Journal of Clinical & Translational Endocrinology 37 (2024) 100364

Contents lists available at ScienceDirect

Journal of Clinical & Translational Endocrinology

journal homepage: www.elsevier.com/locate/jcte

Employing user-centered design and education sciences to inform training of diabetes survival skills

Grace Prince [a,*], Daniel Rees Lewis [b], Teresa Pollack [c], Susan Karam [d], Emilie Touma [e], Rebeca Khorzad [f], Stacy Cooper Bailey [c], David Gatchell [b], Bruce Ankenman [b], Jelena Kravarusic [c], Terri Sabol [g], Jane Holl [h], Amisha Wallia [c]

[a] *Virginia Commonwealth University, Richmond, VA, USA*
[b] *Northwestern University, Evanston, IL, USA*
[c] *Northwestern Feinberg School of Medicine, Chicago, IL, USA*
[d] *Ochsner Medical Center, New Orleans, LA, USA*
[e] *University of Kentucky School of Medicine, Lexington, KY, USA*
[f] *Arvin LLC, Lake Forest, IL, USA*
[g] *Northwestern School of Education and Social Policy, Chicago, IL, USA*
[h] *University of Chicago Biological Science Division, Chicago, IL, USA*

ARTICLE INFO

Keywords:
Diabetes
Diabetes survival skills
Patient education
Learning sciences
User-centered design
Remote delivery
Telemedicine

ABSTRACT

Background: Patients newly diagnosed with diabetes mellitus (diabetes), who require insulin must acquire diabetes "survival" skills prior to discharge home. COVID-19 revealed considerable limitations of traditional in-person, time-intensive delivery of diabetes education and survival skills training (diabetes survival skills training). Furthermore, diabetes survival skills training has not been designed to meet the specific learning needs of patients with diabetes and their caregivers, particularly if delivered by telehealth. The objective of the study was to identify and understand the needs of users (patients newly prescribed insulin and their caregivers) to inform the design of a diabetes survival skills training, specifically for telehealth delivery, through the application of user-centered design and adult learning and education principles.

Methods: Users included patients newly prescribed insulin, their caregivers, and laypersons without diabetes. In semi-structured interviews, users were asked about experienced or perceived challenges in learning diabetes survival skills. Interviews were audio-recorded and transcribed. Investigators performed iterative rounds of coding of interview transcripts utilizing a constant comparative method to identify themes describing the dominant challenges users experienced. Themes were then mapped to adult learning and education principles to identify novel educational design solutions that can be applied to telehealth-based learning.

Results: We interviewed 18 users: patients (N = 6, 33 %), caregivers (N = 4, 22 %), and laypersons (N = 8, 44 %). Users consistently described challenges in understanding diabetes survival skills while hospitalized; in preparing needed supplies to execute diabetes survival skills; and in executing diabetes survival skills at home. The challenges mapped to three educational strategies: (1) spiral learning; (2) repetitive goal directed practice and feedback, which have the potential to translate into design solutions supporting remote/virtual learning; and (3) form fits function organizer, which supports safe organization and use of supplies to execute diabetes survival skills independently.

Conclusion: Learning complex tasks, such as diabetes survival skills, requires time, repetition, and continued support. The combination of a user-centered design approach to uncover learning needs as well as identification of relevant adult learning and education principles could inform the design of more user-centered, feasible, effective, and sustainable diabetes survival skills training for telehealth delivery.

* Corresponding author.
E-mail address: grace.prince@vcuhealth.org (G. Prince).

https://doi.org/10.1016/j.jcte.2024.100364
Received 14 May 2024; Received in revised form 12 July 2024; Accepted 5 August 2024
Available online 6 August 2024

Introduction

With the increasing prevalence of diabetes mellitus (diabetes) in the United States [1], efforts have accelerated to develop practical and effective inpatient diabetes education, collectively referred to as diabetes self-management education and support (DSME) [2]. However, the patient discharge transition from the inpatient setting to home is particularly challenging because of short inpatient stays, chronic comorbidities, and the need for rapid acquisition of complex skills and execution of cognitive tasks to perform diabetes self-management. Many of these patients are considered high-risk, as many are older adults or have additional chronic health morbidities [3]. Indeed, patients with diabetes have high rates of 30-day readmission compared to patients without diabetes [2].

When delivered, in person, by a Certified Diabetes Care and Education Specialist (CDCES), DSME improves glycemic outcomes (e.g., reduced HbA1c), and reduces hospital readmission rates [2,4]. However, only 5–10 % of eligible patients currently receive DSME, in part due to limited availability of CDCES, now additionally exacerbated by the nursing shortage [5]. There has been a growing call to refocus and improve the delivery of DSME in a more patient-centered manner, particularly with regard to the acquisition of diabetes survival skills which include glucose monitoring, insulin dose calculation, and insulin administration [2].

The COVID-19 pandemic revealed many existing but unrecognized challenges in diabetes survival skills training and education (heretofore diabetes survival skills training). The pandemic quickly limited face-to-face clinical care encounters and, with many CDCES reassigned to other types of care delivery, most patient survival skills training sessions transitioned to remote or "telehealth" delivery [6]. However, diabetes survival skills training, already time intensive, proved difficult to deliver remotely with limited staff [6]. As patients with diabetes are an at-risk population [7,8], the need for an education delivery process that promotes safe and effective learning of diabetes survival skills remains critical [9,10]. Furthermore, the American Diabetes Association (ADA) proposed a focus on learning diabetes survival skills to promote safe and effective management in the immediate post-discharge period [2,11]. Successful execution of survival skills including their cognitive tasks represents the most immediate and fundamental need during the discharge transition from the inpatient setting to home [2,12]. However, to design an effective "survival skills" training model that can be delivered by telehealth, engagement of the "users" (diabetes patients and their caregivers), is necessary to assess their learning needs and effectively apply adult learning and education principles to model design.

