Review Article

Visualizing user demands through storyboarding in the mHealth app development for pregnant women: a conceptual framework

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Abstract: In the co-design process of mHealth apps, the intuitiveness of user experience (UE) and user demands (UDs) are very important to the stakeholders. However, there is little research on how UE and UD are visually presented to stakeholders. Similar literature related to the design perspective of pregnant women is rare. Therefore, there is a need to propose a conceptual framework from a design perspective to visualize UD for stakeholders to enhance their communication efficiency and engage their creativity. In the research, we attempt to propose a storyboarding strategy for developing mHealth apps to visualize UDs for stakeholders. This article presents a systematic literature review synthesis process on selected literature on identifying the best storyboarding strategy of mHealth apps for pregnant women that could visualize UDs. Results from the study found the potential application of a storyboarding strategy for visualizing pregnant ladies' demands in developing the mHealth app's early design phase. This study contributes to proposing a conceptual framework for cartoon-like storyboarding in the early design phase of mHealth app development to visualize pregnant ladies' demands to foster user health behavior. This study is significant for integrating UDs into developing mHealth apps for pregnant women. Future studies are recommended to determine the characteristics of storyboarding in developing mHealth apps for pregnant women.

Keywords: mHealth app development; pregnant women; storyboards; visualize user demands (visualize UDs)

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Introduction

Background

This part will introduce the development status of mHealth apps for pregnant women, the existing issues, and the solutions. With the development of 5G technology, the mHealth app plays a significant role for pregnant women. They can use the mHealth app to track their feta's health, search pregnancy-related health information, and consult with doctors online. However, according to Wang *et al.* [2019], the lack of evidence-based health information leads to lower user adherence (1). As with Bland *et al.* [2020],

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the author's research found that pregnant women were confused about the contents of mHealth apps and doubted the accuracy of the mHealth information (2).

Studies have shown this relates to experts' lack of involvement in developing mHealth apps (1,3). Thus, in recent studies, researchers have realized the importance of stakeholders in developing mHealth apps (4-6).

In these articles, which focus on the stakeholders' role in mHealth app development, Eckman *et al.* [2016] highlighted that the communication efficiency and methods in multidisciplinary teams could affect the mHealth app development process (7). In other words, whether the user demands (UDs) and user experience (UE) can be understood without bias will impact the stakeholders' communicateon fluency (8).

Rationale and knowledge gap

Studies have shown that the UD and UE are presented intuitively to stakeholders (8-11). Talgorn *et al.* [2022] argued that collaboration and ideas sharing could lead to tacit knowledge transfer in stakeholder ecosystems, which is essential for developing new product ideas (8). The author also described how storytelling can engage multidisciplinary teams and generate creative ideas from users' perspectives in an open-minded way.

Subramaniam *et al.* [2022] agreed with Talgorn *et al.* [2022], who stated that visual storyboarding could efficiently engage the medical team's communication and make ideas easy to share with other team members (4,8). However, the research did not mention the storyboarding visualization strategy in developing mHealth apps for pregnant women.

There are many approaches to UD visualization, such as user journey maps, user personas, and scenarios. However, storyboarding was an effective co-design tool for visualizing UE (12) and engaging team members in co-creativity (13).

Objective

Thus, this research aims to propose a conceptual framework from a design perspective to visualize pregnant women UD to engage stakeholder collective creativity.

Research methodology

Systematic literature review synthesis approach

The literature review in this paper adheres to the systematic literature review synthesis approach. This method, recognized as a distinct type of literature review, focuses on establishing the theoretical foundation by analyzing selected literature during the initial phase of research conceptualization (14-16). By employing Ibrahim's research question (RQ) construct classification, this study identifies three core RQ constructs: "Who", "What", and "How", which are crucial for developing the primary RQs (17).

In the study, "Who" denotes the group or element affected by the research, "What" refers to the specific information or knowledge that is required to address the issue, and "How" indicates the intended effect or impact of the research (17).

In our research, the "Who" is "mHealth apps development for pregnant women", the "What" is "storyboarding", and the "How" is "visualize user demands". According to Ibrahim's RQ category, the main RQ in this research is: How to visualize UDs through storyboarding in developing mHealth apps for pregnant women? Based on the main RQ, we adopted the systematic literature review synthesis approach to construct a conceptual framework to answer the RQ. Therefore, through Ibrahim's [2011] Eagle System, our main RQ was divided into three sub-RQs (18). The first is about the "Who": What key components should be involved in mHealth app development for pregnant women? The second is about the "What": What is the best storyboarding strategy for developing a mHealth app for pregnant women? The third one is about "How": How do we visualize UDs in developing mHealth apps for pregnant women through a storyboarding strategy? Thus, based on the three sub-RQs, we conducted the literature review through the databases Web of Science (WOS), Scopus, and PubMed with the keywords "mHealth apps development for pregnant women", "storyboarding", and "visualize user demands".

The inclusion and exclusion criteria

Abstracts from selected journals are then reviewed based on their main contents and conclusions, how their work will support future research, and which areas need strengthening (see *Table 1*).

