Received: 1 December 2021 | Revised: 28 September 2022 | Accepted: 11 October 2022

DOI: 10.1002/nop2.1432

RESEARCH ARTICLE

NursingOpen Open Access WILEY

Developing the "Healthcare CEO App" for patients with type 1 diabetes transitioning from adolescence to young adulthood: A mixed-methods study

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Funding information
Chang Gung University, Grant/Award Number: NMRPD1J0341; Ministry of Science and Technology, Grant/Award Number: MOST 108-2314-B-182-022

Abstract

Aim: To develop and test a mobile application that supports the disease self-management of adolescents with type 1 diabetes during their transition to early adulthood.

Design: A sequential mixed-methods design was employed.

Methods: The application content was designed according to previously identified care needs and expectations, followed by application development on the Android operating system. From the outpatient clinic of the Department of Paediatric Endocrinology and Metabolism at a medical centre in northern Taiwan, 35 individuals aged between 16–25 years participated in application testing.

Abbreviations: CEO, chief executive officer.; HbA1c, glycated haemoglobin; mHealth, mobile health; QUIS, questionnaire for user interaction satisfaction.

Yueh-Tao Chiang and Chien-Lung Hsu made equal contributions to this manuscript.

Results: The overall median score of the QUIS was 4–5, most of the 25% quartile was 4–5, and all of the 75% quartile was 5, indicating adequate user interaction satisfaction.

1 | BACKGROUND

Type 1 diabetes in children is most prevalent among adolescents aged 10–14 years, followed by children aged 5–9 years (Haynes et al., 2020). Globally, the incidence and prevalence of this disease have been on the rise (Mobasseri et al., 2020). The upward trend in incidence has been more pronounced for adolescents aged 10–14 and 15–19 years, showing a consistent trend of annual increases estimated to be 2.1% from 2001–2012 (Mayer-Davis et al., 2017). Given the increased onset of type 1 diabetes at an early age, the number of adolescents with type 1 diabetes transitioning to early adulthood is also expected to increase.

1.1 | Challenges and effectiveness of app-based interventions of T1D patients transitioning from adolescence to early adulthood

During this transition period, adolescent patients have to undertake complicated daily care tasks and live a life full of instability (Johansen et al., 2020). Adolescents with type 1 diabetes face multiple challenges, namely, difficulty controlling blood glucose levels due to hormonal changes, the struggle to self-manage type 1 diabetes while pursuing independence, the need to establish new interpersonal networks when transitioning from high school to college, having to compromise disease care due to other competing needs, experiencing concerns about disclosing the disease when starting a new career or relationship and dealing with worries about the heredity of the condition (Ersig, 2019; Holtz et al., 2020; Chiang et al., 2020). As a result, the lowest disease control rates were exhibited by patients during this transition period (Agarwal et al., 2018).

Moreover, the glycated haemoglobin (HbA1c) levels of adolescents with type 1 diabetes may worsen every year (Berg et al., 2018). Although the HbA1c control target should be adjusted based on the patient's condition, such as the frequency of severe hypoglycaemic episodes (American Diabetes Association, 2021a), it is possible to effectively reduce comorbidities of large and small vessels by achieving an HbA1c < 7% and a time-in-range of 70% (American Diabetes Association, 2021b). Thus, an important direction and goal with regard to care is to provide patients with interventional measures that are tailored to their life contexts and to help them maximize their blood glucose control during the transition period.

Given the utility of healthcare-related software applications, the need for a custom-made application for type 1 diabetes self-care is eminent (Chiang et al., 2021). Mobile health (mHealth) applications can promote physical health and alleviate stress, anxiety and depression in patients with long-term diseases (Rathbone & Prescott, 2017). Moreover, mHealth applications were deemed effective in improving HbA1c control (Pramanik et al., 2019; Wang et al., 2019) resulting in enhanced mental health and quality of life of patients by reducing the burden of diabetes (Prahalad et al., 2018). Reports indicate that 75% of adolescents and 69% of parents would use mobile applications to control type 1 diabetes (Barnes et al., 2018). Thus, the adoption of mobile applications as a self-management tool can effectively fulfil the care needs of patients with type 1 diabetes during the transition period, which can lead to improved outcomes (Fleming et al., 2020).

1.2 | Gaps of knowledge

While there are more than 1,000 diabetes-related applications on various platforms (Huang et al., 2018), most have limited utility. First, existing applications have restricted functions. For instance, while users use various diabetes self-management tasks such as physical activity, nutrition, blood glucose testing, medication or insulin dosage, health feedback and education for analysis, each application contains only 2–3 tasks (Chavez et al., 2017). However, users prefer applications with integrated and comprehensive functions (Fleming et al., 2020). Second, the functions of existing applications are not based on recommendations from empirical findings. Not only are rewards and social communities yet to be well adopted, but there is also a lack of individualized designs for target users (Martinez-Millana et al., 2018). Third, most applications only have general functions and, therefore, may not satisfy the specific needs of adolescents who are transitioning to early adulthood (Chiang et al., 2020, 2021). Finally, considering knowledge level as a parameter, most existing applications only contain common knowledge, such as the definition of diabetes, diet control and exercise requirements, whereas the potential impact of secondary sexual characteristics on blood glucose or nutrition advice that considers the growth needs of adolescence are barely included.

1.3 | Aims of the study

In contrast, the development of mobile applications should consider the life contexts and needs of their users to improve effectiveness (Huang et al., 2018; Wyatt et al., 2015). Therefore, with Information System research as its guiding framework, this study aimed to develop a multifunctional application, namely, the "Healthcare Chief Executive Officer (CEO) application," which is dedicated to the needs of patients with type 1 diabetes transitioning from adolescence to young adulthood.

