 35, 36, 78]. This community is comprised of individuals seeking out personalized monitoring solutions that can better support and satisfy their needs and contexts of use [17, 78]. Prior literature has highlighted a series of such DIY high- and low-fidelity approaches such as altering carrying cases [78], decorating devices with stickers [78], modifying data broadcasting and remote monitoring abilities [17, 35, 36], and early-stage modular toolkits (namely, *Diafit*) for the development of multi-modal alerting devices [14]. These undertakings demonstrate the importance of focusing not only on developing new technical solutions for glucose monitoring, but also on providing supports for customizing monitor appearance, placement, and corresponding feedback mechanisms [17, 78]. However, while we know that such DIY approaches are being undertaken, they frequently occur in isolation [17, 78]. This means that many of the individuals who would benefit from customized solutions are attempting to create them while facing barriers towards accessing required technical knowledge and/or tools [78], demonstrating the need for collaboration in designing.

Aside from *DiaFit* [14], to our knowledge, no other support systems have been explored for aiding individuals in designing and developing customized glucose monitors. Further, while Akyol et al. [14] present a toolkit towards modular device customization, a gap remains in providing individuals with the ability to create new designs, get feedback on the developed designs, and access required resources and knowledge for the successful design of effective glucose monitors. Glucose monitors present a promising application for exploring customization due to their potential for individualization [14, 78], their always-on nature [5, 6, 11], their external on-body placement [5, 6, 11], and their breadth of potential feedback relaying possibilities [14, 78].

In clinical research, prior efforts have focused on qualitatively understanding the benefits and drawbacks of existing CGM technologies [34, 52, 80, 85, 106]. These studies highlight challenges that current devices introduce: the need for testing in public and how it is perceived, body and privacy issues, device suitability for use cases, wearability, and pleasantness of safety alarms [34, 80, 106]. While they also discuss benefits, such as sharing glucose trend data and hypoglycemia safety detection [85, 106], they do not begin to explore how the aforementioned challenges might be addressed. Prior literature further suggests and discusses the potential for monitor customization as a next step for study [44, 115].

Together, these studies highlight device customization as a promising solution towards producing more individually-suited monitors, with forms and features that are more relevant to wearers and their contexts of use [53, 90, 114]. They also highlight the need for collaboration in ensuring the development of safe, effective, and technically-sound devices [14, 17, 78].

2.2 Collaborative Design of Interactive Devices in Healthcare

Given our context of healthcare and the necessary depth of expertise that is required to create safe and effective monitoring devices, we consider collaborative efforts towards device design in this domain. Within the broader domain of healthcare, such collaborative design efforts have previously been explored amongst subgroups of the three involved user groups (i.e., product designers and healthcare professionals [12, 13, 20, 57, 79, 86, 101, 105], and end-users and healthcare professionals [48, 107]). For example, Ayobi et al. performed a multidisciplinary co-design study to understand social, technological, and strategic benefits and challenges that stem from such a collaborative approach [20]. They highlight benefits such as learning from one another, gaining general knowledge about health regulations and technologies, and learning new methods and approaches to interdisciplinary co-design [20]. Similarly, Aflatoony et al. explored co-design between occupational therapists and industrial designers and discuss its benefits of co-optimization of knowledge and sharing experiences [12]. They further discuss how customizing healthcare devices is a challenging task due to requiring knowledge over vastly different industries. Therefore, they suggest the exploration of co-design efforts that are inclusive of stakeholders and device users [13]. Multiple authors have further highlighted the significance of involving individuals from the target audience in related research as a means of verifying the work being undertaken, both within HCI and healthcare [12, 13, 20, 32, 53, 57, 59, 69, 75, 79, 86, 112]. However, while many of these studies suggest inclusion of the end-user, few studies have done so [48, 95, 107], and these end-user inclusive studies fail to consider all three relevant user groups. Further, while glucose monitors present a promising application for exploration as previously discussed, no such co-design studies have been conducted within their context. Building on this knowledge, we i) conducted a user-centered formative study including all three relevant user groups to understand user needs and the collaborative design process, and ii) developed *GlucoMaker* to demonstrate one approach towards supporting such collaborative design and customization.

2.3 Prototyping Physical Interactive Devices

Commercial and research projects have demonstrated tools that enable individuals to design and build physical interactive devices. For example, commercial tools such as Tinkercad enable people to design and program the behavior of interactive product designs [19]. Within HCI research literature, examples such as Retrofab [88], Pineal [64], d-Tools [49], Mobiot [16], Snowflakes [26], Astral [66], PEP [77], Objectify [97], and Circuit Assemblies [108] introduce tools and workflows through which individuals can design, retrofit or recreate existing physical interfaces with new, unique, or improved interactions. These technologies encourage self-authoring practices by making fabrication and making activities more accessible and user-friendly to larger demographics of users.

Prior literature has also highlighted benefits of introducing fabrication approaches like 3D printing towards the development of medical devices [15, 101, 109]. For example, several papers discuss how 3D printing is cost-effective, promotes personalization, can be aesthetically appealing, could lead to increased productivity, and could support collaborative efforts [15, 101, 109]. However, this has not yet been studied within the context of type 1 diabetes monitoring devices. We focus on glucose monitors as they present devices that can be customized for each individual [14, 78], are worn externally on the body [5, 6, 11], and present relaying mechanisms for exploration that do not require intrusive technologies [14, 78]. The healthcare context introduces unique challenges when it comes to designing such as required domain knowledge, adherence to regulations, crucial use cases, and potential for design to impact health [17, 78], as well as particular skillset and level of expertise requirements for interacting with software and hardware components [15, 50, 51, 57, 63, 79, 101, 109]. We address these challenges by adapting existing features from the aforementioned technologies such as simplifying the concept of adding electronic components to a 3D model [64] and providing an ideation platform for rapid brainstorming and prototyping [49]. We also introduce multiple unique interaction techniques such as scaffolded preference selection, multi-user project approvals, production of fabrication-ready files, and collaboration through discussion, to further address these challenges. Through these efforts, we aim to encourage a larger demographic of individuals to i) design better-suited customized devices, ii) produce informed designs, and iii) engage with fabrication workflows and technologies. This provides end-users with access to necessary information regarding device feasibility and functionality, and technical know-how, while introducing individuals to new

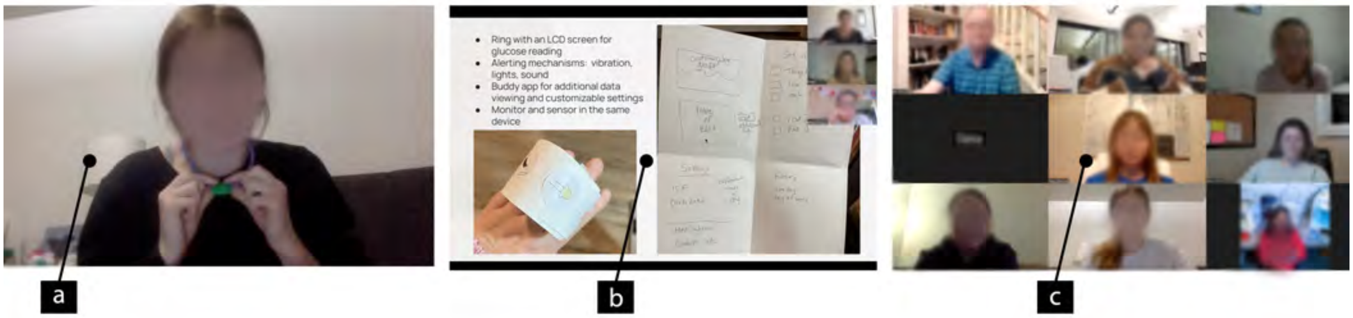


Figure 2: Our three-phase study procedure included: (a) a prototyping phase with end-users wherein participants prototyped a custom glucose monitor using craft materials and discussed how they imagine it would function, (b) a design briefing with stakeholders wherein product designers and healthcare professionals were engaged in a discussion regarding participant-proposed designs to determine what considerations might need to be highlighted through collaborative efforts, and (c) a focus group session with members from all three groups wherein all participants were engaged in discussions regarding proposed designs, how they might be improved or adapted, and how collaboration might unfold.

avenues for ideation and fabrication of their designs. Later in this paper, we share insights and discussions on how we might support varied demographics of individuals through the design process of creating custom healthcare devices.

3 UNDERSTANDING USER NEEDS

To gain insights regarding collaborative glucose monitor customization, we conducted a three-phase co-design study with participants from three user groups: adults with type 1 diabetes, product designers, and healthcare professionals. Our study was approved by our regional ethics board. For the remainder of this paper, we refer to our participants with type 1 diabetes as end-users, product designers as PDs, and healthcare professionals as HCPs.

Through this study, we were interested in understanding:

- **RQ1:** What preferences or requirements do end-users have for their diabetes care technologies?
- **RQ2:** How do end-users imagine these preferences translating onto devices? How can customizations be incorporated into devices while maintaining their functional integrity?
- **RQ3:** How and where might collaboration support such a design process while ensuring devices remain safe, effective, and feasible?

3.1 Study Procedure

We conducted a three-phase study consisting of prototyping, design briefing and focus group sessions (Figure 2a,b,c). All phases were conducted remotely and synchronously via Zoom and we video recorded all sessions for posterior data analysis. For the prototyping phase, prior to participant sessions, a kit consisting of art and craft materials (Figure 3) was shipped to their provided addresses.

3.1.1 Prototyping Phase. In the first phase, we asked end-users to prototype an ideal glucose monitor as part of completing four sequential activities (described below; Figure 2a). End-users had the flexibility to extend their current device design or to create something new. This phase was conducted 1-to-1 between individual end-users and the researcher and took between 90-120 minutes.

Activity 1 engaged end-users in considering, defining, and prioritizing their device and usage preferences (RQ1). As a starting point, we asked end-users to look through a series of glucose monitor requirements (Figure 4) that we gathered from existing literature and device specifications [14, 28, 29, 72, 87]. Participants were free to add additional requirements or select from the existing list.

Activity 2 asked end-users to prototype a glucose monitor using art and craft materials (Figure 3), informed by their previously-identified requirements. We asked participants to think-aloud [46]

Figure 3: The prototyping kit that was provided to end-users, consisting of art and craft materials and some wearables such as a t-shirt, gloves, and a toque.

Design Themes	Considerations	Select at Least One					
Feedback	*Feedback Timing*	I want real time feedback.	I want feedback at predefined or fixed times.				
	Feedback Type	Exact numbers.	Abstracted (average, median, summarized stats, etc.)				
	Feedback Mechanism	Visual (colour, light, text, etc.)	Audio (tones, music, etc.)	Tactile (vibration, contraction, etc.)			

Figure 4: A portion of the requirements table that we developed based on prior literature and current device specifications and requirements. The complete table is available via supplementary materials.

while prototyping to help the researcher understand their design process, design choices, thoughts, and questions. Through such an understanding we began gaining insights into the types of monitors people wanted to create and customize, and where in the design process collaboration might be required or beneficial for sharing knowledge and understanding amongst stakeholders (RQ1-3).

Activity 3 engaged end-users in considering the usability of their design in a series of varied contexts (RQ2). This activity aimed to provide insights towards the real-world aspects of designs that could spark collaborative discussions with other stakeholders. For example, by considering the size of a monitor design, a PD could share their expertise related to the feasibility of the idea.

Activity 4 engaged end-users in reflecting on their proposed design to determine whether or not it met their predefined preferences from Activity 1 (RQ1-2). Through this activity we learned if people wanted to revisit the initially prioritized criteria and gauge whether or not the proposed design satisfied their needs.

3.1.2 Design Briefing. In the design briefing, PDs and HCPs were shown pictures of end-user's prototypes captured during the previous phase (Figure 2b). We gathered information about the type of design features stakeholders deemed to be important and the types of questions they considered discussing with end-users as part of our envisioned collaborative design process (RQ2-3). This phase engaged one HCP, one PD, and the researcher, and took 60 minutes. In total, we conducted two design briefings where each contained one PD and one HCP.

3.1.3 Focus Group. Lastly, in the focus group [25, 27], all participants were engaged in discussions regarding the prototypes and use cases for collaboration in this context (Figure 2c). From the discussions, we gained an understanding of the types of conversations that can take place between ends-users and stakeholders, and participants' perception towards the benefits and challenges of collaboration in this context (RQ3). This phase was conducted many-to-1 between end-users, HCPs, PDs, and the researcher and took 120 minutes. In total, we conducted two focus groups where each contained one PD and one HCP. All participants except for one joined a focus group session. P2 was unable to join the session due to scheduling conflicts, however, their design was still discussed and reflected on in both the design briefing and focus group.