Prior research has shown that current tools (e.g., patient education materials) frequently do not meet user needs, especially for those with chronic illness [13], with the development of most tools relying heavily on expert consensus rather than user input [14]. Such initiatives are especially vulnerable to expert blindspots, whereby experts may not anticipate all learning barriers and potential errors that novice users frequently encounter or commit [15]. The concept of expert blindspot is particularly problematic when designing task-based learning materials, such as a survival skills training, as expert knowledge can be tacit with unrecognized patient challenges [15,16]. Gathering information about the contexts, cognitive barriers, and needs of patient users with diabetes, particularly those who are newly prescribed insulin, could result in a substantially more patient-centered and sustainable [17] design of diabetes survival skills training.

User-centered design

UCD is a multidisciplinary, iterative design approach that engages users to identify the context, requirements, and needs for successful use of products and processes. It is widely used to improve usability in engineering, technology, and education sciences, including adult learning and education sciences [18–20]. UCD has been especially vital in the design and development of remote delivery systems, including mobile-applications and websites [18], and more nominally in healthcare, primarily in the design of electronic medical records and medical devices [17,21]. Healthcare solutions rooted in UCD increase patient engagement, lower user burden, and allow for greater self-sufficiency [21]. In diabetes, understanding patient critical needs, particularly at high-risk transitions of care (e.g., inpatient discharge to home), is lacking and the application of UCD, as well as learning science principles, is underused and innovative [17,22].

Adult learning and education principles

The science of adult learning and education draws from cognitive psychology, neuroscience, information processing theory, developmental psychology and education sciences, and can be referred to as "learning sciences" [23]. The application of these principles and theories to overcome user needs and challenges, which can be identified through UCD, are essential to enhance the learning and skills acquisition process, particularly for remote learning.

The aim of this project was to identify critical user-reported needs, barriers, and challenges to learning and acquiring diabetes survival skills at discharge from the hospital. We then mapped the needs to adult learning and education principles to inform the future design of a diabetes survival skills training that can be delivered by telehealth. We propose specific solutions to create a user-centered, feasible, effective, and sustainable diabetes survival skills training.

Methods

Study participants

Hospitalized patients newly diagnosed with diabetes and newly prescribed insulin as well as their caregivers were recruited at Northwestern Memorial Hospital in Chicago, IL. To further understand the needs of individuals completely new to diabetes, laypersons without a diagnosis of diabetes and unfamiliar with diabetes or diabetes self-care were also recruited. The Northwestern University Institutional Review Board (IRB) approved all study procedures and an IRB-approved consent form was used. Special attention was paid to ensure recruitment of diverse participants to achieve a wide range of perspectives and assure greater credibility through informant triangulation [24].

Data collection

For patients and their caregivers, interviews were conducted shortly after discharge from the inpatient unit to home to aid their recall of initial experiences and challenges with diabetes survival skills [25]. All patients and caregivers received inpatient diabetes survival skills training by a CDCES or nursing staff. They were asked to reflect retrospectively on their experiences and needs during the critical transition period after discharge home. Laypersons, without any prior diabetes experience, were presented with a scenario of a patient newly diagnosed with diabetes and newly prescribed insulin who was receiving diabetes education and training that included an introduction to needed diabetes supplies. They were then asked to reflect and comment on the diabetes education and training process.

Each interview lasted approximately 60–90 min and was audio-recorded. Interviews were conducted by facilitators with direct diabetes clinical care experience and familiarity with needed diabetes survival skills. The facilitator(s) began each interview by emphasizing that there were no "correct" answers to questions and encouraged participants to be open and honest in their responses [24]. A standardized interview guide with open-ended questions about users' experiences with diabetes (either first-hand or theoretical) immediately after diagnosis was used. Facilitators solicited user feedback about the diabetes

education and training process. To further help participants reflect on the diabetes survival skills learning process, facilitators asked questions about participants' perceived preparedness in providing diabetes self-care following diabetes education and training. Whenever appropriate, facilitators asked probing questions to clarify or further explore participant responses [24].

Data analysis

The sessions were professionally transcribed with all identifying information removed. MAXQDA software was used to store and code the transcripts. Three team members independently performed iterative rounds of inductive coding of the transcripts using a constant comparative method [26] to identify codes describing user needs. Dominant codes were revised, merged, and ultimately categorized into themes. Throughout the coding process, investigators returned to the original transcripts to assure coding fidelity of participant responses. As codes were revised, merged, and categorized, investigators held frequent debriefing sessions to review the codes and reach consensus, aiding in the reduction of individual investigator bias [24]. After collectively identifying dominant themes, top themes were mapped to relevant adult learning and education principles.