2 | THE STUDY

2.1 | Theoretical framework

The Healthcare CEO application was developed using the Design Science paradigm in Information System research as its theoretical framework. This framework emphasizes the need to adopt user-centred approaches in developing and testing software applications. Thus, our application was developed in three stages, namely, the Relevance Cycle, the Rigour Cycle and the Design Cycle. In the Relevance Cycle, we discovered developmental and situational problems experienced by adolescents with type 1 diabetes, confirmed user experiences and needs and found opportunities for change. The Rigour Cycle focused on searching for topic-related knowledge, forming a team and discussing preliminary ideas with Information Technology professionals. Lastly, the Design Cycle sought to design, develop and test the application (Hevner, 2007).

2.2 | Study design

This study adopted a mixed-methods design. The Relevance Cycle stage was conducted through qualitative research methods between August 2017–July 2018. To understand the life experiences and care needs during the transition period from adolescence to early adulthood, a sample of 14 patients diagnosed with type 1 diabetes aged 16–25 years were recruited (Chiang et al., 2020). Thereafter, from August 2018–July 2019, we investigated the care needs of patients with type 1 diabetes in the transition period through qualitative research and a literature review. Consequently, a total of 47 stakeholders, consisting of patients, primary caregivers and healthcare providers, were included in a Delphi study to confirm the care needs of patients with type 1 diabetes in the transition period. Based on the results, 71 healthcare needs were identified across five dimensions – technology, external support, internal support, management and health care, of which 56 were reported as extremely important (Chiang et al., 2021). The insights obtained from the results of this stage helped the research team understand user experiences and patient needs for developing a tailor-made application and to identify expectations for the application content. Moreover, we found that patients hoped to become masters at managing their health amidst their diabetes; thus, the application was named "Healthcare CEO."

The purpose of the Rigour Cycle was to incorporate user expectations identified in the previous stage into the application and to reduce cultural gaps. From August 2019–September 2019, the research team found over 100 Chinese applications through extensive investigation of diabetes-related applications and documents written in local languages in the Android and iOS markets. However, most applications were either created for type-2 patients with diabetes or did not specify the diabetes type. There was only one simplified Chinese application, "Donut," dedicated to children with type 1 diabetes. This indicated clearly the scarcity of applications that cater to the needs and expectations of adolescents with type 1 diabetes in the transition period. Moreover, from field observations, it was found that 60% of the 120 adolescent patients with type 1 diabetes in the transition period used Android operating systems. Therefore, during this stage, a multidisciplinary research team was established to discuss the technical specifications and contents of the application. The team, which had 15 members, consisted of physicians, diabetes case managers, nutritionists, senior nurses of the Department of Metabolism, nursing teachers, programming teachers and industry professionals.

Lastly, during the Design Cycle, which was carried out between September 2019–October 2020, the research team designed the content of the Healthcare CEO application and developed a prototype of the application, followed by testing and modification. The study design is shown in Figure 1, and the process of the Design Cycle is detailed below.

2.3 | Participants of healthcare CEO application testing during the design cycle

Patient recruitment was conducted in the outpatient clinic and ward of the Department of Paediatric Metabolism of a medical centre in northern Taiwan. The inclusion criteria were participants: (1) with a diagnosis of type 1 diabetes from an endocrinologist before the age of 16 years; (2) who had developed the condition for at least 6 months; (3) aged between 16–25 years; (4) with the ability to communicate in Mandarin or Taiwanese; (5) having a smartphone and access to the Internet and (6) who agreed to participate in the study. The research participants provided informed consent as they were willing to be recorded. Patients with cognitive and language impairments were excluded. The data collection was completed by a researcher with a medical background along with a research assistant.

2.4 | Research procedure of the design cycle – Designing the healthcare CEO application

Step 1: Content design.

The main content of the application was determined based on the 56 care needs, which were identified as most important by patients, caregivers and healthcare providers in the Relevance cycle (Chiang et al., 2021). Thereafter, the applicability and the clarity of the content were assessed by five experts, and the application was revised and formalized.

Step 2: Technical specifications and prototype.

The research team held regular meetings to determine the technical specifications of the application. Furthermore, academic and industrial experts were invited to collaborate in the development of the application.

Step 3: Testing methods and modification.

The application was evaluated using user-centred approaches, such as heuristic evaluation, the think-aloud evaluation method and