3.2 Participants

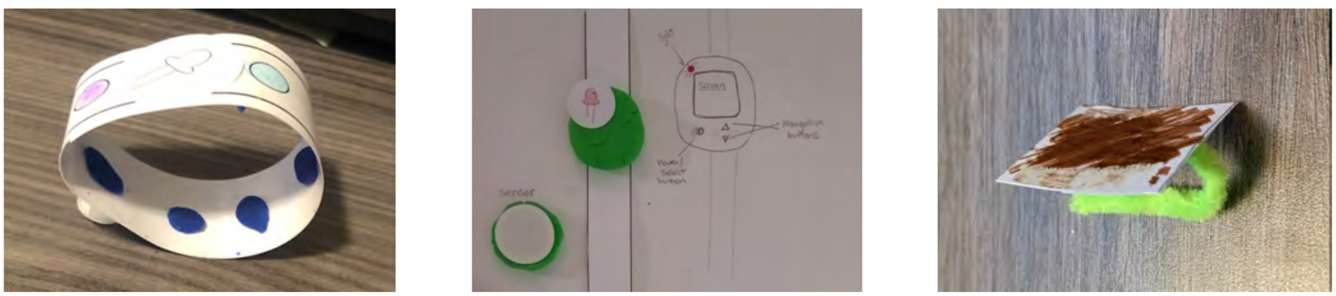
We recruited 12 participants from advertising our study details on a variety of diabetes-management social media groups and within local health authority newsletters. Participants' information is summarized in Table 1. We found that all end-users had engaged with finger pricks and CGMs for managing their diabetes. Based on these experiences, they all expressed a desire to alter some aspect of their current devices to better suit their needs such as concealed usage and data engagement. Six end-users (all but P5-6) were comfortable interacting with technology, seven (all but P5) were comfortable with crafting, and five (all but P3, P5-6) were comfortable partaking in DIY activities. Both PDs had prior experience designing medical devices, however, were less familiar with commercially available glucose monitors. Both HCPs expressed comfort interacting with technology and were very familiar with glucose monitors; one further expressed comfort with crafting and engaging with DIY practices, while the other remained neutral. We opted to work with individuals with type 1 diabetes as they typically have higher (e.g., relative to type 2) and more sensitive requirements for their monitoring devices such as constant monitoring, attachment or proximity to the body, and varied contexts of use [42, 59, 75].

3.3 Analysis

From the prototyping phase, we collected eight activity books, each containing a set of end-user reflections such as device preferences and device contexts of use and pictures of the monitor prototypes. From the entire study, we gathered 12 demographics questionnaires and about 30 hours of video recordings. All recordings were transcribed and analyzed using deductive coding [24]. Two members of the research team coded the transcripts using NVivo for evidence related to two higher-level concepts: collaboration and customization. The list of codes from this pass were discussed amongst the research team, resulting in the development of a codebook containing 203 codes. These codes spanned 24 higher-level categories, and offered insights towards eight main questions, such as *"What types of activities or actions must users be able to engage in to collaboratively design?"* and *"What do end-users perceive are the best ways to incorporate user feedback and preferences into the customization process?"*. The individual codes drove our thematic clustering process and later informed the development of our design goals.

Participant Number	Participant Type	Age	Years of Experience	Gender
P1	End-user	25	15	Male
P2	End-user	54	32	Female
P3	End-user	48	39	Female
P4	End-user	31	19	Female
P5	End-user	25	13	Female
P6	End-user	39	1.5	Female
P7	End-user	24	16	Female
P8	End-user	25	14	Female
PD1	PD - experience designing medical and consumer technologies	29	3	Female
PD2	PD - experience designing medical devices for imaging and manometry	48	22	Male
HCP1	HCP - registered dietitian; experience working with individuals with type 1 diabetes	40	1	Female
HCP2	HCP - registered nurse; experience working with individuals with type 1 diabetes	25	1.5	Female

Table 1: An overview of our participants.



(a) A ring with vibration (represented by Play-doh on the inner band) as its primary alerting mechanism.

(b) A smart watch with a flashing light and LED screen as its primary alerting mechanisms.

(c) A barrette (hairclip) to be worn either under or over hair with vibration as its primary alerting mechanism.

Figure 5: A subset of our participant-proposed device designs from the prototyping phase.

4 RESULTS

We organize our results into two main categories: 1) customization, and 2) the collaborative design process.

4.1 Summary of Customization

Overall, we found that all end-users expressed a desire to have more customized devices that better suited them and their needs (e.g., *"100%. Yes, yes… I just think it would make everyone's lives easier"* [P8], *"I never even thought that that would be an option. So yes, customizing would be great"* [P6]). Participants expressed an interest in customizing all aspects of their glucose monitors, including the sensing components, the software application, and the monitor device. In this section, we focus on the two forms of customization that were most discussed: 1) software customizations relating to data collection, management, and visualization; and 2) physical customizations relating to how and where devices were worn. Figure 5 shows a subset of participant-proposed device designs. A complete set of participant-proposed device designs can be accessed via supplementary materials.

4.1.1 Software-related Customizations. Similar to prior studies [14, 22, 33, 71, 89, 113], end-users were eager to integrate customizations centered around data collection and management, data visualization, and data viewing (Figure 6). All end-users were most concerned with accessing their data (e.g., *"Data is important […] knowing numbers dictates my day"* [P6]) and making their data more visual for their understanding (Figure 6). Additionally, five end-users (P2-4, P6, P8) were interested in receiving all tracked data (e.g., *"I'm a big data girl. So on my monitor, I would like a lot*

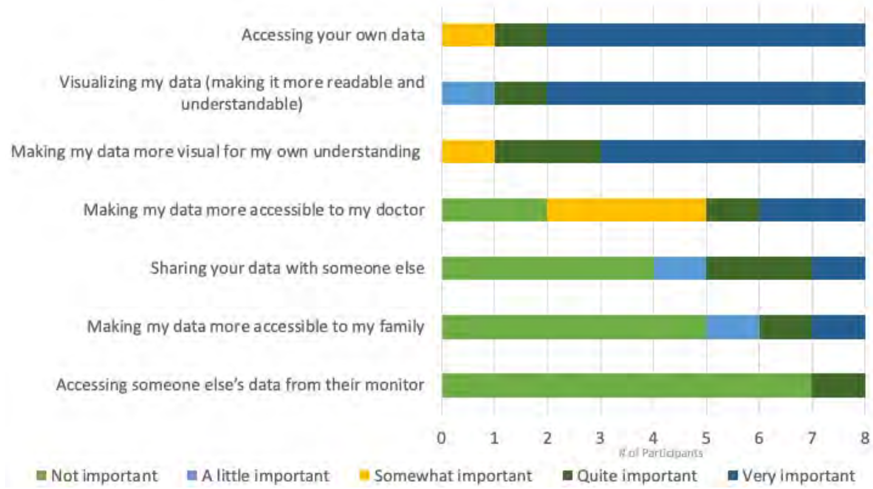


Figure 6: Participants' data-related customization preferences.

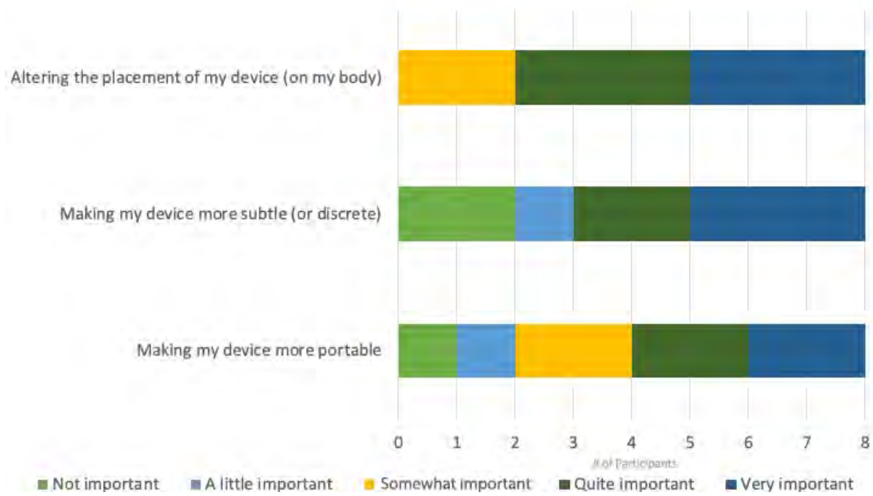


Figure 7: Participants' placement-related customization preferences.

of data" [P8]) and found it acceptable to be overloaded with information (e.g., *"the more numbers that I'm given [...] I'd rather be kind of overloaded with information and I can pick and choose what I want to take from that"* [P8]). These participants also wanted such data to be interactable. For example, P3 said, *"ability to filter the information, if you want to filter by your breakfast blood sugars or filter by a time of day, or by day of the week."*

Five end-users (P2-6) articulated that customizing feedback features such as alarms were important for various contexts. For example, P2 said, *"When I'm playing ice hockey or when I'm back country hiking on the trail, I wish I could have a different alarm"*. Similarly, P5 wanted more control over the feedback mechanism as it made them constantly feel they were undergoing something very serious, *"it's like, 'Okay, like I know I have diabetes', but it's like so medical."*

4.1.2 Placement-related Customizations. Participants in our study were also eager to customize where and how devices were worn, as found in prior studies [14, 72, 74]. As seen in Figure 7, overall, end-users were concerned with the placement, subtlety, and portability of their devices.

All end-users were interested in exploring alternate physical forms for their devices and six (P1-3, P5-7) were drawn towards jewelry-based designs (e.g., *"[...] I think if there was some sort of jewelry"* [P3]). They reasoned that jewelry is subtle (e.g., *"the first two things I thought of even before starting was kind of, a bracelet or ring type [...] people like things to be subtle, especially around illnesses"* [P1]) and portable (e.g., *"Sometimes you want to go out for dinner, and you don't want to wear or bring a big purse, or you know have things be visible."* [P6]).

P1 and P3 explicitly noted jewelry's accessible nature when it came to style (e.g., *"I think I would do the ring [...] because then, you know, it could be [...] different. You can get silver, you can get gold. . . "* [P3]) and on-body placement options (e.g., *"not everyone wears rings [...] So there's a way that it could be fitted with a necklace or a chain."* [P1]). P2, P6, and P7, further highlighted possibilities for being embedded into existing jewelry that was already worn and used (e.g., *"if that medic alert bracelet could be a sensor, that would be fantastic"* [P6]). P6 reasoned such integration could make monitors last longer, be used more, be more cost-effective, and have more value to users.

4.2 Collaborative Customization Model

From analyzing our focus group data, we recognized that the collaboration model our participants had in mind reflected similarities to that previously proposed by researchers in healthcare [82, 101]. Figure 8 provides a visual representation of the collaborative model our participants discussed. This is a user-driven model where each stage varies in its level of collaboration. In this section, informed by our participant's feedback, we describe this model by highlighting the stages and tasks within it (see Table 2), and the stakeholders involved at each stage.

4.2.1 Information Gathering. This stage involves users independently brainstorming and defining design preferences, such as through considering contexts of use [53, 58, 72, 87], to express personal and social needs. End-users in our study considered this step important for three reasons. First, it encouraged them to explore a breadth of ideas that were relevant to their individual needs. For example, P2 discussed a series of use cases they considered to ensure their design would satisfy their needs (e.g., *"when I'm playing ice hockey, I can't always see my number [...] my pump is buried under my goalie gear, and I can hear it beeping, but I don't know if I'm going high or low [...] It would also be very good with my job as a nurse, because I don't always have my pump"* [P2]). Second, it ensured they were able to derive their preferences based on their own contexts of use, without external influence. For example, in the focus groups, participants (P6, P7, HCP2) discussed how their individual preferences and concerns varied based on factors like when they were diagnosed, and how comfortable they were treating highs and lows. Third, explicitly defining their preferences and sharing brainstormed ideas provided a shared understanding amongst stakeholders about their needs and desires for their custom monitor, enabling effective discussions to take place in later phases of collaboration. For instance, in a discussion about what end-users tracked and how often, HCP2 expressed concerns over P6's desire to track certain metrics (e.g., *"I don't want people focusing on their A1C and worrying about it because there's honestly so little that you can do to change it in a day period and I know a lot of people get very anxious about that number"*). This discussion resulted in PD2 suggesting gamification as an approach towards incentivizing decreased tracking, and P6, who hadn't thought of such an approach, expressed interest (e.g., *"I would love for someone to incentivize not over scanning"*). Both PDs further emphasized the significance of understanding user needs as the first step in any design process (e.g., *"the most important part of the design is always like a very initial setup of making sure you have the right requirements from each person"* [PD1]), highlighting the importance of this stage.