Results

Twelve interviews with a total of 18 participants, including patients (N = 6, 33 %), their caregivers (N = 4, 22 %), and laypersons (N = 8, 44 %) were conducted. Six participants (33 %) were over age 65. Participants self-identified as Black, non-Hispanic (N = 3, 17 %), Asian, non-Hispanic (N = 3, 17 %), Hispanic/Latino (N = 2, 11 %), and White, Non-Hispanic (N = 10, 55 %).

Eleven dominant codes composed of representative patient, caregiver, and layperson responses were identified. Codes were categorized into three major themes, each representing overarching challenges faced by users in learning and executing diabetes survival skills. Representative codes and themes are outlined in Table 1. Key themes include: **(1)** challenges in **understanding** diabetes survival skills while hospitalized; **(2)** challenges in **preparing needed supplies** (e.g., medication, equipment) to execute diabetes survival skills; and **(3)** challenges **in executing** diabetes survival skills at home.

Theme 1: Challenges in understanding diabetes survival skills while hospitalized

Many users reflected on the difficulty of both prioritizing and learning complex new skills during the stressful time of hospitalization. Specific challenges included being overwhelmed with information during hospitalization with users reporting difficulty in learning the large volume of new information and knowledge necessary to successfully execute the complex tasks of diabetes survival skills during the limited time of inpatient admission.

Users also described "*feeling overwhelmed by the simultaneous onset of a new acute illness, diabetes, and needing to learn diabetes survival skills.*" Users confirmed that they experienced significant distress while hospitalized [27] and acknowledged that their engagement in learning was likely limited by this distress. Users reported challenges with learning both details and broad concepts of diabetes self-care. They reported "*feeling worried about diabetes survival skills,*" specifically challenges in troubleshooting episodes of hyperglycemia and hypoglycemia. Yet, they reported difficulty in grasping how learning certain skills translated into preparedness for diabetes self-care, reflected by "*not understanding the importance of diabetes self-care.*" Users confirmed that they did not understand the value of learning diabetes survival skills and that their motivation for learning was limited [15]. More broadly, users highlighted a "[lack of] *understanding the entire process of diabetes self-care*" and feeling burdened by the detailed steps of current diabetes survival

Table 1
User-reported challenges in learning diabetes survival skills.

User responses	Codes	Themes
Patient: "They described what time of day you're supposed to take this medication or what time of day you're supposed to take this medication. It was like oh my gosh, you know running me. Yeah, overwhelming."	Being overwhelmed with information during hospitalization	Challenges in understanding diabetes survival skills while hospitalized
Patient: "I think for the patient it's kind of hard because you're not really focused…when you are in so much pain and under so much medication. I mean you don't care about seeing nothing really or talking to nobody, I mean that's the feeling I had, like don't talk to me."	Feeling overwhelmed by acute illness	
Caregiver: "An overview might be a good thing before you're released… but just a small snippet. Not overkill."	Not understanding overview of DM self-care	
Caregiver: [It would be helpful if users could] "have the knowledge of what to watch for," [for example, by telling users], "here's some things that may or may not happen."	Feeling worried about DM self-management	
Patient: "Why do you need to know about a meter, in my mind you'd have to say, 'well, you know, this is a way we, we monitor the blood sugar…' because, 'this is a blood sugar meter,' doesn't mean anything to me."	Not understanding the importance of DM self-care	
Layperson: "It was confusing to me. I mean everything here I have [glucometer, lancet, test strips, insulin pen/needles, insulin vial/syringe]…what do I need? What do I need that stuff for?"	Organizing the volume of items for self-care	Challenges in preparing needed supplies (e.g. medication, equipment) to execute diabetes survival skills
Patient: "Some medication might look alike…that's where you can get going off because some medication [referring to insulin] almost have the same color. You got to be very particular how to use this medication otherwise you gonna end up making mistakes."	Being confused by different types of insulin	
Caregiver: "Trying to get everything together to say to give and then track and all that stuff and then when you talk to the doctor everything is there."	Tracking glucose levels	Challenges in executing diabetes survival skills at home
Patient: "There are times where you know how to remove the cap [of the	Remembering self-care steps	

(*continued on next page*)

Table 1 (*continued*)

User responses	Codes	Themes
insulin pen] but you forgot something like…perform a safety check or something like that."		
Caregiver: "If I'm in the middle of giving her a shot or I'm getting ready to and I'm like oh, my gosh, I don't remember how much am I supposed to give her…for me it was the dose, going from what her blood sugar is to what I need to give. It was the dose I needed to give, the correction…because you don't want to overdo, you don't want to under… that's where you're stressing out the most, it's like oh, my gosh, if I overdo it, then we're going to have even more problems and she was having problems already with other issues."	Feeling uncomfortable dosing insulin	
Patient: "I didn't want to shoot myself with this [insulin]."	Feeling fearful about injecting	

skills education and training without yet having a sufficient view of the entire process.

Theme 2: Challenges in preparing supplies for self-care

Users frequently commented on challenges associated with preparing the supplies required to execute diabetes survival skills (Table 1). For example, users experienced difficulty "*organizing the volume of supplies,"* such as pre-filled insulin pens or insulin vials and syringes, and described feeling stressed about getting all supplies ready for timely use. Users also experienced "*being confused by different types of insulin"* which left users susceptible to making mistakes with insulin administration, a major safety concern.