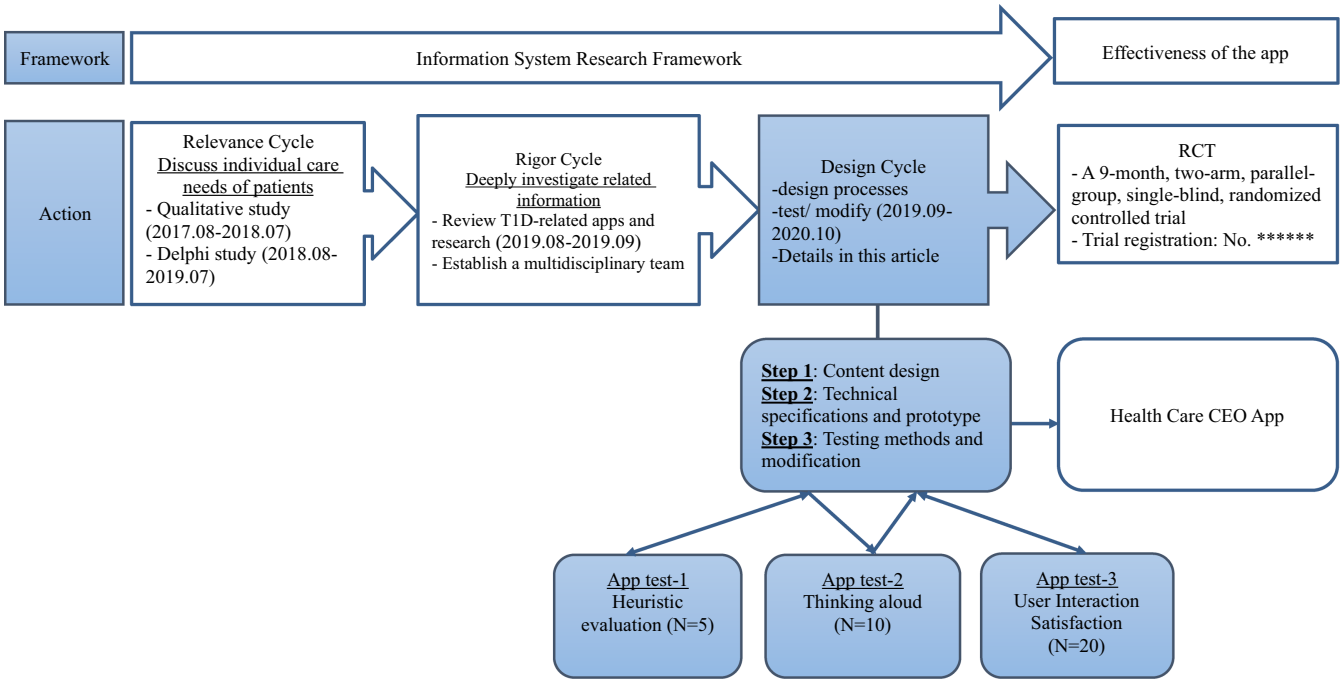


FIGURE 1 Development and evaluation of the Healthcare CEO app

user interaction satisfaction assessment. The purpose of heuristic evaluation, which uses Nielsen's 10 heuristic principles, is to identify usability problems in the application interface (Nielsen, 1994). While three participants are adequate to identify more than 75% of the problems, testing usually involves 1–5 participants (Nielsen & Molich, 1990). Therefore, in this study, five patients explored the several interfaces of the application, while researchers observed and asked questions according to the research guidelines. All participants completed the assessment individually (Nielsen, 1994).

The think-aloud evaluation method aims to identify the application's operational problems, namely, a user performs 3–4 tasks and is asked to think aloud to explain what they are doing at each stage and why. Usually, 6–16 participants are involved during this evaluation process (Alfonsi et al., 2020; Castensoe-Seidenfaden et al., 2017). In this study, 10 participants completed multiple designated tasks, after the application functions were explained. Participants were required to state their perceived operating method and feelings while using the application. Meanwhile, researchers observed and asked questions according to the research guidelines and calculated their task completion time. The entire process was recorded and later transcribed verbatim for analysis (Castensoe-Seidenfaden et al., 2017; Kueh, 2016; Kushniruk & Patel, 2004). The designated tasks read as follows: (1) fill in personal information; (2) set HbA1c control targets; (3) read the electronic database of the CEO application and complete the test; (4) answer the situational questions in "Barrier-free Communication"; (5) enter a favourite exercise and calculate the calories consumed by the exercise; (6) complete the diet exchange list; (7) enter the user chatroom and send a message; (8) set a reminder for follow-up consultations; (9) upload a photo in "Help Me, Detective!"; and (10) check point balance.

Finally, user interaction satisfaction was assessed according to methods listed in previous studies. To understand user satisfaction levels, a total of 20 patients completed the 7th edition of the Questionnaire for User Interaction Satisfaction (QUIS) after engaging with the Healthcare CEO application for 4 weeks (Kueh, 2016).

2.5 | Instruments

The parameters for heuristic evaluation included: (1) display of system status: the system can generate appropriate feedback in specific intervals so that users can learn what is currently running; (2) degree of correspondence with the real world; (3) user control freedom: users can choose to exit the application or return to the previous step; (4) consistency; (5) fool-proof and error-proof mechanisms; (6) application problem resolution using cognition instead of memory; (7) flexibility and efficiency of use; (8) design aesthetics; (9) error detection, debugging and recovery from errors; and (10) appropriate assistance and instructions (Nielsen, 1994).

Guidelines for the think-aloud evaluation included asking the users to speak loudly about (1) how to operate the application; (2) why the operation is completed this way; and (3) how they feel about it (Kushniruk & Patel, 2004).

The QUIS was initially developed by Harper et al. (Harper et al., 1997). Its Chinese version includes seven aspects, namely, (1) overall user response; (2) interface; (3) learning; (4) multimedia; (5) content; (6) system performance; and (7) online consultation. The questionnaire contains 19 items, each scored on a 5-point Likert scale, with a higher score indicating higher user satisfaction. The Cronbach's α of the questionnaire was .95 (Kueh, 2016). In this study,

an open-ended question, "Your suggestions for the application?" was added at the end of the questionnaire, allowing patients to provide crucial qualitative insights.

2.6 | Data analysis

A content analysis was conducted of the verbatim records derived from the heuristic and think-aloud evaluations performed. Descriptive statistics of user interaction satisfaction were computed using Statistical Package for the Social Sciences (SPSS) Version 21.0 (IBM Corp. Released 2012. Armonk, NY, USA).

2.7 | Ethics consideration

This study was approved by the Ethics Committee of XXX Foundation Institutional Review Board. Submission Ref: Xxxxx. Written consent forms were signed by all participants, and the legal representatives of patients who were minors.