4.2.2 Concept Development. This stage involves prioritizing, sorting, filtering, and merging gathered information into a cohesive first iteration device design. Five end-users (P1, P4-6, P8) appreciated the independence and open-endedness that enabled them to produce an unbiased and ideal solution for their needs (e.g., *"I like the idea that when we were instructed to sort of like create this prototype that we were looking at, it was sort of like [...] there's no limit to what we could create"* [P4]). All participants also expressed that collaboration from the get-go might impose limitations on creativity and possibilities (e.g., *"I think if you bring the people who are in the know intuitively, it puts you in a potential position where you are going to be limited"* [P1]).

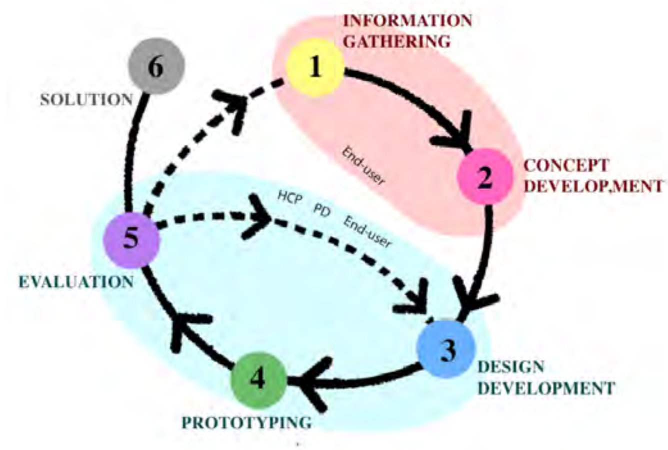


Figure 8: The collaborative customization model identified from our results, inspired by previously proposed collaboration models in healthcare [82, 101].

4.2.3 Design Development. This stage involves collaboratively developing the design through step-wise improvements and discussions with stakeholders. This was the first collaborative stage wherein stakeholders engaged to support the iterative development of designs (e.g., *"this sort of stepwise improvement [...] can really facilitate for the individual with diabetes to look a little introspectively"* [P1], *"if you have the communication, you're gonna get something that works for everybody"* [HCP2]). At this stage, collaboration was seen as an opportunity to develop, share, and discuss designs that were informed by the two previously completed stages (e.g., *"it was great to get involved after the ideas were sort of initiated"* [HCP1], *"if we then have devices that we know were made with us in mind, all of our preferences, then we do feel more connected and that, its just a little bit better"* [P7]).

Multiple participants (P2-4, P6, P7) discussed their lack of knowledge regarding performing customizations (e.g., *"that's not something I'm comfortable doing. Because I just don't know enough about it"* [P3], *"I would probably do it if I knew how to do that kind of thing."* [P4]). Such lack of confidence towards technical design was

Tasks \ Stages	Information Gathering	Concept Development	Design Development	Prototyping	Evaluation
Brainstorming	✔		✔	✔	✔
Defining Preferences	✔	✔			✔
Implementing			✔	✔	
Testing			✔	✔	✔

Table 2: The set of tasks that could occur throughout the collaborative customization design process as per our participants. These stages and tasks are elaborated upon in section 4.2.

often addressed through their increased confidence in collaborative efforts with professionals, highlighting the importance of ensuring designs were reviewed and approved by stakeholders prior to continuing with the customization process (e.g., *"I wouldn't know where to start with that...But if we could do anything with the help of a designer, yeah."* [P7]). Similar to findings by Zhu et al., they reasoned that iterative design might result in sharing inspiration, ideas, and concerns, and taking part in discussions regarding potential differing perspectives, design justifications, and (re)considerations [116]. An example of such reconsiderations occurred in our second focus group wherein P5 and P6 raised a concern regarding P8's design of a hairclip based monitor (Figure 5c) (e.g., *"when I have like a bobby pin in my hair, like it falls out a lot. So I'm just wondering how well they can make it to like, stay in your hair..."* [P5], *"my question, was the sleep factor right like, would you end up getting like compression, you know low, for example [...] And how would it stay in place?"* [P6]). These concerns and discussions therefore resulted in P8 reconsidering their idea.

4.2.4 Prototyping. This stage involves developing a physical model of the device. While some participants did express having comfort with DIY practices, they still voiced hesitations towards performing customizations independently (e.g., *"but it's a big leap when you're gonna start manipulating something on your own that could negatively impact your health, too [...] that terrifies me a little bit to try and do any of that on my own"* [P3]). Therefore, prototyping was, in most cases, recognized as a primarily PD-led process due to the required technical expertise and resource access. All participants emphasized the importance of collaboration when prototyping (e.g., *"[the PD] can't do [their] job properly if [they] don't understand my lifestyle and what I want"* [P8], *"if you have the communication, you're gonna get something that works for everybody."* [HCP2]). More specifically, in our focus groups, both stakeholders highlighted a number of areas impacting the prototyping stage where they felt their input would support end-users. For example, all participants except P4 raised questions regarding the feasibility of technical aspects like device size (e.g., *"the more you try and pack in there, the larger footprint you're going to get. . . "* [PD2]) and placement (e.g., *"when sensors come out [...] on the market, they tell us where they're approved for use in terms of where on the body"* [HCP1]) of their designs which stakeholders were more knowledgeable about. This highlights the need for communication amongst collaborators. Lastly, PDs also highlighted the importance of iteration in the device development cycle (e.g., *"then going and developing something so that people can play with it and then decide okay, yeah, we are still missing these features, let's do another revision"* [PD1]), and the potential need for independent work cycles to produce prototypes without too much derailing such as scope creep (e.g., *"because as the product developer [...] you [...] need time to work on things, work through problems, make things work, and then you can present them"* [PD2]).

4.2.5 Evaluation. This stage involves testing the developed prototype to ensure it satisfies highlighted needs. This is the final stage of the collaboration model. In our study, evaluation was viewed as an opportunity to collaboratively test the developed device and ensure all stakeholder needs, such as usability in different contexts [58, 72, 87, 110], and compliance with security concerns and regulations, were met. PDs were inclined towards an iterative evaluation process that overlapped with the prototyping stage of the collaboration model, with testing primarily being conducted by end-users. HCPs, on the other hand, were more interested in collaborative evaluation wherein all user groups tested devices to have direct experiences with each iteration (e.g., *"once you get back into like actual testing of these prototypes [...] that's when you need a lot more feedback there"* [PD1], *"everyone involved wears all, 3 or 4 for a week, and gets to experience the differences of them"* [HCP2]). End-users, however, did not share any immediate thoughts on how they might evaluate or test their customized monitors.

5 DESIGN GOALS

Informed by our user study, we identified a set of five design goals for a collaborative tool to support the design of customized glucose monitors. These design goals reflect information that was repeatedly highlighted by our participants. Due to the scope of our study, wherein we focused on understanding the types of customizations that were desired, and what a collaborative customization design process for performing such customizations might look like, we did not consider a design goal for evaluation.

DG1: Provide each end-user with access to customization guidance that helps inform their design. As mentioned by our end-users, multiple considerations inform device design, and determining these considerations can be challenging. Prior research has also similarly found that users often require support in making choices [102]. To address this challenge, we suggest providing end-users with two forms of guidance when designing glucose monitors to introduce some level of structure: 1) supporting users in considering relevant use cases, and 2) providing users with flexible design generation avenues (i.e., how the design is created and what types of customizations inform the design). Such guidance can further be augmented by providing end-users with recommended device designs based on their defined preferences.

DG2: Provide each end-user with access to a private, independent workspace. As discussed previously, several end-users were keen on combining and translating their defined preferences onto a device design prior to interacting with stakeholders. This approach reflects the typical process seen in face-to-face healthcare practices wherein end-users typically approach healthcare professionals with already-thought-out and prioritized questions and concerns prior to attending appointments [23]. To address this desire, we suggest providing each end-user with a private workspace in which they can independently engage in some initial ideation tasks and produce a first-draft device design without external influences hindering their creativity or impacting their design choices.

DG3: Provide each user group with access to a collaborative workspace. Being a collaborative model, a support tool must provide collaborative workspaces for group brainstorming, discussions, and idea development. As demonstrated in our focus groups, discussions amongst user groups encouraged sharing of ideas, experiences, and concerns, which further led to design refinement and/or reconsideration. Prior research has begun to address collaborative approaches towards diagnoses [23], and integrating individuals needs when it comes to improvising, and adapting projects and ideas [102]. To support these collaborative tasks, we suggest providing opportunities for discussion, project sharing, and design development, that are accessible to all individuals who have been granted project access by the end-user. These collaborative workspaces can enable the completion of tasks such as sharing ideas, highlighting design-specific concerns, sharing existing projects, and iterating on ideas.

DG4: Provide all users with access to a learning portal. While all end-users had a desire to customize their current devices, they also shared hesitation towards performing customizations independently. In our results we discuss how end-users were more open towards participating in PD-led prototyping phases, and had some level of comfort when it came to engaging in DIY activities. Research has found similar results, wherein end-users require low-barrier of entry tools to enable their engagement in design practices [49]. To address this hesitation and encourage end-users to be more comfortable in designing and prototyping device designs, we suggest providing users with access to external resources that can provide inspirational ideas, instructional videos or tutorials, and examples to guide fabrication and physical development of self-authored projects. To avoid overwhelming users, such resources should also provide filtering mechanisms for categories such as data, implementation, placement, and fabrication techniques.

DG5: Provide all users with an overview of the collaborative design process and the progress of their current project. As participants discussed the need for iteration and needing to stay connected with stakeholders throughout the design process, we suggest the inclusion of a project overview that can provide all project users with information regarding their ongoing projects (such as what stage the project is in and who is currently working on it). A feature like this should also incorporate phased supports towards sharing and approving designs to ensure each collaborator reviews and agrees with monitor designs before transitioning into the next phase. Similar approaches have previously been demonstrated in other such fabrication-oriented systems wherein end-users are supported through completing procedural tasks [60, 62, 99, 102].

6 *GLUCOMAKER*: DESIGN AND IMPLEMENTATION

To demonstrate and evaluate our design goals, we developed *GlucoMaker*, a tool that supports end-users to design custom glucose monitors in collaboration with relevant stakeholders (Figure 9). *GlucoMaker* is a web application implemented using HTML, CSS, JavaScript, and OpenJSCAD [56]. *GlucoMaker*'s UI consists of five main components: customization guidance interface, device designer interface, collaborative discussion interface, learning portal feature, and project overview feature. These features support:

(1) end-users to design their own glucose monitors by selecting their preferences and adapting existing digital design files (such as SVG or STL) or creating their own monitor designs using simple 3D shapes similar to CAD modeling software (Figure 9a,b),
(2) end-users and stakeholders (product designers and healthcare professionals) to discuss the created design by asking questions (e.g., "can this specific shape be fabricated?") and by engaging in feedback cycles (e.g., a healthcare professional could point out that the designed monitor can be difficult to access in emergencies) (Figure 9c,e), and
(3) end-users who want to make the monitors themselves with access to a learning portal page, through which users can search for tutorial videos to understand the technical aspects of design (Figure 9d).

6.1 Customization Guidance

The customization guidance interface is an interactive webpage through which end-users can independently begin their ideation phase (DG1, DG2). After logging in, end-users first explore and select a set of preferences regarding the monitor they want to create based on the location for wearing the monitor and the device feedback mechanisms.

The guidance page shows the user an interactive human figure consisting of clickable parts (shown via gray dots) that correspond to where the monitor can be worn (Figure 9a). End-users can select single or multiple locations on the body, and accordingly are presented with options for monitor designs. For example, as seen in Figure 10a, when a user clicks on "neck", the most relevant device option they are presented with is a necklace. The system also lists other possible designs and an open-ended "create-your-own" option, so as to not limit the end-user's ideation process. On this page, end-users are also shown feedback mechanism options and these include possible modalities such as audio, haptic and visual. To progress from design selection to exploration of specific designs, end-users click on the design and feedback options they would like and are taken to the device designer page (explained in more detail in the following section).