Theme 3: Challenges in administering self-care at home

Finally, users noted difficulty in carrying out routine diabetes survival skills consistently after discharge home (Table 1). They reported challenges in "*tracking glucose levels,"* with users describing "logging" their glucose levels for review by their clinician to receive advice about their insulin dose as difficult and burdensome. They also struggled to "*remember self-care steps,"* having difficulty independently recalling each step of the diabetes survival skills process, including the critical "safety check" (eliminating air from the pen) performed prior to injecting insulin. In complex tasks that require multiple steps, failure to remember each step can disrupt successful self-care delivery.[15].

After discharge, users noted "*feeling uncomfortable dosing insulin,*" describing stress surrounding insulin dosing with fear of both under- or over-dosing their insulin. One user identified insulin dosing as the most stressful aspect of diabetes self-care (Table 1).

Users voiced "*feeling fearful about injecting*" insulin. Discomfort with needles and, therefore, discomfort with insulin injections, was cited as a major barrier and limitation of users in executing diabetes survival skills after discharge.

Mapping user-centered needs: using adult learning and education principles

Dominant codes and major themes developed from the user data were reviewed and mapped to appropriate adult learning and education principles. Strategies rooted in these principles were then identified as potential solutions for the redesign of diabetes survival skills training. Fig. 1 shows the primary and secondary learning and education principles that best suit the learning challenges described by users. Current practical applications of these principles outside of healthcare and potential future applications to a diabetes survival skills training are described in Table 2. Three identified adult learning and education sciences strategies are described below.

Spiral learning

Some user needs, barriers, and challenges can be overcome by applying the adult learning and education principles of spiral learning. Spiral learning provides learners, as the first step, with a simplified overview of all tasks that will need to be acquired or learned. Learners then repeatedly revisit each task and its underlying concepts with increasing complexity [28]. For example, patients new to diabetes might first be introduced to an overview of all self-care or survival skill steps (e.g., measuring blood glucose levels, injecting insulin) and foundational diabetes concepts (e.g., dangers of hypoglycemia/hyperglycemia) before being introduced to the details of how to execute each step (e.g., how to load, use, clean, and unload a lancing device, how to calculate the correct insulin dose).

Specific features of spiral learning, applied to curriculum design, are outlined in Table 2. In general, curricula rooted in spiral learning engage learners without overwhelming them with specific details, while also providing new and more complex learning at a rate that parallels learner comprehension [28]. Over time, learners can achieve mastery of each task as well as a deeper understanding of associated knowledge and concepts that can be applied to problem solving [28]. As described in Table 2, spiral learning can be applied to the design of a diabetes survival skills training in a multitude of ways, including digital and telehealth solutions. For example, application of a spiral learning approach to website design about diabetes survival skills would first introduce learners to an overview of the diabetes survival skills and then provide users with options to explore the details related to each increasingly complex task [29,30].

Using a form fits function organizer

Adult learning and education theory suggests that user-reported challenges associated with identifying and preparing self-care supplies can be overcome by designing a form fits function organizer, a visual or physical scheme to organize or group supplies according to their function within a task [15,31]. As detailed in Table 2, a form fits function organizer is a specific form of scaffolding [15,23,31], supporting task performance by offloading non-essential and burdensome components of a task in order to assist learners with completing the task itself, thereby reducing cognitive load [31]. Design strategies that employ a form fits function organizer to support users who need to prepare their supplies for diabetes self-care could be, for example, a physical box to group and organize diabetes medications and supplies according to task (Table 2). A similar concept is illustrated in the use of procedural trays by medical professionals (central line kits, for example). Cognitive load theory suggests that when users must dedicate time and effort to organizing supplies for a task, it becomes more burdensome to then focus on the critical aspects of a task [31–33], such as differentiating between insulin types. Therefore, incorporation of a form fits function organizer like those used in other procedure-based tasks could offload this cognitive burden and prevent medication errors.