3 | RESULTS

3.1 | General characteristics of the participants

A total of 35 patients with type 1 diabetes participated in the application testing process, including the heuristic, think-aloud and user interaction satisfaction evaluations. Table 1 reports the participants' basic information.

3.2 | Designing the healthcare CEO application

Step 1: Application Contents.

The Healthcare CEO application originally consisted of nine interfaces: (1) CEO's Profile; (2) Health Tracking; (3) CEO Knowledge Base; (4) Barrier-free Communication; (5) See Here: Diet and Exercise; (6) Help Me, Detective!; (7) CEO Chat Room; (8) CEO's Secretary; and (9) Who's the Best CEO. The content of the application was customized for patients with type 1 diabetes. In addition to providing health trend analysis, the "Health Tracking" interface combined insulin dosage, diet and exercise with blood glucose changes to provide references for dosage adjustment. In the "CEO Knowledge Base" section, information that was not related to type 1 diabetes was removed, whereas topics of interest to adolescent patients, such as career development, sex, pregnancy and heredity, were compiled into e-books and divided into elementary and advanced levels. This was done to allow users access to age-appropriate information based on their current situation and experiences.

In the "Barrier-free Communication" section, users could learn interpersonal skills for peer, workplace and gender-specific communications, undertake situational exercises and adjust their interactions with family members during the transition period. This section, especially focused on parent–child interactions, to help patients navigate conflicts that commonly occur during the transition period. The "See Here: Diet and Exercise" section provided electronic instructions on diet and exercise, based on the food and exercise preferences of most adolescent patients during the transition period. By linking to the exercise computer from the Health Promotion Administration of Taiwan, this section helps users master the principles of healthy diet and exercise and record their daily activity and eating patterns. The "Help Me, Detective!" section, which was in the format of a dropdown list of health-check questions, allowed users to record the incidence of severe comorbidities, either immediately or subsequently, to help them understand the precipitating factors of blood glucose instability and serve as a reference for disease self-management.

In the "CEO Chat Room" interface, to meet the desire for privacy and independence of patients in the transition period, participants were divided into "Insiders" and "Outsiders," with the former composed of peer patients, and the latter, medical professionals, allowing users to join anonymously and discuss their concerns. In addition to experience sharing sessions, two thematic discussions are held monthly, the topics of which focus on either patients' individual needs or disease self-management for patients in the transition

TABLE 1 General characteristics of the participants

Test method	*N*	Age(years) Mean (±*SD*)	BH(cm) Mean (±*SD*)	BW(kg) Mean (±*SD*)	BMI Mean (±*SD*)	HbA1c (%) Mean (±*SD*)	Mean duration of diabetes(years) Mean (±*SD*)	Student (*N*)/ Employment(*N*)
A	5	19.60 (±2.07)	157.84 (±9.18)	54.50 (±11.47)	22.08 (±5.89)	9.46 (±2.55)	10.02 (±3.52)	3/2
B	10	19.70 (±2.16)	163.25 (±8.65)	58.31 (±8.80)	21.79 (±2.26)	7.51 (±2.07)	10.60 (±3.41)	5/5
C	20	21.10 (±2.51)	166.79 (±7.36)	61.90 (±11.33)	22.20 (±3.68)	9.11 (±2.56)	12.29 (±5.11)	9/11

Note: A, Heuristic evaluation; B, Thinking aloud; C, User satisfaction.

Abbreviations: BH, body high; BMI, body mass index; BW, body weight; HbA1c, glycated haemoglobin; *SD*, standard deviation.

period. Alternatively, users can freely choose who can join the "Outsider" chatroom. For example, primary caregivers can be added to this chatroom to aid patients when needed.

The "CEO's Secretary" interface sends notifications not only when follow-up visits are due, but also when the user's blood glucose levels exceed the standard value for three consecutive days, or when the frequency of blood glucose measurements was lesser than required. Furthermore, the interface sends reminders for booking online consultations. Lastly, in the "Who's the Best CEO" interface, users gain points after completing tasks, which function as rewards. This section allows the top three users who had the most points to redeem coupons, thereby promoting disease control via the application.

By incorporating functions that are not included in existing applications, the Healthcare CEO application is expected to better satisfy the needs of patients with type 1 diabetes in the transition period. After reviewing relevant literature, the readability of the application was set at Grade 6–8 reading level (Tsai et al., 2010). The calculated expert validity of the application indicated that the content validity index of each individual interface ranged between 0.97–1, while the overall expert validity was 0.985. Therefore, all interfaces were retained.

Step 2: Healthcare CEO application prototype.

Most adolescents with type 1 diabetes in the transition period used Android phones, and the Android operating system is more flexible with fewer cross-hardware compatibility issues. Therefore, after eight multidisciplinary research team meetings, it was decided that the application would be developed on the Android operating system rather than iOS. On this basis, a prototype of the Healthcare CEO application that integrated the application with Bluetooth transmission and cloud technologies was developed. The system architecture of the prototype is shown in Figure 2.

Step 3: Testing and modification of the Healthcare CEO application.

Test 1: Heuristic evaluation.

After logging in, five participants first tested the "Health Tracking" interface and suggested that being able to set HbA1c control targets was a great function. The usability problems found in this stage could be divided into three categories: (1) Visibility: Participants mentioned that there was no button to return to the previous page, and the interface text was not clear ($N = 3$). For example, Participant A said that "I find it impossible to return to the previous page, and therefore have to go back to the home page and start again …"; (2) Controllability: There was neither a reset function nor an error-proof mechanism ($N = 2$). "It is frustrating that when you make a mistake in entering texts, you cannot reset, but have to start from scratch" (Participant C); (3) Convenience: there were too many places where manual input was required ($N = 3$). "There are too many instances where I have to manually enter the text. It will be great if I can upload photos for diet records (Participant D)."