In our current implementation, the list of available monitor designs are generated from the ideas we gathered from our formative study and existing literature regarding wearable forms [45]. We use a simple heuristic to recommend the most appropriate device

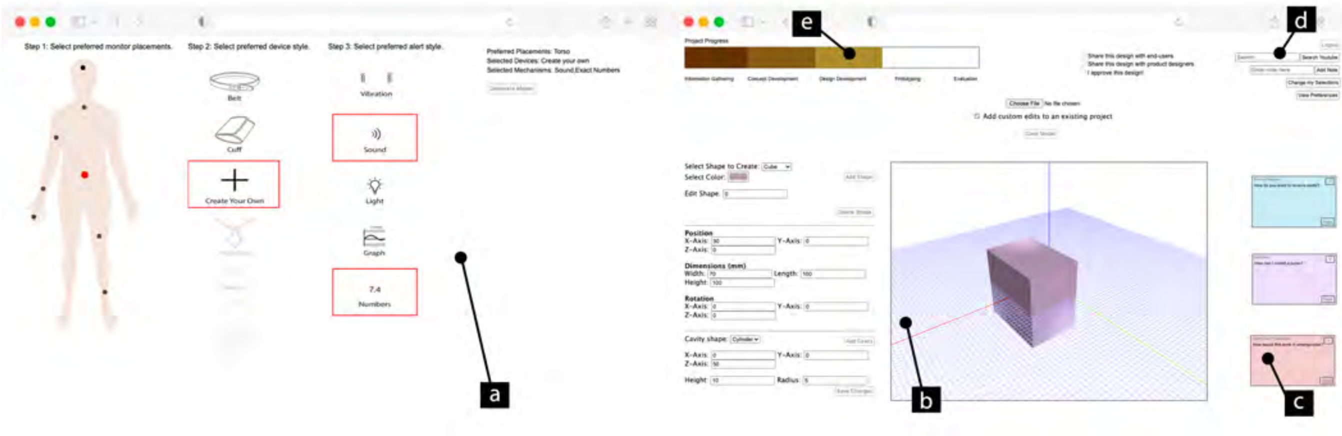


Figure 9: *GlucoMaker*'s five main components: (a) customization guidance interface that prompts users to select placement and alerting mechanism preferences, (b) the device designer interface where designs can be created or edited, (c) collaborative discussion interface where collaborators can discuss designs and ideas using sticky notes, (d) the learning portal feature that connects users to external learning resources, and (e) the project overview feature that provides users with a high-level overview of the state of the project.

design based on the user's selection for monitor location. The alerting mechanisms, however, are not recommended in any particular order because in theory, any alerting mechanism can be applied to any device. If the end-user prefers a specific feedback mechanism that could be less effective in real-world interactions, then they can discuss and learn about their design's strengths and limitations with stakeholders during discussions (as explained in the collaborative discussion feature).

Within the broader scope of design tools such as CAD modeling and product prototyping tools (e.g., [7, 8, 19, 49, 56, 92]), and particularly within the scope of medical device prototyping tools, the guidance feature is novel. Often CAD and prototyping tools focus on scaffolding the design process but not how people can make choices about what to design, an aspect that can be vital for domain-specific contexts such as ours.

6.2 Device Designer

The device designer interface is an interactive 3D editor on which people can create and edit device design models (DG2) after making selections on the guidance page. The device designer supports a predefined workflow for editing existing models, and a custom workflow for creating new or editing user-supplied designs.

The predefined workflow provides end-users with pre-made device models such as the necklace shown in Figure 10b. Users can interact with the pre-made models using an edit menu to change the size and color of the presented model (Figure 10b). The designer page also provides users with options to add cavities to house electronic components on their device models. We opted to abstract individual components into larger cavities to decrease the level of required knowledge to embed such details into models, thereby enabling end-users to interact with such functionality with ease. The predefined workflow provides users with options to add a square or round cavity (both of which are predefined sizes based on existing microcontrollers), while the "create-your-own" workflow allows users to create round or square cavities of any size.

The custom workflow provides end-users with the option to either import digital design files (such as an SVG or STL) or create a 3D model by manipulating basic shapes (Figure 9b). For the import option, models can be sourced from open-source design sites such as Instructables [4] and Thingiverse [2], on which models for various devices and objects are publicly available. In future iterations, the designer could be extended to allow users to perform 3D modeling via scanning in real-world objects that are translated into editable models [40, 41, 111].

The designer page with its two workflows was implemented using and extending OpenJSCAD's 3D-modeling library [56]. The custom workflow extends OpenJSCAD's modeling capabilities such as scaling, adding and subtracting shapes and editing colour. Our current implementation offers a narrower set of functionalities than general purpose CAD tools [7, 8, 19]. Based on the comments we received from our participants regarding their comfort level with technologies, we considered this limited set to be more useful than overwhelming our end-users by providing them an exhaustive list of options. Although end-users can continue to use third party CAD tools, we think that the integration of a subset of CAD tools within *GlucoMaker* enables more seamless interactions for design exploration by end-users.

6.3 Collaborative Discussion

The collaborative discussion interface is a set of sticky notes with which all user groups can discuss and collaborate on a device design (DG3). This feature encourages discussions amongst stakeholders to ensure appropriate considerations such as safety, effectiveness, and feasibility, are accounted for in a design.

Every user can create and add a discussion note. The color of a sticky note and the responses to a note are colour-coded by the user group - purple for end-users, red for healthcare professionals and blue for product designers (Figure 9c). The sticky note can be overlaid on the model to spatially associate the notes in relation to parts of the design. For example, in the pendant model as seen in Figure 10c, if a user is unsure about what the hollow circular component of the model is for, they can create a sticky note with their question, and drag and place it closer to that part of the model. This not only provides a visual reference to what the note is about, but also supports the notion of gaining shared understandings amongst stakeholders. Digital sticky notes as a collaboration technique is commonly used in design tools that support collaboration (e.g., [9, 54, 83]). Their ability to draw shared attention and modulate turn taking in discussions and designing have previously been found to facilitate design collaboration [21, 31]. We adapt sticky notes as easily interactive, movable, and creativity-provoking components that can facilitate conversations amongst end-users and stakeholders about their glucose monitor designs.

6.4 Learning Portal

The learning portal is a feature through which users can access learning resources that support their design and fabrication processes (DG4). The learning portal feature enables all collaborators to access external learning resources such as skill-learning, tutorials, and general-knowledge content. This feature was implemented as a keyword search that is available to users on the device designer page (Figure 9d), similar to other design-related systems [1–4, 10, 55, 68]. In its current state, the learning portal connects users to relevant YouTube videos. In future iterations, the learning portal can be expanded to include a database of user-created glucose monitor projects to serve as inspiration, tutorials for learning how to create specific monitor designs, and curated content to gain skills and general knowledge regarding strengths and limitations of specific monitor designs.

6.5 Project Overview

The project overview feature is a progress bar summary that provides collaborators with status updates about the current project (Figure 9e) (DG5). The project overview provides a high-level representation of the collaborative model as discussed in our results. Therefore, it is broken into five sections with each one correlating to a stage of the collaboration model. Hovering over the project overview provides users with information about the project such as the status of that phase (i.e., complete, in progress, or not started), and who is currently working on the project. The project overview is updated based on where the project currently is in terms of development and who is logged in. For example, when the end-user is developing a first draft of their device design, the project overview shows that concept development is currently in progress by the end-user. Once they share the project, this updates to design development, and when either of the stakeholders are editing the design, the project overview reflects that. In future iterations, the project overview can be expanded to incorporate additional project details such as overall timeline, available funds and resources, and history of the design process.

Such overviews have been seen in prior research projects [60, 62, 99, 102], albeit for monitoring individual progress. In designing the project overview we considered how a project might be shared amongst collaborators, particularly, how we might support the movement of a project from a private workspace to a shared one and what permissions such movement might require. Thus, in our implementation, we have integrated two thresholds, one for sharing projects and one for approving projects. For each project, the end-user must first share the project with stakeholders in order for it to be accessible to them (Figure 10d). Similarly, once in the hands of stakeholders, they must make similar sharing selections to make the project visible to their collaborators once they are done working on it. Further, when any collaborator is viewing a design, if they are satisfied with it, they can also approve it (Figure 10f). While project sharing makes projects visible to collaborators, approving projects indicates individual satisfaction with the design (e.g., a healthcare professional may select to approve a design once they think all potential concerns have been appropriately discussed and addressed). A project can only be exported, and therefore transition into the prototyping phase, once all stakeholders have approved the design. This multi-user approval process and permissions consideration present novelty within tools for designing physical interactive healthcare devices. In our current implementation, the approval process is not grounded in any standard checklists, but in the future, checklists, when available, can be integrated into the system to enable more standardized approval procedures.

7 SYSTEM WALKTHROUGH - VIBRATING PENDANT

To demonstrate how an end-user might use *GlucoMaker*, we describe a walkthrough of Alice (our persona) collaboratively designing a pendant-based glucose monitor with stakeholders.

Consider Alice, a 39 year-old woman who works for a fashion design company and prioritizes her overall look and aesthetics. She is not satisfied with her current off-the-shelf monitor because it is bulky and rigid. She also does not like that her monitor only offers audio-based feedback, which has often led to her silencing the monitor in meetings, therefore missing alerts. Alice wants a custom glucose monitor that is aesthetically pleasing and receives feedback subtly. She discovers that she can design her own glucose monitor using *GlucoMaker*. Given her work and personal preferences, she is inclined to design something that can mimic an everyday-wear accessory and receive feedback that only notifies her.

We constructed Alice's persona based on our study participants and their expressed needs (discussed in section 4.1). Alice represents who we consider to be a typical user for our system. Such individuals have specific needs and the means (financial and some technology literacy) to design and develop their own custom monitors. The pendant glucose monitor design and surrounding conversations between the persona and a stakeholder demonstrated in this example are also derived directly from our gathered results with minor modifications to maintain participant anonymity.

To design the custom pendant monitor, Alice would complete the following steps using *GlucoMaker*:

Selecting Preferences. Alice begins her customization process by logging into *GlucoMaker*. When signed in, she is presented with the customization guidance interface where she is prompted to select the placement of her device, its style, and feedback mechanism

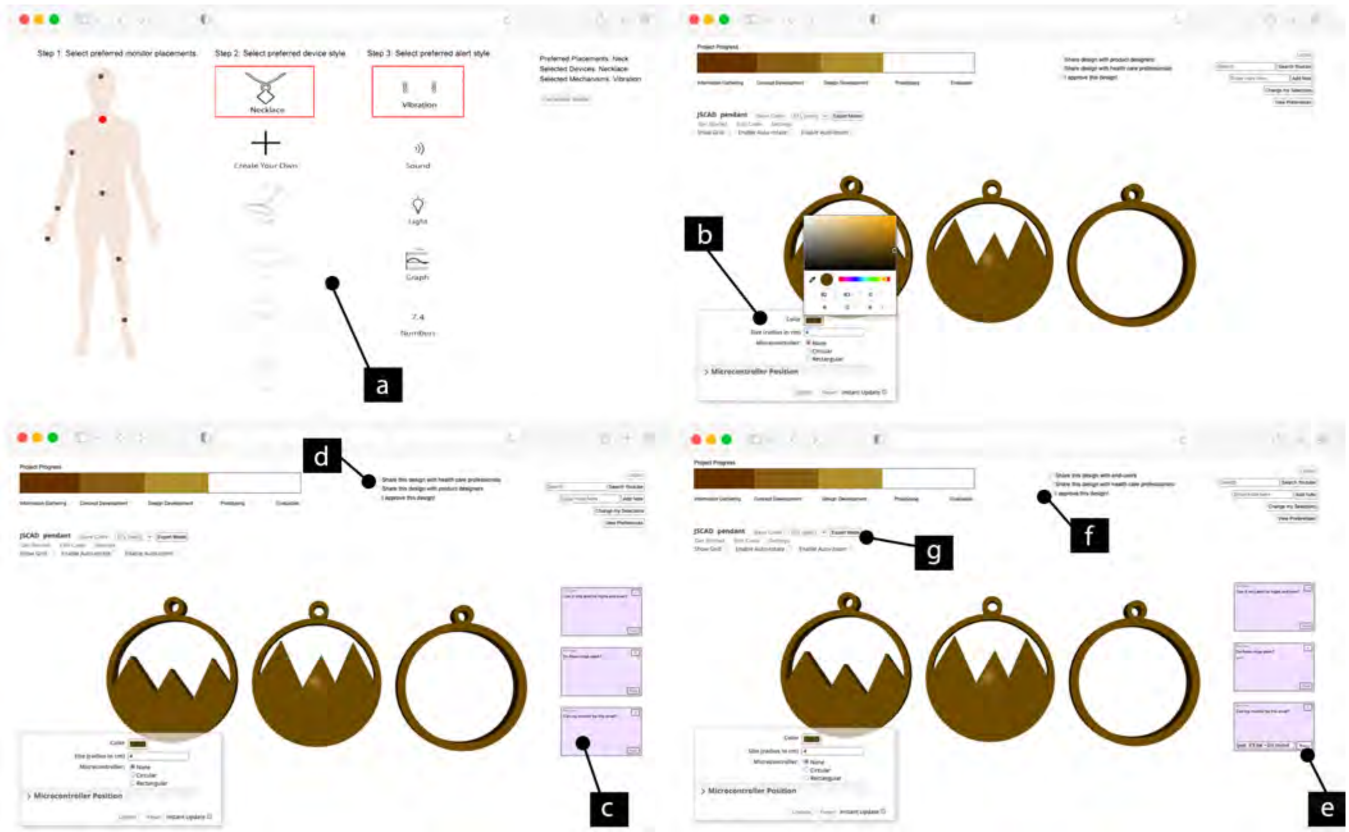


Figure 10: Steps in using *GlucoMaker* to design a bespoke glucose monitor: (a) making placement and alerting mechanism-related preference selections, (b) editing a model using the device designer interface, (c) adding comments and/or questions for stakeholders using sticky notes, (d) sharing a model with one, or both stakeholders, (e) partaking in discussions about the model through the collaborative discussion interface, (f) approving the design once satisfied with it, and (g) exporting the model for fabrication once all stakeholders are satisfied with the design.