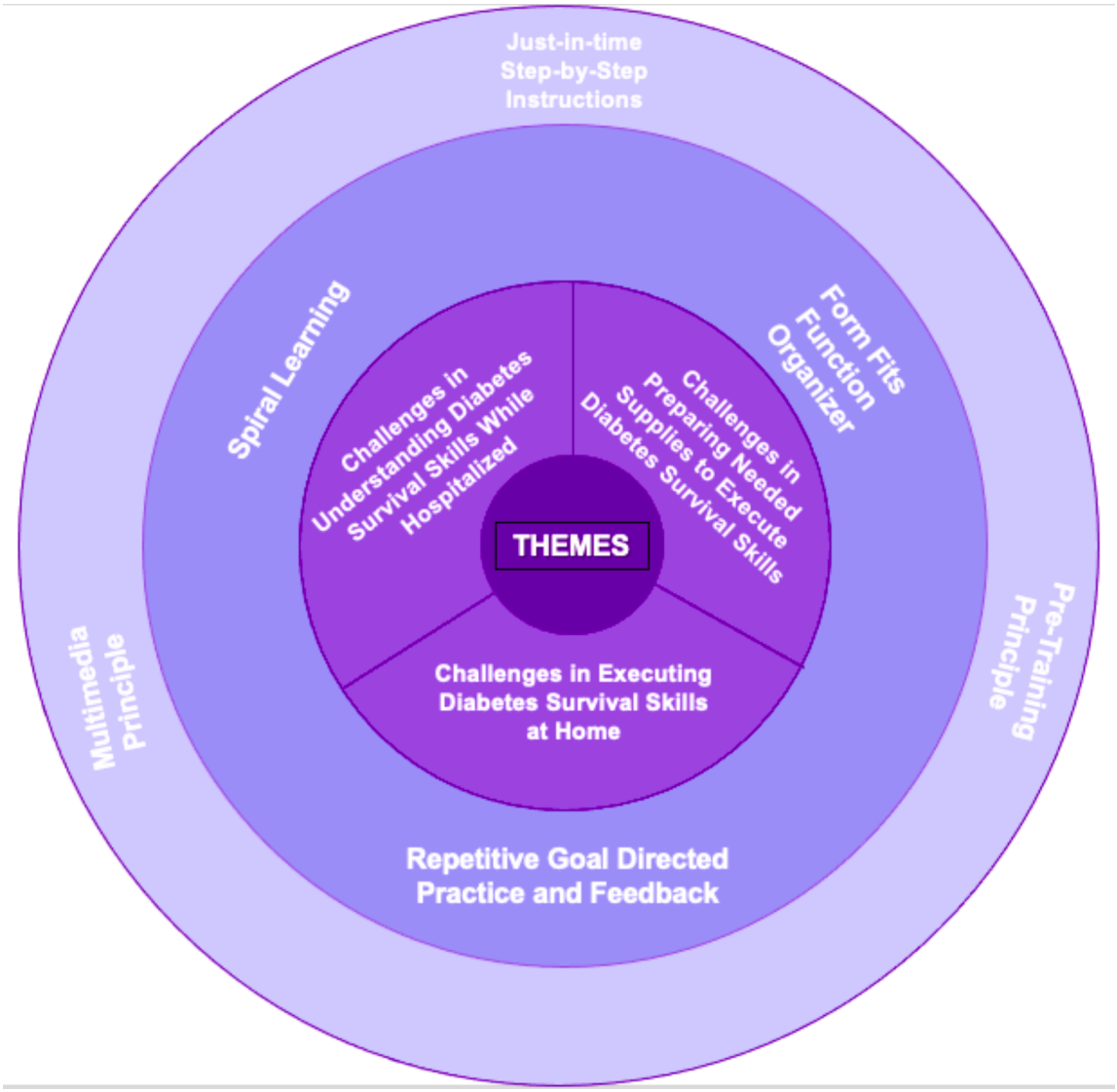

Fig. 1. Mapping of User-reported Challenges in Assuming Immediate Diabetes Survival Skills to Associated Adult Learning and Education Principles. Three themes representing dominant user-reported challenges in learning diabetes survival skills are shown in the center of the figure. Themes mapped to adult learning and education principles, represented in the surrounding circles. These principles provided theoretical support for innovative solutions to overcome the identified user-reported learning challenges. Themes mapped strongly to spiral learning [28], a form fits function organizer [15], and repetitive goal directed practice and feedback [48,34]. Additional adult learning and education principles were identified to provide further theoretical support to inform strategic educational redesign, including the multimedia principle [49], pre-training principle [49], and just-in-time step-by-step instructions [49].

Goal directed practice and feedback

Difficulty remembering steps of self-care and tracking blood glucose data, as well as stress and concern about calculating and administering the correct insulin dose were major user-reported challenges. For complex tasks that require multiple steps, failure to remember each step can disrupt successful self-care delivery [15]. Such challenges can be overcome by applying the adult learning and education science principle of repetitive goal directed practice and feedback. This approach provides learners with timely feedback on tasks [34], which can be particularly advantageous for high-stake tasks such as calculating the correct insulin dose to administer.

Table 2 outlines key features of repetitive goal directed practice and feedback. From a learning perspective, the gold standard in education is continuous 1-to-1 support from an expert who can provide direct feedback to the individual over time. Indeed, repetitive goal directed practice and feedback is employed during in-person inpatient diabetes education, and users reported a need for similar support in, for example, a telehealth diabetes survival skills training. This is not surprising; adult learning and education principles suggest that for complex tasks, such as diabetes self-care, a "one-and-done" approach is likely not to be effective as most patients need longer term support to master self-care [35]. However, repetitive goal directed practice and feedback may not be feasible for diabetes survival skills training in all settings, such as after discharge. Nevertheless, repetitive goal directed practice and feedback could be applied to diabetes survival skills training by using, for example, artificial intelligence supports, such as a cognitive tutor (Table 2) [36].

Cognitive tutors are intelligent learning systems that are often virtual and are designed to engage learners in problem-solving within a particular domain of interest. Perhaps one of the best-known examples is a cognitive tutor for Algebra, but similar technology could be applied to diabetes survival skills training [37]. For example, a cognitive tutor could provide learners with a platform to navigate through virtual scenarios where they calculate insulin doses all while receiving immediate feedback on their choices. Such an innovation may help to promote

Table 2
Future applications of key adult learning and education principles identified by users for diabetes survival skills education delivery.