Based on the above feedback, the following changes were made to the application: (1) magnification of interface texts; (2) adding both a reset and a return button; (3) adding notifications for data deletion and input errors. For example, text prompts would appear when the input value of the insulin injection dose exceeded 100 units/ml (U); (4) Photo upload function was introduced in the "See Here: Diet and Exercise" and the "Help Me, Detective!" interfaces, to reduce manual input; and (5) The input method for prescriptions was changed to selection from a list, to avoid possible errors when manually entering drug names and dosage, as shown in Table 2.

Test 2: Think-aloud evaluation.

All the participants successfully completed the designated tasks. After reviewing participants' task execution processes and their perceived operation method, the research team identified two interface operation problems including time-on-task and technical effectiveness. In terms of time-on-task, the average operation time for each task ranged between 5.50–41.00 s; for all the tasks, the fastest completed time was 5 s, and the slowest was 52 s, details of which are listed in Table 3.

Furthermore, about technical effectiveness, issues identified by the users included: (1) a lack of interface function descriptions, making it difficult to know the purpose of the interface ($N = 5$): "There is no function description, so I have to slowly go through "Notifications" one by one to find out where to change settings" (Participant H); (2) insufficient icons ($N = 6$): "Reading texts is time consuming, while icons are more trendy. With clearer icons, I can understand the function of the interface intuitively" (Participant G); (3) difficulty finding where to set control targets as participants were unaware that the English abbreviation for glycosylated haemoglobin is HbA1c ($N = 1$): "What is HbA1c?" (Participant L); (4) the application had comprehensive functions, but the operation was a little cumbersome ($N = 3$): "Multifunctionality has its pros and cons, as I don't know where to start from. However, this shouldn't be an issue when I am more familiar with the app" (Participant M); (5) the "Add New" button was not clear; (6) interface texts would not display properly on Xiaomi phones, for example, "Barrier-free Communication" would only appear as "Barrier-free" ($N = 2$): "All interface texts were incomplete on my mobile phone" (Participant F); (7) the application would crash ($N = 5$): "The app crashed when linking to the exercise computer of the Health Promotion Administration" (Participant K); (8) participants did not want to speak in the "Outsider" group ($N = 2$) – "I don't want others to know my thoughts" (Participant J); and (9) there was no SOS function in the "Help Me, Detective!" interface upon an emergency ($N = 2$) – "I thought there would be an SOS function here" (Participant P).

Based on these responses, the following changes were made: (1) function descriptions and icons in the application interfaces were added; (2) HbA1C was changed to its Chinese equivalent; (3) crash and text display issues were fixed; (4) the "Add New" button in all interfaces was highlighted; (5) the "SOS Calls" function including up to three numbers was added so that users can get immediate support according to their preferences; (6) a "Q&A" section was added to allow users with privacy concerns to ask questions individually and (7) a LINE Bot was added to the chat room to engage in individual instant chat with the participants, as shown in Table 2.

Test 3: User interaction satisfaction.