(Figure 10a). To create a subtle accessory, Alice considers a necklace. For this, she selects *"neck"* as the on-body location, *"necklace"* as the device type, and *"vibration"* as the alerting mechanism for subtlety. Next, she clicks *"Generate Model"*.

Creating Device Design. Alice is then brought to the device designer where she is presented with an automatically loaded, predefined pendant model (Figure 10b). Alice is happy with the predefined pendant design that *GlucoMaker* presented to her and decides to only slightly edit the model by changing its size and color.

Sharing and Discussing Design with Collaborators. Once Alice is happy with her design, she wants to confirm if her design is safe and feasible to produce. She uses sticky notes to post questions for the product designer (PD), including clarifying how the model would look physically, and the feasibility of her desired size. Due to her specific desires regarding contexts of use, Alice also leaves a note to clarify that she would only like to be alerted when her blood sugar reading is either too high or low (Figure 10c). Next, to begin collaborating with stakeholders, she selects two checkboxes to share her design (Figure 10d). Once it has been shared, both stakeholders gain access to the design to review it and respond to her posted comments to engage in asynchronous conversations (Figure 10e). Once satisfied with the design, all stakeholders approve the design (Figure 10f).

Approving Design and Checking its Progress. Alice has decided that she would like the PD to make the device for her and therefore, once the design is approved by all users, the PD exports the model to begin producing the device (Figure 10g). The model is exported as an STL. The PD finds that laser cutting the design would be more cost- and time-efficient, and so they opt to convert this model into an SVG offline. While the PD produces the device, other stakeholders can view the progress bar to see its status.

Constructing the Physical Device. From our study, we learned that in most cases, the PD prefers to independently construct the device to avoid "scope creep" from continued back and forth conversation. In this example too, the PD works independently by laser cutting the model using the desired material, gathering required electronic components, soldering the circuit, programming the alerts in relation to the data, and polishing the finished device. Based on Alice's note regarding when she would like to receive feedback and her selection of vibration as an alerting mechanism, the PD programs the device to provide a three-second long vibration for high blood sugar reading alerts, a one-second long vibration

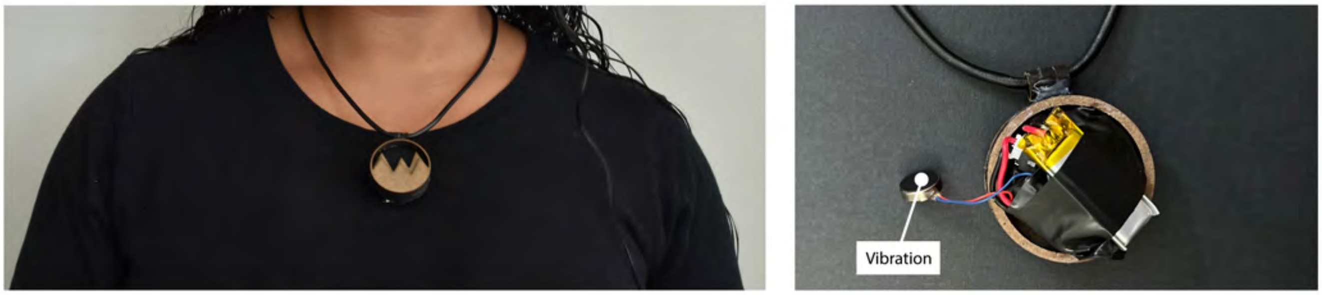


Figure 11: The developed pendant monitor worn by a user on the left, and the circuitry encapsulated within it on the right.

for low blood sugar reading alerts, and no vibration for an in-range blood sugar reading. Throughout these steps, the learning portal and the sticky notes with discussed information remain accessible to provide reference. Once the physical device is constructed (Figure 11), the monitor is sent to Alice, and the process shifts into an iterative evaluation stage wherein Alice tries using her monitor and shares any necessary follow-up details or questions using *GlucoMaker* to further improve the design.

8 EXAMPLES

In this paper, we present an *evaluation-by-demonstration* approach for highlighting the strengths and limitations of *GlucoMaker* [64–66, 96]. Before conducting a usability study, we considered it more important to understand the breadth of glucose monitor customizations that *GlucoMaker* supports. To this end, we developed three prototype monitoring devices to highlight a series of participant considerations and reflections. Participant-proposed designs (i.e., the pendant and hairclip from the formative study) served as starting examples, and we also crafted a new design (i.e., the purse) to better understand *GlucoMaker*'s strengths and limitations as they relate to our design goals. Figure 12 highlights the different considerations that informed and are encapsulated within our examples.

To make our example monitors functional, we integrated a publically available glucose monitor dataset that was tracked by an individual with type 1 diabetes [91]. The glucose level ranges for providing feedback were determined using the Centre for Disease Control's classifications [42].

Figure 12: Design space covered by the example monitor designs related to hardware, software and use-case considerations, where the gray boxes highlight the considerations demonstrated by each example.

8.1 Pendant

Our first example is a pendant (Figure 11) as was demonstrated in the walkthrough in the previous section. This is an example of a subtle, always-alerting, on-body device that provides abstract feedback in the form of haptic alerts. The pendant example highlighted *GlucoMaker*'s predefined model designer workflow, and as previously discussed, demonstrates fabrication using laser cutting in a PD-led prototyping phase.

8.2 Purse

Our second example is a purse (Figure 13) that demonstrates a sometimes-alerting, public, semi-on-body device that provides visual and audio feedback and can be worn in either a subtle or obvious manner. We classify the purse as a sometimes-alerting and semi-on-body device because while a purse is typically worn on the body, there are times when it may not be. This results in not being able to provide continuous alerts to its user. This example demonstrates the custom device designer workflow and the need for collaboration while designing.

This example was developed by the research team to highlight the need for a collaborative interface in such open-ended design. For example, while end-users might not consider the safety of such a monitor, a HCP would quickly question this due to the contexts they are familiar with (i.e., emergency situations). This example also highlights fabrication from a 2D monitor design using laser cutting and sewing.

Figure 13: The developed purse-based monitor worn by a user on the left, and the provided feedback on the right.

8.3 Hairclip

Our third example is a hairclip (Figure 14) that demonstrates a semi-on-body, sometimes-alerting device that provides haptic, abstract, and private feedback, and can be worn in both subtle and obvious manners. Like the purse, a hairclip is an accessory that may not worn at all times, and therefore, similarly, it may only be able to provide intermittent alerts to its user.

This example was derived from a participant-proposed idea (Figure 5c), and therefore, its considerations as defined in Figure 12 are reflective of conversations that took place amongst our participants in our user study (as previously discussed in section 4.2.3). The hairclip example demonstrates fabrication from a 3D monitor design using 3D printing.

9 DISCUSSION

The overarching goal of our work was to understand and demonstrate how end-users can create custom healthcare devices, such as glucose monitors, with support from relevant stakeholders. Our approach to addressing this goal was comparatively more bottom-up (i.e., user-centered) than top-down (i.e., mass manufacturing varied designs). With the recent success of DIY and similar initiatives in health, wherein people-driven products have received regulatory approval [36, 67], we find that tools such as ours can become a valid option for people with diabetes. Additionally, in our work, to address challenges surrounding limited technical skills and professional know-how, we decided to engage relevant stakeholders to support the process of customization. While our participants were optimistic of this approach, we also recognize the work and effort that is needed to engage in collaborative initiatives. We know that more work must happen (e.g., work schedule adjustments, manufacturers must make custom devices compatible with their sensors) before such collaborative designing becomes a reality. The recent Nature article [36], however, highlights the growing alignment between end-users, healthcare professionals and industries to bring forth a more human-centered approach to healthcare, pointing towards a more favourable future for tools such as *GlucoMaker*.

With the above context, in this section, we discuss how *GlucoMaker* can support individuals with varied levels of interest, comfort, and confidence in designing and developing a customized healthcare device. Due to end-user's varied needs and levels of expertise, we opted to frame our discussion using Sanders et al.'s levels of creativity (adapters, makers, creators) [94]. These levels of creativity demonstrate various roles and approaches that end-users can take during a design process, thereby enabling us to consider varied approaches towards providing customization support. This framing also enables us to reflect on the various tasks within the different workflows that are derived from, and depend on, stakeholder interactions, and the varied levels of collaboration that might be required across each workflow.

9.1 Adapters

We had two end-users who self-identified as having little comfort when working with electronics or technologies and partaking in DIY activities (P5, P6). These end-users were motivated by appropriation, and wanted to make artifacts their own by adding personal touches to existing products. For example, multiple participants

Figure 14: The developed hairclip-based monitor worn by a user on the left, and showcasing its embedded circuitry on the right.

were interested in designing monitors in the form of everyday wearable accessories to mimic devices they already used and were comfortable with (Figure 5). Using Sander's classification of designers, we can consider such end-users as adapters [94]. In this section, we reflect on how our system can support such adapters.

For adapters, a scaffolded design process could be a useful approach to build upon in technology design. For example, features such as the customization guidance and the simpler predefined modeling workflow could be more useful compared to open-ended design tools such as existing CAD softwares. As demonstrated in our necklace example, a user can select a pre-made model and adapt it by editing its appearance such as color and form-related features like size to create a custom design that addresses context-specific needs [14, 58, 72, 87, 110]. These relatively minor editing processes also aim to decrease the potential for misunderstandings between designers when it comes to user needs and translating them onto designs [81, 116]. Such considerations also decrease the need for extensive collaboration. This subset of users are likely to perform minor customizations on existing models, such as those related to size or visual appearances (e.g., changing the wristband of a smartwatch, replacing the chain on a pendant, or decorating a case), that do not impact monitor functionality, and therefore, would not introduce additional risks that require technical or domain expertise or review. In the future, by expanding the database of available predefined options for each device type, it is possible to increase the likelihood that this workflow would be more efficient in reducing the amount of collaboration required in such predefined projects, while also increasing their application and usefulness to end-users.

From our study, we observed that some participants, while wanting to create customized devices, mostly posed questions towards stakeholders regarding their feasibility (i.e., size, functionality). Informed by this, we presume that access to extensive technical resources might be less important for adapters, and thus, envision presenting adapters with a simpler learning portal (DG4), such as in the current implementation. This observation also leads to considerations regarding the potential inclusion of more structured sticky notes or approval processes. For example, when a user selects a predefined model option, it may be beneficial to automatically provide them with information regarding a standard set of questions and their respective answers (such as the range of sizes the model supports and the types of alerts it can accommodate well). This information could be tied to the sticky notes wherein if the typed text on a note matches one of the provided pieces of information, the system redirects the user to such details.

9.2 Makers

We had three end-users (P3, P4, P7) who self-identified as having intermediate-level comfort when working with electronics or technologies and partaking in DIY activities. These end-users were motivated by exercising their ability or skill, and wanted to make custom artifacts with some assistance. Using Sander's classification of designers, we can consider such end-users as makers [94]. In this section, we reflect on how our system can support such makers.

For makers, more open-ended system features such as the "create-your-own" pathway can be a useful approach for enabling more flexibility in design. For example, we noticed that our more intermediate end-users were inclined to i) integrate concepts from existing devices into their designs, or ii) use existing devices as inspiration to start their designs (Figure 5b). As demonstrated by the purse example, *GlucoMaker* supports this desire by enabling individuals to build upon existing project models (2D or 3D) by importing externally-sourced designs. This open-endedness provides makers with opportunities to practice and gain skills while building upon existing projects that can provide them with the starting point they may require in translating their preferences onto device designs. This also provides makers with increased creative flexibility and allows them to individualize their design without being design experts. We anticipate such inclinations also correlating to a need for accessing increased brainstorming, design, and fabrication resources, therefore demonstrating the need for a more in-depth and exhaustive learning portal that includes content such as inspirational designs, pre-approved models, and tutorials for creating 3D models (DG4) [61].