Themes	Challenges in understanding diabetes survival skills while hospitalized	Challenges in preparing needed supplies (e.g. medication, equipment) to execute diabetes survival skills	Challenges in executing diabetes survival skills at home
Adult learning and education principles	Spiral Learning	Form Fits Function Organizer	Repetitive Goal Directed Practice and Feedback
Key features and design benefits	- Includes an overview followed by introduction of details of a task in order of increasing complexity in an iterative fashion [28] - Allows for individualization and flexibility to meet different learning speeds [28] - Promotes problem-solving [28]	- Groups equipment according to function in a task, promoting better understanding of function [15,31] - Exemplifies the principle of *scaffolding* as it applies to "structuring the task" [15,23,31] - Offloads non-essential components of a task, reducing *cognitive load* [31–33]	- Provides immediate, timely feedback on high-stakes tasks [34] - Reduces fear associated with high-stakes tasks - Assists with induction and refinement of learning by providing an evaluative response [34] (correct vs incorrect) [34]
Future applications in remote learning environment	- Digital solutions (i.e. website design) [29,30]	- Organizing scheme (visual, physical, etc.)	- Artificial intelligence (i.e. cognitive tutor) [36]

Shown are key features of three primary adult learning and education principles, their design benefits, and examples of future applications for the purposes of re-designing diabetes survival skills education. These applications translate readily to remote and/or virtual learning solutions.

independent and safe performance of diabetes self-care, reducing patient need to contact their clinicians with self-management-related concerns and thus potentially reducing healthcare resource utilization [38]. Design of such a digital tool also responds to the growing number of patients who, following introduction to telehealth during the COVID-19 pandemic, often prefer virtual platforms for much of their healthcare [39].

While many users reported discomfort and even fear of insulin injections, this significant challenge did not map to a corresponding adult learning and education principle. Such a barrier is likely rooted in the complex interplay between a fear of pain, needle-phobia, and disease stigma, all of which commonly affect patients with diabetes [40]. This barrier could potentially be mitigated through the incorporation of other fields of study, for example cognitive behavioral domains.

Discussion and conclusion

This study identified user-reported critical needs, barriers, and challenges associated with learning diabetes survival skills during the transition period of discharge from the inpatient setting to home. The challenges begin while learners are still inpatient, when they report feeling overwhelmed by the simultaneous onset of a new acute illness, diabetes, and the need to learn complex and new diabetes survival skills before discharge. Learning science principles, including spiral learning and repetitive goal directed practice and feedback, are potentially valuable strategies for the design of a telehealth solution that introduces essential concepts in the diabetes survival skills process. Such a solution can be implemented when patients are still hospitalized but can also be repeated over time after discharge, providing layered learning and skills acquisition.

Costly emergency department visits for hyperglycemia remain high and are rising, particularly among racial/ethnic minority populations and the elderly [41], suggesting that user concerns about self-management of glycemic extremes may be warranted. Revision of current diabetes survival skills education and training is critical for fostering safe and effective self-care and prevention of re-hospitalization and associated morbidity and mortality, which disproportionately afflicts vulnerable patients with diabetes [41,42]. With decreasing numbers of inpatient CDCES [43], exacerbated by COVID-19, design solutions that enable the delivery of a telehealth diabetes survival skills training is paramount to meeting patients' learning needs and overcoming the gap in access to in-person diabetes education and training.

User concerns about accurate distinction between different types of insulin is supported by national surveillance data that has historically identified administration of an incorrect type of insulin as the second leading cause of emergency department visits for hypoglycaemia [44]. Indeed, a design using a form fits function organizer to provide structure to the task of learning diabetes survival skills could reduce the stress that users associate with organizing and using multiple diabetes supplies and, therefore, could be helpful in overcoming this safety risk.

This study shows that combining UCD to identify user needs, barriers, and challenges, which can then be mapped to learning sciences principles and theories, could inform the development of a more patient-centered, feasible, effective, and sustainable diabetes survival skills training model that could even be delivered via telehealth. In general, the learning sciences offer an innovative approach to better serving user needs within the domain of healthcare-based education. Conceivably, these principles could be applied with a similar method to other high-risk endocrine disease states requiring self-care education and possibly to other cognitive specialties similarly facing a high need for safe and autonomous learning.

As part of the next steps in the iterative UCD process, design solutions incorporating learning sciences principles must be developed and tested by users. While COVID-19 demonstrated the general need to provide ongoing patient education support that supplements or even replaces in-person clinical encounters, all future efforts to design diabetes survival skills training must ensure that the solutions meet the needs of all users.

The application of UCD and learning and education sciences principles could specifically benefit racial and ethnic minorities and the elderly, who have the highest prevalence of diabetes and risk of diabetes-associated complications and mortality [45], by extending the reach of accessible and user-centered diabetes survival skills training, particularly through telehealth interventions [46,47]. Future studies will need to evaluate the effectiveness of such diabetes survival skills training, particularly telehealth solutions, to ensure the needs of all individuals with diabetes needs are met successfully.

Lastly, this study serves as yet another example of the emotional distress patients newly diagnosed with diabetes and/or starting insulin therapy may experience. As users reported, such distress impedes successful acquisition of diabetes survival skills. While adult learning and education sciences did not offer a clear solution to this particular learning challenge, further multidisciplinary work, potentially in the realm of the cognitive and behavioral sciences, is needed to overcome the significant emotional challenges new users face.