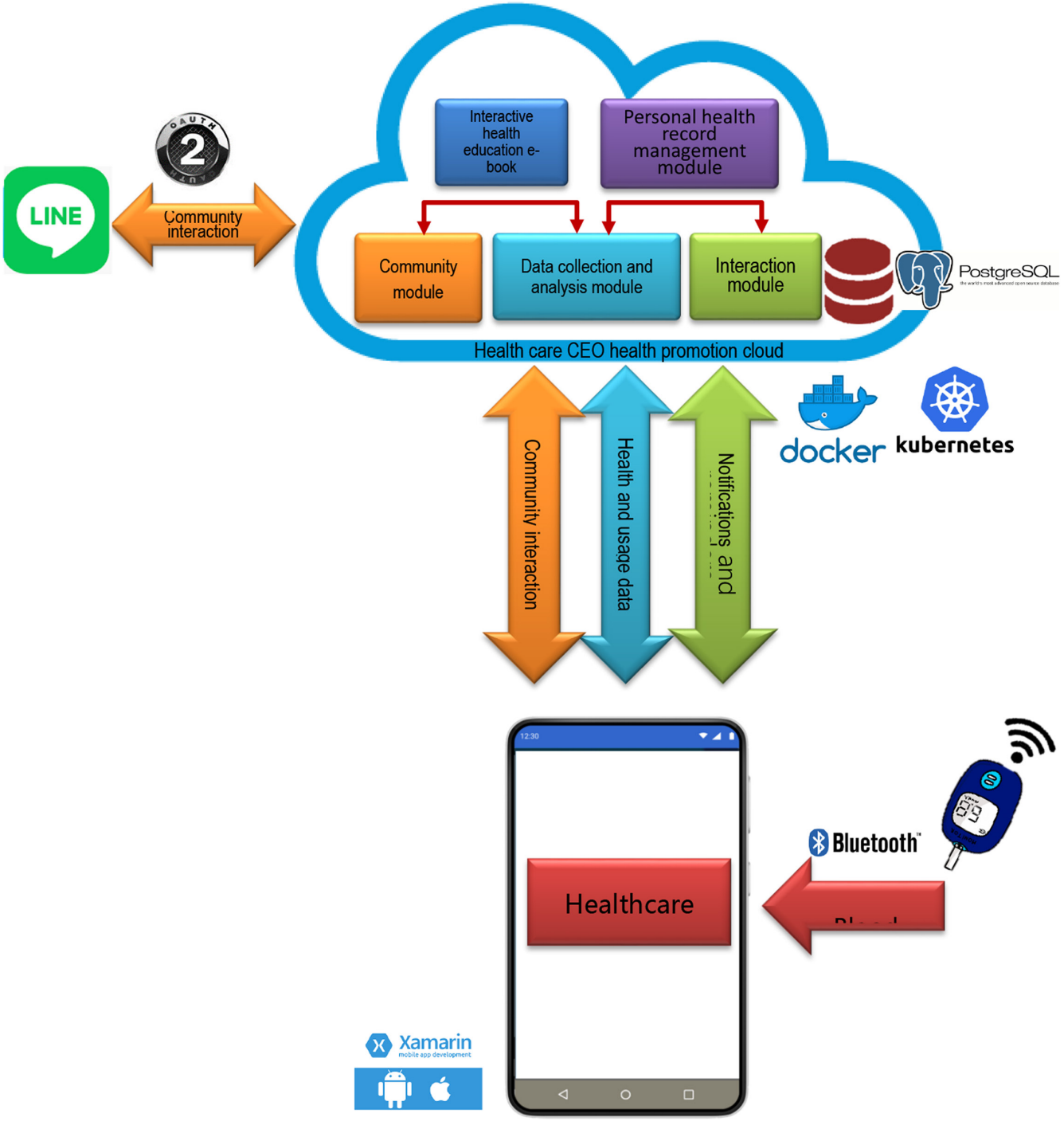


FIGURE 2 System architecture of the Healthcare CEO app

The overall median score of the QUIS was 4–5, most of the 25% quartile was 4–5, and all of the 75% quartile was 5, indicating adequate user interaction satisfaction. Details are listed in Table 4.

Furthermore, responding to the open-ended question about modification suggestions, over 90% of the participants indicated that the CEO application was rich in content, had multiple functions and was tailor-made for them. However, participants also proposed some suggestions: (1) design aesthetics could be improved ($N = 3$); (2) the reminder music could incorporate the user's personal database ($N = 1$); (3) password should be used to unlock the application to protect privacy ($N = 2$); and (4) concerns about a data breach if the application is logged in through Line (a predominant texting app in Taiwan) ($N = 3$). Therefore, in addition to adding the password unlock function and allowing users to apply for a new account as a non-linked login option, the research team also hired a program developer with art expertise to redesign the interface icons and the e-book layout, so that the application was both more secure and aesthetically appealing, as shown in Table 2. The final version of the Healthcare CEO application consisted of 11 interfaces as shown in Figure 3.

TABLE 2 Participant's suggestion and modification of the Healthcare CEO application

Test method (*N*)	Participant's suggestions	Modification
Heuristic evaluation (*N* = 5)	1. Visibility: Participants mentioned that there was no button to return to the previous page, and the interface text was not clear (*N* = 3). 2. Controllability: There was neither a reset function nor an error-proof mechanism (*N* = 2). 3. Convenience: There were too many places where manual input was required (*N* = 3).	1. Magnification of interface texts 2. Adding both a reset and return button 3. Adding notifications for data deletion and input errors 4. Photo upload function was introduced in the "See Here: Diet and Exercise" and the "Help Me, Detective!" interfaces. 5. The input method for prescriptions was changed to selection from a list, to avoid possible errors when manually entering drug names and dosage.
Think-aloud evaluation (*N* = 10)	1. A lack of interface function descriptions, making it difficult to know the purpose of the interface (*N* = 5). 2. Insufficient icons (*N* = 6). 3. Difficulty finding where to set control targets, as participants were unaware that the English abbreviation for glycosylated haemoglobin is hba1c (*N* = 1). 4. The application had comprehensive functions, but the operation was a little cumbersome (*N* = 3). 5. The "Add New" button was not clear. 6. Interface texts would not display properly on Xiaomi phones. 7. The application would crash (*N* = 5). 8. Participants did not want to speak in the "Outsider" group. 9. There was no SOS function in the "Help Me, Detective!" interface for an emergency (*N* = 2).	1. Function descriptions and icons in the application interfaces were added. 2. Hba1c was changed to its Chinese equivalent. 3. Crash and text display issues were fixed. 4. The "Add New" button in all interfaces was highlighted. 5. The "SOS Calls" function, including up to three numbers, was added so that users can get immediate support according to their preferences. 6. A "Q&A" section was added to allow users with privacy concerns to ask questions individually. 7. Added a LINE Bot to the chat room, to allow participants to engage in individual instant chat.
User interaction satisfaction (*N* = 20)	1. Design aesthetics could be improved (*N* = 3). 2. The reminder music could incorporate the user's personal database (*N* = 1). 3. Password should be used to unlock the application to protect privacy (*N* = 2). 4. Concerns about a data breach if the application is logged in through Line (a predominant texting app in Taiwan) (*N* = 3).	1. Hired a program developer with art expertise to redesign the interface icons and the e-book layout. 2. Adding the password unlock function 3. Allowing users to apply for a new account as a non-linked login option

TABLE 3 Think-aloud evaluation tasks

Task	Completion time (s) mean	Fastest/ Slowest (s)
(1) Fill in personal information	26.00	22/30
(2) Set HbA1c control targets	35.00	18/52
(3) Read the electronic database of the CEO app and complete the test	41.00	35/48
(4) Answer the situational questions in "Barrier-free Communication"	18.5	15/22
(5) Enter a favourite exercise and calculate the calories consumed by the exercise	33.33	27/45
(6) Complete the diet exchange list	36.00	20/52
(7) Enter the user chatroom and send a message	21.00	15/27
(8) Set a reminder for follow-up consultations	18.50	8/29
(9) Upload a photo in Help Me, Detective!	7.50	7/8
(10) Check point balance	5.50	5/6

4 | DISCUSSION

4.1 | Principal results

As a mixed-methods multi-stage study, we spent 3.5 years developing and testing the Healthcare CEO application to design it specifically for the target group of adolescents with type 1 diabetes who are transitioning into early adulthood. When the youth use mobile health technologies to manage their health, they are likely to use only some of the functions and discontinue using the application after a while, which can compromise the effectiveness of interventional treatment (Hightow-Weidman et al., 2021).