GlucoMaker further enables users to build overtop of existing models, and easily discuss questions or concerns about their model with stakeholders through the use of sticky notes (DG3). The inclusion of sticky notes provides a platform on which collaborations can occur effectively in order to discuss topics such as device usability, safety, and feasibility - conversations that could be of utmost importance given the flexibility and open-endedness offered by the "create-your-own" workflow. Through these discussions the end-user can become aware of potential limitations presented by their design, such as a purse not always being worn, and make an informed decision regarding the development and usage of their proposed design in consideration with their contexts of use [14, 58, 72, 87, 110]. Given their desire to make custom artifacts with assistance, it is likely makers will require more collaboration iterations when designing. This is due to the nature of the workflow wherein any existing device model can be imported to build off of and the end-user's comfort level and knowledge in designing. For example, in the design development phase of our purse monitor, we envision the need for multiple iterations to reach a consensus regarding the safety and reliability of the device, its size and appearance, and how and when it provides feedback. Following development and evaluation of the prototype, changes to such a monitor, like altering its size, alerting mechanism, or frequency of alert, would require input from all three collaborators as it is unlikely that other such monitor designs exist that can be borrowed from easily.

Given makers' expertise and comfort levels, we presume the fabrication of their devices might also require custom-orders at times, thereby resulting in increased production times and costs. However, their ability to source existing designs might also present an advantage wherein, depending on where models were sourced from, they may include pre-existing resources or tutorials to support the fabrication process [2, 4], enabling makers to engage more deeply with the fabrication process.

9.3 Creators

We had three end-users (P1, P2, P8) who self-identified as being comfortable when working with electronics or technologies and partaking in DIY activities. These end-users were motivated by their interests in engaging with DIY practices, and wanted to express themselves and their creativity by creating unique artifacts themselves. Using Sander's classification of designers, we can consider such end-users as creators [94]. In this section, we reflect on how our system can support such creators.

For our more expert users, consistent open-ended possibilities (like other, similar tools [7, 8, 19]) offer opportunities for engaging in DIY practices and fabrication, and personal and creative expression. For example, features such as the "create-your-own" workflow could be beneficial by enabling individuals to build models from scratch and explore models in various file formats. As demonstrated by our hairclip example, this maximizes the flexibility of what can be designed, how designs can be fabricated, what materials can be used, and how simple or complex a design can be.

This, however, also requires increased collaboration and investment from all three user groups. The increased level of flexibility and customization introduces infinite options for design that require more discussion, reviews, and iterations in order to ensure their safety, effectiveness, usability, and wearability. For example, designing a monitor like the hairclip could result in multiple iterations to first determine the viability of such a device, followed by many more iterations to refine its design. In terms of a workflow, this would result in first, the user spending more time brainstorming and modeling the design; and second, collaborators investing increased time towards understanding the design and discussing its safety, effectiveness, and feasibility to reach a shared understanding [81, 116]. Post-evaluation, it is likely that creators will be more involved in adapting or redesigning their monitor to increase their satisfaction with it. Given their increased comfort level and interest in engaging with DIY activities, this could equate to requiring additional collaborator support in ensuring alterations do not negatively impact the device or its effectiveness. For example, a creator may design a ring-based monitor, however, post-development and evaluation, they may be interested in wearing it as a pendant instead. This change would require input from all three collaborators to ensure the feedback mechanism remains effective, and the method of wearing the device doesn't impair its ability to share alerts.

Lastly, as creators may be inclined to also fabricate devices independently, these users would likely require increased access to supporting resources. We envision creators' motivations and desires as designers resulting in their needing a larger ecosystem of tools and resources within the learning portal to support independent device design and development (D4) [1–4, 61, 68]. For example, a creator who is inclined to partake in the fabrication process might require resources regarding from where electronic components can be sourced, and how circuits might be built in a more permanent manner. Similarly, they might require assistance or technical knowledge when it comes to how to prepare a file for a laser cutter or 3D printer, or what settings to use when interacting with such equipment.

10 LIMITATIONS AND FUTURE WORK

GlucoMaker, to the best of our knowledge, is the first tool to demonstrate how people can design custom glucose monitors with support from stakeholder collaboration. As such, the research also has four key limitations that must be addressed through future work.

First, our formative study had a limited number of participants in each group. In particular, the majority of our end-user participants were female, and therefore, this might have impacted the types of device designs we saw. Although we found repetition in the responses among participants and we found similarities in our study results with those from the literature, more studies with diverse participants could offer richer insights into the types of customization support future tools must include.

Second, as a first prototype, while demonstrating different features, our system also offers a single perspective on how customization and collaboration can be supported. For example, collaboration in our work is primarily supported through asynchronous communication facilitated by sticky notes. We implemented it this way because we considered that the busy schedules of the stakeholders and participants may not lend itself well to synchronous forms of collaboration. However, with further studies and support for additional tasks such as evaluation, we anticipate the need to include more synchronous and different forms of collaboration support such as community forums and video calling. Such extensions can also be considered for other features such as providing support for more advanced fabrication workflows, more tutorials for the DIY enthusiasts, and a more exhaustive database of pre-made monitor model designs.

Third, in this paper we evaluated *GlucoMaker* through an evaluation-by-demonstration method and did not conduct a usability study. As explained previously, prior to conducting a thorough user study we wanted to first understand the versatility of our system. Informed by our current understanding, in the near future, we plan to evaluate *GlucoMaker* with participants. To understand the scope of systems such as *GlucoMaker*, several different studies could be conducted: to evaluate support for customization only, collaboration only, and them combined. We hope that with future efforts in this area and our own studies, collectively, we can contribute to a more thorough understanding of this space.

Fourth, *GlucoMaker* focuses primarily on physical customizations including appearance, placement and alerting mechanism as these were most often discussed by our participants. Future works can and should consider additional dimensions of customization such as visual elements of displays [90], connecting collected data to individual goals [53, 114], and sensing components and functionalities of devices [30, 37].

11 CONCLUSION

In this paper, we explored how individuals with diabetes can be supported in creating custom healthcare devices that better meet their individual needs. We presented insights from our formative study that showed i) how individuals with type 1 diabetes want to customize their glucose monitors, and ii) a collaboration model to support customized device design processes. We designed and developed *GlucoMaker*, a system on which individuals can design customized glucose monitors in collaboration with healthcare professionals and product designers. *GlucoMaker* consists of five components: customization guidance interface, device designer interface, collaborative discussion interface, learning portal feature, and project overview feature. Each of these features supports individuals in engaging in four key tasks towards collaboratively customizing glucose monitors: a) selecting monitor form and function preferences, b) altering design files (whether predefined, self-made, or externally sourced), c) discussing monitor designs with stakeholders to iteratively improve the design, and d) gaining technical design and fabrication knowledge. Through demonstration of glucose monitors designed using *GlucoMaker*, we showed how form and function considerations can guide the development of next generation monitors. We hope our efforts will inform future studies and enable addressing necessary individualized healthcare needs via user-centered collaborative design approaches.

ACKNOWLEDGMENTS

We would like to thank our participants for their valuable feedback. This work is supported by NRC grant DHGA-114-1.

REFERENCES

[1] 2022. *Arduino projects.* https://create.arduino.cc/projecthub
[2] 2022. *Digital designs for physical objects.* https://www.thingiverse.com/
[3] 2022. *Fun Electronic Projects.* https://learn.adafruit.com/guides/projects
[4] 2022. *Yours for the making.* https://www.instructables.com/
[5] 2023. https://www.dexcom.com/en-us/continuous-glucose-monitoring
[6] 2023. https://www.freestyle.abbott/ca-en/learn/continuous-glucose-monitoring.html
[7] 2023. https://www.autodesk.ca/en/products/fusion-360/overview
[8] 2023. https://www.solidworks.com/
[9] 2023. https://miro.com/
[10] 2023. https://www.fablabs.io/
[11] 2023. Diabetes treatment - CGM systems. https://www.medtronic.com/ca-en/diabetes/home/products/cgm-systems.html
[12] Leila Aflatoony and Su Jin (Susan) Lee. 2020. AT Makers: A Multidisciplinary Approach to Co-Designing Assistive Technologies by Co-Optimizing Expert Knowledge. In *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 2* (Manizales, Colombia) *(PDC '20)*. Association for Computing Machinery, New York, NY, USA, 128–132. https://doi.org/10.1145/3384772.3385158
[13] Leila Aflatoony, Su Jin Lee, and Jon Sanford. 2023. Collective making: Co-designing 3D printed assistive technologies with occupational therapists, designers, and end-users. *Assistive Technology* 35, 2 (2023), 153–162. https://doi.org/10.1080/10400435.2021.1983070 arXiv:https://doi.org/10.1080/10400435.2021.1983070 PMID: 34550049.
[14] Erman Akyol, Roberta Cabral Cabral Ramos Mota, and Sowmya Somanath. 2021. DiaFit: Designing Customizable Wearables for Type 1 Diabetes Monitoring. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI EA '21)*. Association for Computing Machinery, New York, NY, USA, Article 437, 6 pages. https://doi.org/10.1145/3411763.3451716
[15] Rahaf Alharbi, Ada Ng, Rawan Alharbi, and Josiah Hester. 2020. "I Am Not an Engineer": Understanding How Clinicians Design & Alter Assistive Technology. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '20)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3334480.3382982
[16] Abul Al Arabi, Jiahao Li, Xiang 'Anthony Chen, and Jeeeun Kim. 2022. Mobiot: Augmenting Everyday Objects into Moving IoT Devices Using 3D Printed Attachments Generated by Demonstration. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 273, 14 pages. https://doi.org/10.1145/3491102.3517645
[17] Lora Arduser. 2018. Impatient Patients: A DIY Usability Approach in Diabetes Wearable Technologies. *Commun. Des. Q. Rev* 5, 4 (feb 2018), 31–39. https://doi.org/10.1145/3188387.3188390
[18] Muhammad Asad, Usman Qamar, Aimal Khan, and Rahmat Ullah Safdar. 2019. A Systematic Literature Review of Continuous Blood Glucose Monitoring and Suggesting the Quantity of Insulin or Artificial Pancreas (AP) for Diabetic Type 1 Patients. In *Proceedings of the 2019 11th International Conference on Machine Learning and Computing* (Zhuhai, China) *(ICMLC '19)*. Association for Computing Machinery, New York, NY, USA, 539–545. https://doi.org/10.1145/3318299.3318352
[19] Autodesk. 2023. https://www.tinkercad.com/
[20] Amid Ayobi, Katarzyna Stawarz, Dmitri Katz, Paul Marshall, Taku Yamagata, Raul Santos-Rodriguez, Peter Flach, and Aisling Ann O'Kane. 2021. Co-Designing Personal Health? Multidisciplinary Benefits and Challenges in Informing Diabetes Self-Care Technologies. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW2, Article 457 (oct 2021), 26 pages. https://doi.org/10.1145/3479601
[21] Linden J. Ball, Bo T. Christensen, and Kim Halskov. 2021. Sticky notes as a kind of design material: How sticky notes support design cognition and design collaboration. *Design Studies* 76 (2021), 101034. https://doi.org/10.1016/j.destud.2021.101034
[22] Katharine D Barnard, Tim Wysocki, Hood Thabit, Mark L Evans, Stephanie Amiel, Simon Heller, Amanda Young, Roman Hovorka, and Angela Consortium. 2015. Psychosocial aspects of closed-and open-loop insulin delivery: closing the loop in adults with Type 1 diabetes in the home setting. *Diabetic Medicine* 32, 5 (2015), 601–608.
[23] Andrew B.L. Berry, Catherine Y. Lim, Calvin A. Liang, Andrea L. Hartzler, Tad Hirsch, Dawn M. Ferguson, Zoë A. Bermet, and James D. Ralston. 2021. Supporting Collaborative Reflection on Personal Values and Health. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW2, Article 299 (oct 2021), 39 pages. https://doi.org/10.1145/3476040
[24] Richard E Boyatzis. 1998. *Transforming qualitative information: Thematic analysis and code development.* sage.
[25] Julian Brinkley, Brianna Posadas, Julia Woodward, and Juan E. Gilbert. 2017. Opinions and Preferences of Blind and Low Vision Consumers Regarding Self-Driving Vehicles: Results of Focus Group Discussions. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility* (Baltimore, Maryland, USA) *(ASSETS '17)*. Association for Computing Machinery, New York, NY, USA, 290–299. https://doi.org/10.1145/3132525.3132532
[26] Oğuz 'Oz' Buruk, Çağlar Genç, undefinedhsan Ozan Yıldırım, Mehmet Cengiz Onbaşlı, and Oğuzhan Özcan. 2021. Snowflakes: A Prototyping Tool for Computational Jewelry. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for

Computing Machinery, New York, NY, USA, Article 636, 15 pages. https://doi.org/10.1145/3411764.3445173

[27] Antonella Camilleri, Sanja Dogramadzi, and Praminda Caleb-Solly. 2022. Learning from Carers to Inform the Design of Safe Physically Assistive Robots - Insights from a Focus Group Study. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction* (Sapporo, Hokkaido, Japan) *(HRI '22)*. IEEE Press, 703–707.