CRediT authorship contribution statement

Grace Prince: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Daniel Rees Lewis:** Writing – review & editing, Writing – original draft,

Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Teresa Pollack:** Writing – review & editing, Data curation, Conceptualization. **Susan Karam:** Writing – review & editing, Data curation. **Emilie Touma:** Formal analysis, Data curation. **Rebeca Khorzad:** Methodology, Investigation. **Stacy Cooper Bailey:** Writing – review & editing. **David Gatchell:** Writing – review & editing, Investigation. **Bruce Ankenman:** Writing – review & editing, Investigation. **Jelena Kravarusic:** Writing – review & editing. **Terri Sabol:** Writing – review & editing, Methodology. **Jane Holl:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Amisha Wallia:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Amisha Wallia reports financial support was provided by National Institute of Diabetes and Digestive and Kidney Diseases. Susan Karam reports a relationship with Eli Lilly and Company that includes: consulting or advisory. Stacy Cooper Bailey reports a relationship with National Institutes of Health that includes: funding grants. Stacy Cooper Bailey reports a relationship with Pfizer that includes: consulting or advisory and funding grants. Stacy Cooper Bailey reports a relationship with Merck & Co Inc that includes: funding grants. Stacy Cooper Bailey reports a relationship with Eli Lilly and Company that includes: funding grants. Stacy Cooper Bailey reports a relationship with Lundbeck that includes: consulting or advisory and funding grants. Stacy Cooper Bailey reports a relationship with Gordon and Betty Moore Foundation that includes: consulting or advisory and funding grants. Stacy Cooper Bailey reports a relationship with Sanofi that includes: consulting or advisory. Stacy Cooper Bailey reports a relationship with University of Westminster that includes: consulting or advisory. Stacy Cooper Bailey reports a relationship with Luto that includes: consulting or advisory. Amisha Wallia reports a relationship with Novo Nordisk Inc that includes: funding grants. Amisha Wallia reports a relationship with UnitedHealth Group Inc that includes: employment. Corresponding author is an associate editor for the Journal of Clinical and Translational Endocrinology, and is one of the guest editors on the special issue to which the manuscript is submitted – G.P. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Support for this work came from the National Institute of Diabetes and Digestive and Kidney Diseases grant P30 DK092949 (through the Chicago Center for Diabetes Translation Research), NIH/NIDDK R01DK131469; and NIH/AHRQ R18 HS026143.