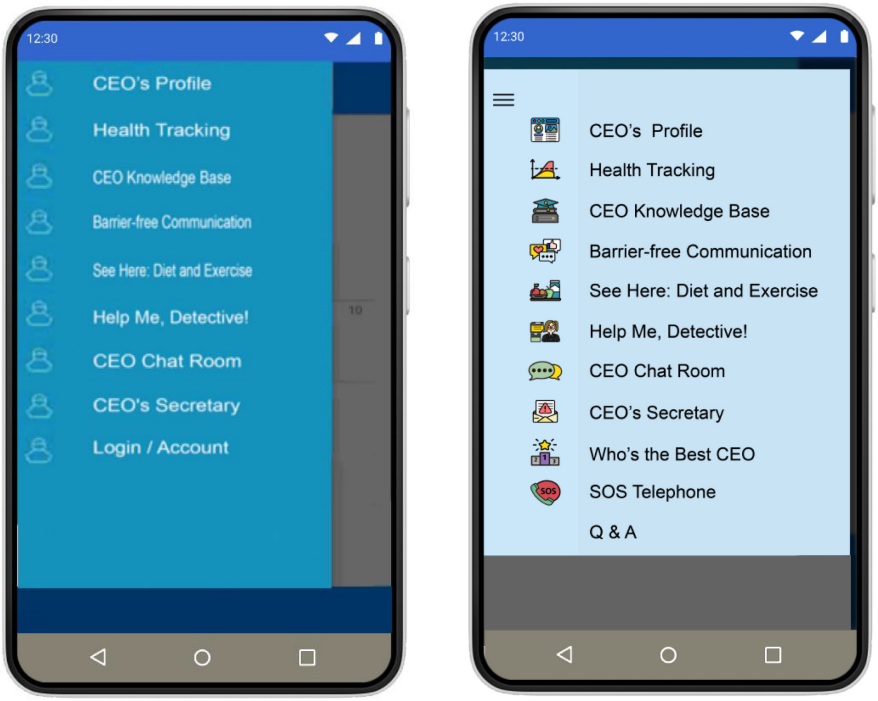
TABLE 4 Analysis of questionnaire for user interaction satisfaction ($N = 20$)

Interface	Number	Question	Median (Quartile 25%/75%)
Overall user response	1–1	I think the "Healthcare CEO" app is very suitable for me.	4 (4/5)
	1–2	I think the "Healthcare CEO" app is easy to operate.	5 (4/5)
	1–3	I think I am capable of operating the "Healthcare CEO" app.	5 (5/5)
	1–4	I think the functions of the "Healthcare CEO" app are very flexible.	5 (4/5)
	1–5	I would recommend the "Healthcare CEO" app to others.	4.55 (4/5)
Interface	2–1	I think the content of the "Healthcare CEO" app is easy to read.	5 (4/5)
	2–2	I think the interfaces of the "Healthcare CEO" app are clear.	5 (4.25/5)
Learning	3–1	I think the functions of the "Healthcare CEO" app are easy to learn.	5 (5/5)
	3–2	I think the function names of the "Healthcare CEO" app are easy to remember.	5 (4/5)
Multimedia	4–1	I think pictures in the "Healthcare CEO" app are well designed.	4 (4/5)
	4–2	I think the sounds of the "Healthcare CEO" app are very clear.	4 (3/5)
	4–3	I think the multimedia of the "Healthcare CEO" app is very practical.	4 (4/5)
Content	5–1	I think the content of the "Healthcare CEO" app is very comprehensive.	4 (4/5)
	5–2	I think the content of the "Healthcare CEO" app meets my disease management needs well.	5 (4/5)
	5–3	I think the content of the "Healthcare CEO" app is correct.	5 (4/5)
	5–4	I think the terminology of the "Healthcare CEO" app is easy to understand.	5 (4/5)
	5–5	I think the content of the "Healthcare CEO" app is consistent.	5 (4/5)
System performance	6–1	I think the "Healthcare CEO" app is very smooth to use.	5 (4/5)
Online consultation	7–1	I think online consultations offered by the "Healthcare CEO" app can resolve my problems.	5 (4/5)

In contrast, theory-based development has been established as an important strategy to improve usage efficiency (Hightow-Weidman et al., 2021). As a result, this study adopted the Design Science paradigm of Information Systems research as its theoretical framework, employed a user-centred approach in application development and testing and attempted to maximize the number of care needs included in the application that was deemed important by the patients.