[28] Yoon Jeong Cha, Arpita Saxena, Alice Wou, Joyce Lee, Mark W Newman, and Sun Young Park. 2022. Transitioning Toward Independence: Enhancing Collaborative Self-Management of Children with Type 1 Diabetes. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 522, 17 pages. https://doi.org/10.1145/3491102.3502055

[29] Yunan Chen. 2010. Take It Personally: Accounting for Individual Difference in Designing Diabetes Management Systems. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (Aarhus, Denmark) *(DIS '10)*. Association for Computing Machinery, New York, NY, USA, 252–261. https://doi.org/10.1145/1858171.1858218

[30] Loubna Chhiba, Sidqui Mustapha, and Abdelaziz Marzak. 2019. Design of a Non-Invasive Blood Glucose Meter Connected to an Android Diabetes Monitoring Application. In *Proceedings of the 4th International Conference on Smart City Applications* (Casablanca, Morocco) *(SCA '19)*. Association for Computing Machinery, New York, NY, USA, Article 44, 5 pages. https://doi.org/10.1145/3368756.3369022

[31] Bo T. Christensen, Kim Halskov, and Clemens N. Klokmose. 2020. Chapter 1 - The properties of sticky notes for collaborative creativity: An introduction. In *Sticky Creativity*, Bo T. Christensen, Kim Halskov, and Clemens N. Klokmose (Eds.). Academic Press, 1–16. https://doi.org/10.1016/B978-0-12-816566-9.00001-X

[32] Chia-Fang Chung, Kristin Dew, Allison Cole, Jasmine Zia, James Fogarty, Julie A. Kientz, and Sean A. Munson. 2016. Boundary Negotiating Artifacts in Personal Informatics: Patient-Provider Collaboration with Patient-Generated Data. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (San Francisco, California, USA) *(CSCW '16)*. Association for Computing Machinery, New York, NY, USA, 770–786. https://doi.org/10.1145/2818048.2819926

[33] Pooja M. Desai, Elliot G. Mitchell, Maria L. Hwang, Matthew E. Levine, David J. Albers, and Lena Mamykina. 2019. Personal Health Oracle: Explorations of Personalized Predictions in Diabetes Self-Management. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300600

[34] Daniel DeSalvo and Bruce Buckingham. 2013. Continuous glucose monitoring: current use and future directions. *Current diabetes reports* 13 (2013), 657–662.

[35] L Dowling, EG Wilmot, and P Choudhary. 2020. Do-it-yourself closed-loop systems for people living with type 1 diabetes. *Diabetic Medicine* 37, 12 (2020), 1977–1980.

[36] Liam Drew. 2023. A DIY "Bionic Pancreas" is changing diabetes care - what's next? https://www.nature.com/articles/d41586-023-02648-9

[37] Melissa Eadie and Robert J. Steele. 2017. Non-Invasive Blood Glucose Monitoring and Data Analytics. In *Proceedings of the International Conference on Compute and Data Analysis* (Lakeland, FL, USA) *(ICCDA '17)*. Association for Computing Machinery, New York, NY, USA, 138–142. https://doi.org/10.1145/3093241.3093283

[38] International Diabetes Federation. 2023. https://idf.org/about-diabetes/type-1-diabetes/

[39] Sissi De Flaviis. 2023. Global diabetes cases could soar to 1.3 billion by 2050, New Study says. https://beta.ctvnews.ca/national/health/2023/6/23/1_6454062.amp.html

[40] Sean Follmer, David Carr, Emily Lovell, and Hiroshi Ishii. 2010. CopyCAD: Remixing Physical Objects with Copy and Paste from the Real World. In *Adjunct Proceedings of the 23nd Annual ACM Symposium on User Interface Software and Technology* (New York, New York, USA) *(UIST '10)*. Association for Computing Machinery, New York, NY, USA, 381–382. https://doi.org/10.1145/1866218.1866230

[41] Sean Follmer and Hiroshi Ishii. 2012. KidCAD: Digitally Remixing Toys through Tangible Tools. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI '12)*. Association for Computing Machinery, New York, NY, USA, 2401–2410. https://doi.org/10.1145/2207676.2208403

[42] Centers for Disease Control and Prevention. 2022. https://www.cdc.gov/diabetes/managing/manage-blood-sugar.html

[43] Noreen Frisch, Pat Atherton, Mary M Doyle-Waters, Martha LP MacLeod, Anastasia Mallidou, Vanessa Sheane, John Ward, and Jinelle Woodley. 2020. Patient-oriented research competencies in health (PORCH) for researchers, patients, healthcare providers, and decision-makers: results of a scoping review. *Research involvement and engagement* 6, 1 (2020), 1–14.

[44] Satish K Garg and Halis K Akturk. 2017. The future of continuous glucose monitoring.

[45] F. Gemperle, C. Kasabach, J. Stivoric, M. Bauer, and R. Martin. 1998. Design for wearability. In *Digest of Papers. Second International Symposium on Wearable Computers (Cat. No.98EX215)*. 116–122. https://doi.org/10.1109/ISWC.1998.729537

[46] Amy M. Gill and Blair Nonnecke. 2012. Think Aloud: Effects and Validity. In *Proceedings of the 30th ACM International Conference on Design of Communication* (Seattle, Washington, USA) *(SIGDOC '12)*. Association for Computing Machinery, New York, NY, USA, 31–36. https://doi.org/10.1145/2379057.2379065

[47] Rúben Gouveia and Daniel A. Epstein. 2023. This Watchface Fits with My Tattoos: Investigating Customisation Needs and Preferences in Personal Tracking. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 327, 15 pages. https://doi.org/10.1145/3544548.3580955

[48] Luke Hale, Emma Linley, and Deepak M Kalaskar. 2020. A digital workflow for design and fabrication of bespoke orthoses using 3D scanning and 3D printing, a patient-based case study. *Scientific reports* 10, 1 (2020), 7028.

[49] Bjoern Hartmann. 2005. d. tools: Visually prototyping physical UIs through statecharts. In *Proceedings of UIST 2005*.

[50] Megan Hofmann, Julie Burke, Jon Pearlman, Goeran Fiedler, Andrea Hess, Jon Schull, Scott E Hudson, and Jennifer Mankoff. 2016. Clinical and maker perspectives on the design of assistive technology with rapid prototyping technologies. In *Proceedings of the 18th international ACM SIGACCESS conference on computers and accessibility*. 251–256.

[51] Megan Hofmann, Kristin Williams, Toni Kaplan, Stephanie Valencia, Gabriella Hann, Scott E. Hudson, Jennifer Mankoff, and Patrick Carrington. 2019. "Occupational Therapy is Making": Clinical Rapid Prototyping and Digital Fabrication. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300544

[52] Anna Holubová, Martina Vlasáková, Jan Mužík, and Jan Brož. 2019. Customizing the types of technologies used by patients with type 1 diabetes mellitus for diabetes treatment: Case series on patient experience. *JMIR mHealth and uHealth* 7, 7 (2019), e11527.

[53] Sam James, Miranda Armstrong, Zahraa Abdallah, and Aisling Ann O'Kane. 2023. Chronic Care in a Life Transition: Challenges and Opportunities for Artificial Intelligence to Support Young Adults With Type 1 Diabetes Moving to University. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 559, 16 pages. https://doi.org/10.1145/3544548.3580901

[54] Mads Møller Jensen, Roman Rädle, Clemens N. Klokmose, and Susanne Bodker. 2018. Remediating a Design Tool: Implications of Digitizing Sticky Notes. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173798

[55] Lee Jones, Alaa Nousir, Tom Everrett, and Sara Nabil. 2023. Libraries of Things: Understanding the Challenges of Sharing Tangible Collections and the Opportunities for HCI. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 430, 18 pages. https://doi.org/10.1145/3544548.3581094

[56] Jscad. 2023. JSCAD/openjscad.org: JSCAD is an open source set of modular, browser and command line tools for creating parametric 2D and 3D designs with JavaScript code. it provides a quick, precise and reproducible method for generating 3D models, and is especially useful for 3D printing applications. https://github.com/jscad/OpenJSCAD.org

[57] Shaun K. Kane, Amy Hurst, Erin Buehler, Patrick A. Carrington, and Michele A. Williams. 2014. Collaboratively Designing Assistive Technology. *Interactions* 21, 2 (mar 2014), 78–81. https://doi.org/10.1145/2566462

[58] Dmitri S. Katz, Blaine A. Price, Simon Holland, and Nicholas Sheep Dalton. 2018. Data, Data Everywhere, and Still Too Hard to Link: Insights from User Interactions with Diabetes Apps. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174077

[59] Xiao Ying Khor, Joseph M Pappachan, and Mohammad Sadiq Jeeyavudeen. 2023. Individualized diabetes care: Lessons from the real-world experience. *World Journal of Clinical Cases* 11, 13 (2023), 2890.

[60] Jarrod Knibbe, Tovi Grossman, and George Fitzmaurice. 2015. Smart Makerspace: An Immersive Instructional Space for Physical Tasks. In *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces* (Madeira, Portugal) *(ITS '15)*. Association for Computing Machinery, New York, NY, USA, 83–92. https://doi.org/10.1145/2817721.2817741

[61] Stacey Kuznetsov and Eric Paulos. 2010. Rise of the Expert Amateur: DIY Projects, Communities, and Cultures. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* (Reykjavik, Iceland) *(NordiCHI '10)*. Association for Computing Machinery, New York, NY, USA, 295–304. https://doi.org/10.1145/1868914.1868950

[62] Matthew Lakier, Michelle Annett, and Daniel Wigdor. 2018. Automatics: Dynamically Generating Fabrication Tasks to Adapt to Varying Contexts.

ACM Trans. Comput.-Hum. Interact. 25, 4, Article 22 (aug 2018), 44 pages. https://doi.org/10.1145/3185065

[63] Udaya Lakshmi, Megan Hofmann, Stephanie Valencia, Lauren Wilcox, Jennifer Mankoff, and Rosa I. Arriaga. 2019. "Point-of-Care Manufacturing": Maker Perspectives on Digital Fabrication in Medical Practice. *Proc. ACM Hum.-Comput. Interact.* 3, CSCW, Article 91 (nov 2019), 23 pages. https://doi.org/10.1145/3359193

[64] David Ledo, Fraser Anderson, Ryan Schmidt, Lora Oehlberg, Saul Greenberg, and Tovi Grossman. 2017. Pineal: Bringing Passive Objects to Life with Embedded Mobile Devices. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 2583–2593. https://doi.org/10.1145/3025453.3025652

[65] David Ledo, Steven Houben, Jo Vermeulen, Nicolai Marquardt, Lora Oehlberg, and Saul Greenberg. 2018. Evaluation Strategies for HCI Toolkit Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–17. https://doi.org/10.1145/3173574.3173610

[66] David Ledo, Jo Vermeulen, Sheelagh Carpendale, Saul Greenberg, Lora Oehlberg, and Sebastian Boring. 2019. Astral: Prototyping Mobile and Smart Object Interactive Behaviours Using Familiar Applications. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 711–724.

[67] Howard Look. 2023. https://www.tidepool.org/blog/tidepool-loop-has-received-fda-clearance

[68] Emily Lovell and Leah Buechley. 2011. LilyPond: An Online Community for Sharing e-Textile Projects. In *Proceedings of the 8th ACM Conference on Creativity and Cognition* (Atlanta, Georgia, USA) *(C&C '11)*. Association for Computing Machinery, New York, NY, USA, 365–366. https://doi.org/10.1145/2069618.2069698

[69] Stephanie Ludi. 2007. Introducing Accessibility Requirements through External Stakeholder Utilization in an Undergraduate Requirements Engineering Course. In *Proceedings of the 29th International Conference on Software Engineering (ICSE '07)*. IEEE Computer Society, USA, 736–743. https://doi.org/10.1109/ICSE.2007.46

[70] Mon Arjay Malbog and Noel Linsangan. 2018. Non-Invasive Glucose Meter for Android-Based Devices. In *Proceedings of the 2018 10th International Conference on Computer and Automation Engineering* (Brisbane, Australia) *(ICCAE 2018)*. Association for Computing Machinery, New York, NY, USA, 161–165. https://doi.org/10.1145/3192975.3192979

[71] Lena Mamykina, Elizabeth M. Heitkemper, Arlene M. Smaldone, Rita Kukafka, Heather J. Cole-Lewis, Patricia G. Davidson, Elizabeth D. Mynatt, Andrea Cassells, Jonathan N. Tobin, and George Hripcsak. 2017. Personal Discovery in Diabetes Self-Management. *J. of Biomedical Informatics* 76, C (dec 2017), 1–8. https://doi.org/10.1016/j.jbi.2017.09.013

[72] Gillian M. McCarthy, Edgar R. Rodriguez Ramírez, and Brian J. Robinson. 2017. Participatory Design to Address Stigma with Adolescents with Type 1 Diabetes. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (Edinburgh, United Kingdom) *(DIS '17)*. Association for Computing Machinery, New York, NY, USA, 83–94. https://doi.org/10.1145/3064663.3064740

[73] Samantha McDonald, Niara Comrie, Erin Buehler, Nicholas Carter, Braxton Dubin, Karen Gordes, Sandy McCombe-Waller, and Amy Hurst. 2016. Uncovering Challenges and Opportunities for 3D Printing Assistive Technology with Physical Therapists. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility* (Reno, Nevada, USA) *(ASSETS '16)*. Association for Computing Machinery, New York, NY, USA, 131–139. https://doi.org/10.1145/2982142.2982162

[74] LH Messer, R Johnson, KA Driscoll, and J Jones. 2018. Best friend or spy: a qualitative meta-synthesis on the impact of continuous glucose monitoring on life with type 1 diabetes. *Diabetic Medicine* 35, 4 (2018), 409–418.