References

[1] National Diabetes Statistics Report, 2020: Estimates of Diabetes and its Burden in the United States U.S. Department of Health and Human Services, Centers for Disease Control and Prevention2020.
[2] Nassar CM, Montero A, Magee MF. Inpatient diabetes education in the real world: an overview of guidelines and delivery models. Curr Diab Rep 2019;19(10):103.
[3] Petrosyan Y, Bai YQ, Koné Pefoyo AJ, et al. The relationship between diabetes care quality and diabetes-related hospitalizations and the modifying role of comorbidity. Can J Diabetes 2017;41(1):17–25.
[4] Wexler DJ, Beauharnais CC, Regan S, Nathan DM, Cagliero E, Larkin ME. Impact of inpatient diabetes management, education, and improved discharge transition on glycemic control 12 months after discharge. Diabetes Res Clin Pract 2012;98(2):249–56.
[5] Strawbridge LM, Lloyd JT, Meadow A, Riley GF, Howell BL. Use of Medicare's diabetes self-management training benefit. Health Educ Behav 2015;42(4):530–8.
[6] Caballero AE, Ceriello A, Misra A, et al. COVID-19 in people living with diabetes: an international consensus. J Diabetes Complications 2020;34(9):107671.
[7] Apicella M, Campopiano MC, Mantuano M, Mazoni L, Coppelli A, Del Prato S. COVID-19 in people with diabetes: understanding the reasons for worse outcomes. Lancet Diabetes Endocrinol 2020;8(9):782–92.
[8] Bode B, Garrett V, Messler J, et al. Glycemic characteristics and clinical outcomes of COVID-19 patients hospitalized in the United States. J Diabetes Sci Technol 2020 [1932296820924469].
[9] Garg SK, Rodbard D, Hirsch IB, Forlenza GP. Managing new-onset type 1 diabetes during the COVID-19 pandemic: challenges and opportunities. Diabetes Technol Ther 2020;22(6):431–9.
[10] Gujral UP, Johnson L, Nielsen J, et al. Preparedness cycle to address transitions in diabetes care during the COVID-19 pandemic and future outbreaks. BMJ Open Diabetes Res Care 2020;8(1).
[11] Magee MF, Khan NH, Desale S, Nassar CM. Diabetes to go: knowledge- and competency-based hospital survival skills diabetes education program improves postdischarge medication adherence. Diabetes Educ 2014;40(3):344–50.
[12] Peeples M, Tomky D, Mulcahy K, Peyrot M, Siminerio L. Evolution of the American association of diabetes educators' diabetes education outcomes project. Diabetes Educ 2007;33(5):794–817.
[13] Hews-Girard J, Guelcher C, Meldau J, McDonald E, Newall F. Principles and theory guiding development and delivery of patient education in disorders of thrombosis and hemostasis: reviewing the current literature. Res Pract Thromb Haemost 2017;1(2):162–71.
[14] Johnson JA. Self-efficacy theory as a framework for community pharmacy-based diabetes education programs. Diabetes Educ 1996;22(3):237–41.
[15] Ambrose SA, Bridges MW, DiPietro M, Lovett MC, Norman MK. How learning works: 7 research-based principles for smart teaching. San Francisco, CA: Jossey-Bass; 2010.
[16] Nathan MJ, Koedinger KR. An investigation of teachers' beliefs of students' algebra development. Cogn Instr 2000;18(2):209–37.
[17] Graham AK, Fitzsimmons-Craft EE. Accelerating the research-to-practice translation of eating disorder apps and other digital interventions: commentary on O'Leary and Torous (2022). Int J Eat Disord 2022.
[18] Mao J, Vredenburg K, Smith P, Carey T. The state of user-centered design practice. Commun ACM 2005;48:105–9.
[19] Easterday MW, Rees Lewis DG, Gerber EM. The logic of design research. Learn Res Pract 2018;4(2):131–60.
[20] User Centered Design. Interaction Design Foundation https://www.interaction-design.org/literature/topics/user-centered-design. Accessed.
[21] Tippey KG, Weinger MB. User-centered design means better patient care. Biomed Instrum Technol 2017;51(3):220–2.
[22] Ratwani RM, Benda NC, Hettinger AZ, Fairbanks RJ. Electronic health record vendor adherence to usability certification requirements and testing standards. JAMA 2015;314(10):1070–1.
[23] Sawyer RK. The Cambridge handbook of the learning sciences. 2nd ed. New York, NY: Cambridge University Press; 2014.
[24] Shenton AK. Strategies for ensuring trustworthiness in qualitative research projects. Educ Inf 2004;22:63–75.
[25] Weiss RS. Learning from strangers: the art and method of qualiative interview studies. New York, NY: Maxwell Macmillan International; 1994.
[26] Corbin J, Strauss A. Basics of qualitative research: techniques and procedures for developing grounded theory. 4th ed. Sage Publications.; 2015.
[27] Kuniss N, Kramer G, Müller UA, Wolf G, Kloos C. Diabetes related distress is high in inpatients with diabetes. Diabetol Metab Syndr 2021;13(1):40.
[28] Harden RM. What is a spiral curriculum? Med Teach 1999;21(2):141–3.
[29] Songer NB. BioKIDS: an animated conversation on the development of curricular activity structures for inquiry science. In: Sawyer RK, editor. Cambridge handbook of the learning sciences. New York: Cambridge University Press; 2006. p. 355–69.
[30] Bruner J. The culture of education. Cambridge, Massachusetts: Harvard University Press; 1996.
[31] Reiser BJ. Scaffolding complex learning: the mechanisms of structuring and problematizing student work. J Learn Sci 2004;13(3):273–304.
[32] Beier ME, Ackerman PL. Age, ability, and the role of prior knowledge on the acquisition of new domain knowledge: promising results in a real-world learning environment. Psychol Aging 2005;20(2):341–55.
[33] Paas F, Renkl A, Sweller J. Cognitive load theory: instructional implications of the interaction between information structures and cognitive architecture. Instr Sci 2004;32(1/2):1–8.
[34] Koedinger KR, Corbett AT, Perfetti C. The knowledge-learning-instruction framework: bridging the science-practice chasm to enhance robust student learning. Cogn Sci 2012;36(5):757–98.
[35] National Academies of Sciences E, and Medicine. How people learn II: learners, contexts, and cultures National Academies Press; 2018.
[36] VanLehn K. The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. Educ Psychol 2011;46(4):197–221.
[37] Koedinger KR, Corbett A. Cognitive Tutors: Technology Bringing Learning Sciences to the Classroom. In: Sawyer RK, editor. The Cambridge Handbook of the Learning Sciences. Cambridge: Cambridge University Press; 2005. p. 61–78.
[38] Ellahham S. Artificial intelligence: the future for diabetes care. Am J Med 2020;133(8):895–900.
[39] Effects of the COVID-19 Pandemic on People with Diabetes: December 2020 Survey Summary Report. The American Diabetes Association2020.
[40] Abu Hassan H, Tohid H, Mohd Amin R, Long Bidin MB, Muthupalaniappen L, Omar K. Factors influencing insulin acceptance among type 2 diabetes mellitus

patients in a primary care clinic: a qualitative exploration. BMC Fam Pract 2013; 14:164.
[41] Echouffo-Tcheugui JB, Garg R. Management of hyperglycemia and diabetes in the emergency department. Curr Diab Rep 2017;17(8):56.
[42] Sircar M, Bhatia A, Munshi M. Review of hypoglycemia in the older adult: clinical implications and management. Can J Diabetes 2016;40(1):66–72.
[43] Rinker J, Dickinson JK, Litchman ML, et al. The 2017 diabetes educator and the diabetes self-management education national practice survey. Diabetes Educ 2018; 44(3):260–8.
[44] Geller AI, Shehab N, Lovegrove MC, et al. National estimates of insulin-related hypoglycemia and errors leading to emergency department visits and hospitalizations. JAMA Intern Med 2014;174(5):678–86.
[45] Golden SH, Brown A, Cauley JA, et al. Health disparities in endocrine disorders: biological, clinical, and nonclinical factors–an Endocrine Society scientific statement. J Clin Endocrinol Metab 2012;97(9):E1579–639.
[46] Hartz J, Yingling L, Powell-Wiley TM. Use of mobile health technology in the prevention and management of diabetes mellitus. Curr Cardiol Rep 2016;18(12): 130.
[47] Vangeepuram N, Mayer V, Fei K, et al. Smartphone ownership and perspectives on health apps among a vulnerable population in East Harlem. New York Mhealth 2018;4:31.
[48] Hattie J. Visible learning for teachers: maximizing impact on learning. 1st ed. Routledge; 2012.
[49] Mayer R. Multimeda learning. 2nd ed. Cambridge Cambridge University Press; 2009.