However, during the user-centred evaluation, more than 1 out of 3 participants mentioned that although the content was very comprehensive, it was also cumbersome. Therefore, in the subsequent review and modification process, the research team focused on making the functions more comprehensive and closer to the needs of patients, while further simplifying the operations. Based on user feedback and multidisciplinary discussions, several functional adjustments were implemented. In terms of simplifying operations, the ability to transfer readings from the blood glucose meter to the application via Bluetooth in "Health Tracking," the option of uploading photos in "See Here: Diet and Exercise" and "Help Me, Detective!," and calorie and exercise calculation functions were introduced. Moreover, e-books in "CEO Knowledge Base" were reorganized and redesigned to ensure that the content was clearer and easier to use. Our findings indicated that despite access to chat rooms and thematic discussions and the opportunity of joining anonymously, some participants were reluctant to engage in group interactions. Therefore, to bring the app functions closer to actual patient needs, and based on user recommendations, a "Q&A Email" section was added, allowing users to ask questions individually. Additionally, to allow individual instant chat with the participants, the research team added a LINE Bot to the chat room. For more urgent or common issues, such as emergency treatment of hyperglycaemia or hypoglycaemia, common acute and long-term complications of T1D, and insulin preservation and precautions, the AI chat bots were used to maintain unrestricted interactions and solve the participants' issues in a timely manner. Moreover, the added "SOS calls" function allows users to call for help with one click in an emergency. Further, icons and pop-up prompts explaining the content and functions of the interfaces were introduced, to ensure that the application was more intuitive and practical.

Furthermore, the research team was aware that it was difficult for most adolescents with type 1 diabetes in the transition period to maintain their HbA1C levels in the normal range (American Diabetes Association, 2021a). Thus, to facilitate their diabetes self-management tasks and increase their enthusiasm in addition to monitoring changes in blood glucose levels, the Healthcare CEO application also allowed users to set targets and completion dates in the HbA1c section. While taking the patient's personal circumstances into account, each HbA1C control or progress target could be discussed and determined jointly by the patient and the doctor. Most study participants believed that such a design was both practical and motivating.



Prototype of Healthcare CEO APP

Final version of Healthcare CEO APP

FIGURE 3 Pictures of Healthcare CEO APP

Cybersecurity is not only a focus of this study but also a duty of application developers (Brown et al., 2019). A small number of participants highlighted concerns about the security of personal information while using the application. Specifically, their concerns included whether their personal information could be accessed by people close to them or be stolen via the application. Therefore, the lock function was added to the application. Furthermore, to ensure personal data security, user authentication and end-to-end data encryption were used for mobile communication, and the advanced encryption standard 256 bits (AES-256) algorithm was adopted to ensure data security.

4.2 | Limitations

Certain limitations of this empirical study would encourage further research. First, due to limited funding, the application was only developed on the Android operating system and not on iOS. However, the Xamarin programming language, which could support cross-platform operating systems, was extensively used by the development team, thereby substantially reducing the cost and time required for the future implementation of the Healthcare CEO application on iOS. Second, the Healthcare CEO application tried to incorporate as many of the patients' care needs as possible. Despite its rich functions that could facilitate the integration of disease management information, it can also discourage the user from using the application due to relatively complicated functions and content. Therefore, by hosting workshops previous to application development, future studies can include target users to jointly determine the content of the application, thereby making it more suitable for users.

5 | CONCLUSION

The Healthcare CEO application is one of the few applications that is based on empirical evidence. Based on Information Systems research, it considers the individual care needs of adolescent patients with type 1 diabetes in the transition period to adulthood. The final version of the application was the result of repeated and rigorous tests run by a multidisciplinary team consisting of medical professionals, patients and programmers. Future research will use a randomized controlled trial (RCT) design to evaluate the effectiveness of the application (Trial registration: listed on Xxxxx, identifier: Xxxxx on Xx. Xx. Xxx.). After it is publicly available for free, the Healthcare CEO application is expected to be extensively used by youth with type 1 diabetes, effectively increasing their choice of disease management tools and improving their quality of care during the transition period.

AUTHOR CONTRIBUTIONS

YTC involved in conceptualization, methodology, data curation, investigation, writing the original draft, project administration and funding acquisition. CW Chang involved in methodology and software. HYY involved in data curation, writing the original draft. PKT involved in methodology, visualization and investigation. FSL involved in data curation and investigation. CW Chen involved in supervision, reviewing and editing. WYL provided the software. CLH

involved in conceptualization, methodology, software, validation, writing the original draft. CA involved in reviewing and editing. PM involved in reviewing and editing and visualization.

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE (http://www.icmje.org/recommendations/)]:

- substantial contributions to conception and design, acquisition of data or analysis and interpretation of data.
- drafting the article or revising it critically for important intellectual content.

ACKNOWLEDGEMENT

The authors thank all the participants to the completion of this study.

FUNDING INFORMATION

The project was funded by the Ministry of Science and Technology under Grant (grant number: MOST 108-2314-B-182-022); and Chang Gung University (grant number: NMRPD1J0341).

CONFLICT OF INTEREST

None

DATA AVAILABILITY STATEMENT

All data are available in this manuscript.

ETHICS STATEMENT

The study was approved by the Ethics Committee of Chang Gung Medical Foundation Institutional Review Board. Submission Ref: 201900547B0, April 29, 2019.

TRIAL REGISTRATION

Future research will use a randomized controlled trial (RCT) design to evaluate the effectiveness of the application. Trial registration: listed on ClinicalTrials.gov, identifier: NCT05022875, on August 21, 2021.

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How to cite this article: Chiang, Y.-T., Chang, C.-W., Yu, H.-Y., Tsay, P.-K., Lo, F.-S., Chen, C.-W., Lin, W.-Y., Hsu, C.-L., An, C., & Moons, P. (2023). Developing the "Healthcare CEO App" for patients with type 1 diabetes transitioning from adolescence to young adulthood: A mixed-methods study. *Nursing Open*, *10*, 1755–1766. https://doi.org/10.1002/nop2.1432