[75] L Kurt Midyett. 2023. One Size Fits All Versus Individualized Medicine in Type 1 Diabetes Management. *Diabetes Technology & Therapeutics* 25, S3 (2023), S–42.

[76] Betsy Phillips M.S. and Hongxin Zhao Ph.D. 1993. Predictors of Assistive Technology Abandonment. *Assistive Technology* 5, 1 (1993), 36–45. https://doi.org/10.1080/10400435.1993.10132205 arXiv:https://doi.org/10.1080/10400435.1993.10132205 PMID: 10171664.

[77] Hyunjoo Oh, Tung D. Ta, Ryo Suzuki, Mark D. Gross, Yoshihiro Kawahara, and Lining Yao. 2018. PEP (3D Printed Electronic Papercrafts): An Integrated Approach for 3D Sculpting Paper-Based Electronic Devices. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174015

[78] Aisling Ann O'Kane, Amy Hurst, Gerrit Niezen, Nicolai Marquardt, Jon Bird, and Gregory Abowd. 2016. Advances in DIY Health and Wellbeing. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI EA '16)*. Association for Computing Machinery, New York, NY, USA, 3453–3460. https://doi.org/10.1145/2851581.2856467

[79] Johanna Okerlund and David Wilson. 2019. DIY Assistive Technology for Others: Considering Social Impacts and Opportunities to Leverage HCI Techniques. In *Proceedings of FabLearn 2019* (New York, NY, USA) *(FL2019)*. Association for Computing Machinery, New York, NY, USA, 152–155. https://doi.org/10.1145/3311890.3311914

[80] Tom Owen, George Buchanan, and Harold Thimbleby. 2012. Understanding user requirements in take-home diabetes management technologies. In *The 26th BCS Conference on Human Computer Interaction 26*. 268–273.

[81] Sharoda A. Paul and Madhu C. Reddy. 2010. Understanding Together: Sensemaking in Collaborative Information Seeking. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work* (Savannah, Georgia, USA) *(CSCW '10)*. Association for Computing Machinery, New York, NY, USA, 321–330. https://doi.org/10.1145/1718918.1718976

[82] Belinda Paulovich. 2015. Design to Improve the Health Education Experience: using participatory design methods in hospitals with clinicians and patients. *Visible Language* 49, 1-2 (2015).

[83] Matthew Peveler, Jeramey Tyler, Dacoda B. Nelson, Renato Cerqueira, and Hui Su. 2020. Browser Based Digital Sticky Notes for Design Thinking. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 349–352. https://doi.org/10.1145/3393914.3395824

[84] Isabelle ; T Vaillancourt Vanessa ; Débarges Béatrice ; Poirier Annie ; Prévost Karina ; Spence Claude Poitras, Marie-Eve ; Godbout. 2020. Step-by-step Strategies for an Integrated Patient-Oriented Research: Lessons Learned from a Multicentered Study. *Science of Nursing and Health Practices / Science infirmière et pratiques en santé* 3, 2 (2020), 1–9. https://doi.org/10.31770/2561-7516.1068

[85] William H Polonsky and Danielle Hessler. 2013. What are the quality of life-related benefits and losses associated with real-time continuous glucose monitoring? A survey of current users. *Diabetes technology & therapeutics* 15, 4 (2013), 295–301.

[86] Christian Quintero. 2022. A review: accessible technology through participatory design. *Disability and Rehabilitation: Assistive Technology* 17, 4 (2022), 369–375.

[87] Shriti Raj, Kelsey Toporski, Ashley Garrity, Joyce M. Lee, and Mark W. Newman. 2019. "My Blood Sugar is Higher on the Weekends": Finding a Role for Context and Context-Awareness in the Design of Health Self-Management Technology. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300349

[88] Raf Ramakers, Fraser Anderson, Tovi Grossman, and George Fitzmaurice. 2016. RetroFab: A Design Tool for Retrofitting Physical Interfaces Using Actuators, Sensors and 3D Printing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 409–419. https://doi.org/10.1145/2858036.2858485

[89] Judy Rashotte, Kelley Tousignant, Christine Richardson, Frances Fothergill-Bourbonnais, Meranda M Nakhla, Patricia Olivier, and Margaret L Lawson. 2014. Living with sensor-augmented pump therapy in type 1 diabetes: adolescents' and parents' search for harmony. *Canadian journal of diabetes* 38, 4 (2014), 256–262.

[90] Jordyn Reich and Lucy E. Dunne. 2016. Multi-Modal Wearable Ambient Display: An Investigation of Continuous Glucose Monitoring. In *Proceedings of the 2016 ACM International Symposium on Wearable Computers* (Heidelberg, Germany) *(ISWC '16)*. Association for Computing Machinery, New York, NY, USA, 24–27. https://doi.org/10.1145/2971763.2971801

[91] UCI Machine Learning Repository. 2023. https://archive.ics.uci.edu/dataset/34/diabetes

[92] Jan Rod, Chunxiao Li, Dongliang Zhang, and Hyowon Lee. 2016. Designing a 3D Modelling Tool for Novice Users. In *Proceedings of the 28th Australian Conference on Computer-Human Interaction* (Launceston, Tasmania, Australia) *(OzCHI '16)*. Association for Computing Machinery, New York, NY, USA, 140–144. https://doi.org/10.1145/3010915.3010957

[93] José A Sacristán. 2013. Patient-centered medicine and patient-oriented research: improving health outcomes for individual patients. *BMC medical informatics and decision making* 13, 1 (2013), 1–8.

[94] Elizabeth B-N Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *Co-design* 4, 1 (2008), 5–18.

[95] M Ferri Sanz, B Vallina Acha, and M Ferrando García. 2021. Co-design for people-centred care digital solutions: a literature review. *International Journal of Integrated Care* 21, 2 (2021).

[96] Valkyrie Savage, Sean Follmer, Jingyi Li, and Björn Hartmann. 2015. Makers' Marks: Physical Markup for Designing and Fabricating Functional Objects. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (Charlotte, NC, USA) *(UIST '15)*. Association for Computing Machinery, New York, NY, USA, 103–108. https://doi.org/10.1145/2807442.2807508

[97] Valkyrie Savage, Sarah Homewood, and Irina Shklovski. 2023. Objectify: Better Living Through Anticipatory, Just-for-You 3D Printing!. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 418, 8 pages. https://doi.org/10.1145/3544549.3582748

[98] Marcia J Scherer. 1996. Outcomes of assistive technology use on quality of life. *Disability and rehabilitation* 18, 9 (1996), 439–448.

[99] Eldon Schoop, Michelle Nguyen, Daniel Lim, Valkyrie Savage, Sean Follmer, and Björn Hartmann. 2016. Drill Sergeant: Supporting Physical Construction Projects through an Ecosystem of Augmented Tools. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI EA '16)*. Association for Computing Machinery, New York, NY, USA, 1607–1614. https://doi.org/10.1145/2851581.2892429

[100] Kristen Shinohara and Jacob O. Wobbrock. 2016. Self-Conscious or Self-Confident? A Diary Study Conceptualizing the Social Accessibility of Assistive Technology. *ACM Trans. Access. Comput.* 8, 2, Article 5 (jan 2016), 31 pages. https://doi.org/10.1145/2827857

[101] Karin Slegers, Kristel Kouwenberg, Tereza Loučova, and Ramon Daniels. 2020. Makers in Healthcare: The Role of Occupational Therapists in the Design of DIY Assistive Technology. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3313831.3376685

[102] Jessi Stark, Fraser Anderson, George Fitzmaurice, and Sowmya Somanath. 2020. MakeAware: Designing to Support Situation Awareness in Makerspaces. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1005–1016. https://doi.org/10.1145/3357236.3395472

[103] Wiktoria Staszak, Jonas Chromik, Katarina Braune, and Bert Arnrich. 2021. Impact of Custom Features of Do-it-yourself Artificial Pancreas Systems (DIYAPS) on Glycemic Outcomes of People with Type 1 Diabetes. In *2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*. 1472–1475. https://doi.org/10.1109/EMBC46164.2021.9629487

[104] Cristiano Storni. 2014. Design Challenges for Ubiquitous and Personal Computing in Chronic Disease Care and Patient Empowerment: A Case Study Rethinking Diabetes Self-Monitoring. *Personal Ubiquitous Comput.* 18, 5 (jun 2014), 1277–1290. https://doi.org/10.1007/s00779-013-0707-6

[105] Jennifer Sumner, Lin Siew Chong, Anjali Bundele, and Yee Wei Lim. 2021. Co-designing technology for aging in place: A systematic review. *The Gerontologist* 61, 7 (2021), e395–e409.

[106] M Tansey, L Laffel, J Cheng, R Beck, J Coffey, E Huang, C Kollman, J Lawrence, J Lee, K Ruedy, et al. 2011. Satisfaction with continuous glucose monitoring in adults and youths with type 1 diabetes. *Diabetic Medicine* 28, 9 (2011), 1118–1122.

[107] Rune Thorsen, Denise Cugnod, Marina Ramella, Rosa Maria Converti, and Maurizio Ferrarin. 2023. From patient to maker - a workflow including people with cerebral palsy in co-creating assistive devices using 3D printing technologies. *Disability and Rehabilitation: Assistive Technology* 0, 0 (2023), 1–11. https://doi.org/10.1080/17483107.2023.2177754 arXiv:https://doi.org/10.1080/17483107.2023.2177754 PMID: 36880457.

[108] Tiffany Tseng and Yoshihiro Kawahara. 2021. Circuit Assemblies: Electronic Modules for Interactive 3D-Prints. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference* (Virtual Event, USA) *(DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1115–1128. https://doi.org/10.1145/3461778.3462024

[109] C Lee Ventola. 2014. Medical applications for 3D printing: current and projected uses. *Pharmacy and Therapeutics* 39, 10 (2014), 704.

[110] Mary Webster, Emma Foster, Rob Comber, Simon Bowen, Tim Cheetham, and Madeline Balaam. 2015. Understanding the Lived Experience of Adolescents with Type 1 Diabetes: Opportunities for Design. In *Proceedings of the 14th International Conference on Interaction Design and Children* (Boston, Massachusetts) *(IDC '15)*. Association for Computing Machinery, New York, NY, USA, 140–149. https://doi.org/10.1145/2771839.2771854

[111] Christian Weichel, Manfred Lau, David Kim, Nicolas Villar, and Hans W. Gellersen. 2014. MixFab: A Mixed-Reality Environment for Personal Fabrication. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 3855–3864. https://doi.org/10.1145/2556288.2557090

[112] Anusha Withana. 2023. Co-Designing Personalized Assistive Devices Using Personal Fabrication. *Commun. ACM* 66, 7 (jun 2023), 89–90. https://doi.org/10.1145/3589150

[113] Tim Wysocki, Fiona Hirschfeld, Louis Miller, Neil Izenberg, Steven A Dowshen, Alex Taylor, Amy Milkes, Michelle T Shinseki, Carolina Bejarano, Chelsea Kozikowski, et al. 2016. Consideration of insulin pumps or continuous glucose monitors by adolescents with type 1 diabetes and their parents: stakeholder engagement in the design of web-based decision aids. *The Diabetes educator* 42, 4 (2016), 395–407.

[114] Yihan Yu and David W. McDonald. 2023. Conflicts of Control: Continuous Blood Glucose Monitoring and Coordinated Caregiving for Teenagers with Type 1 Diabetes. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW2, Article 306 (oct 2023), 32 pages. https://doi.org/10.1145/3610097

[115] W Patrick Zeller, Rachel DeGraff, and William Zeller. 2020. Customized treatment for Type 1 diabetes patients using novel software. *Journal of Clinical and Translational Endocrinology: Case Reports* 16 (2020), 100057.

[116] Li Zhu. 2011. Cultivating Collaborative Design: Design for Evolution. In *Proceedings of the Second Conference on Creativity and Innovation in Design* (Eindhoven, Netherlands) *(DESIRE '11)*. Association for Computing Machinery, New York, NY, USA, 255–266. https://doi.org/10.1145/2079216.2079253