The synthesized analysis process

As we can see from *Figure 1*, for the "Who" construct, when we type the keywords "health pregnant women" in the WOS, Scopus, and PubMed databases, one by one. A total

Table 1 The inclusion and exclusion criteria

Research construct	The sub-theme	RQ	Inclusion criteria	Exclusion criteria
Who	mHealth application development for pregnant women	What are the key components that should be involved in developing a mHealth application for pregnant women?	The title and abstract include "pregnant women" AND "mHealth"	Studies not eligible according to title, keywords, abstract, introduction, and conclusion removed
What	Storyboarding strategy	What is the best storyboarding strategy for developing mHealth apps for pregnant women?	The title and abstract include "storyboarding" OR "storyboards"	
How	Visualize UDs	How to visualize UDs through storyboarding in developing mHealth apps for pregnant women?	The title and abstract include "visualize user demands" OR "user demands visualization"	

RQ, research question; UD, user demand.

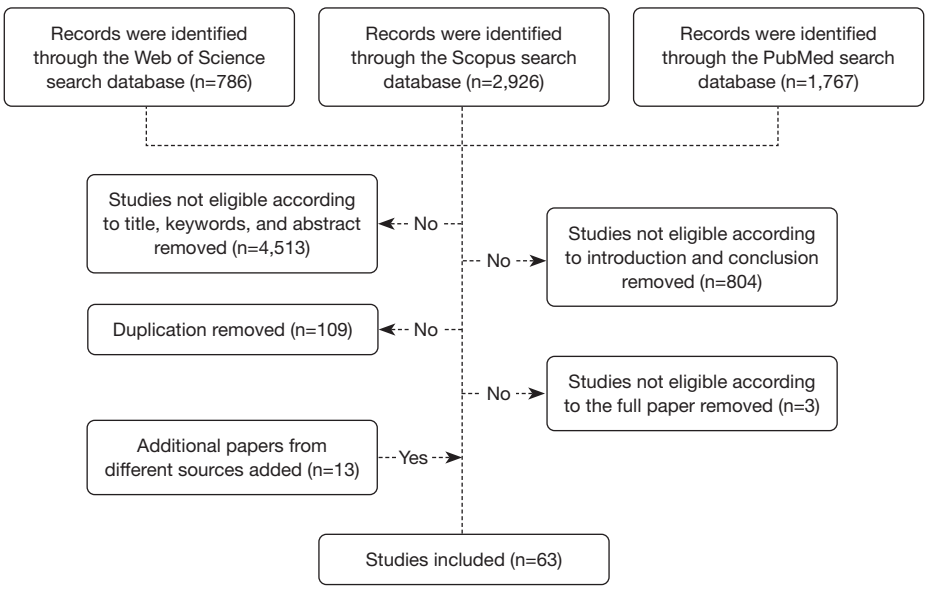

Figure 1 The workflow of the systematic literature review synthesis process.

of 7,809 articles came up in the initial search time. For the "What" construct, when we put the keywords "storyboards" OR "storyboarding" into the three databases, we found 2,926 articles. For the "How" construct, when we followed the above search steps with the keywords "visualize user demands" OR "user demands visualization", we found 1,767 articles.

Thus, 5,479 articles were selected for the filter section after the first phase. Studies not eligible according to the title, keywords, and abstract were removed from 4,513 articles. The studies that were not eligible according to the introduction and conclusion were removed from 804 articles, and then we removed the duplication articles 109 and according to three full papers. Finally, we added the additional 13 papers from different sources.

Results of the systematic literature review synthesis process

In total, 63 research articles were selected because of the full abstract for detailed review and then assigned to specific subtopics based on the importance of their existence (see *Table 2*). The results of this stage then generated a comprehensive summary for each of the main topics, which was further cross-analyzed to integrate and prioritize

Table 2 Reference list

Issue	Author	Year	Title	Methods	Source
Fetal health	Scaioli *et al.* (19)	2015	Pregnancy and internet: sociodemographic and geographic differences in e-health practice. Results from an Italian multicentre study	Physically survey	WOS, Scopus, PubMed
	Farrant and Heazell (20)	2016	Online information for women and their families regarding reduced fetal movements is of variable quality, readability and accountability	Systematic search	WOS, Scopus, PubMed
Prenatal stress	Norbeck and Tilden (21)	1983	Life Stress, Social Support, and Emotional Disequilibrium in Complications of Pregnancy: A Prospective, Multivariate Study	Multivariate approach	WOS, Scopus, PubMed
	Abdelmalak *et al.* (22)	2024	Consideration of inequalities in effectiveness trials of mHealth applications – a systematic assessment of studies from an umbrella review	Synthesized systematic reviews	WOS, Scopus, PubMed
MFA	Alhusen *et al.* (23)	2012	The influence of maternal-fetal attachment and health practices on neonatal outcomes in low-income, urban women	Longitudinal descriptive study	WOS, Scopus, PubMed
	Ross and Gao (24)	2016	Overcoming the language barrier in mobile user interface design: A case study on a mobile health app	Case study	Scopus
	Smith *et al.* (25)	2020	The relationship between digital media use during pregnancy, maternal psychological wellbeing, and maternal-fetal attachment	Self-report questionnaire	WOS, Scopus, PubMed
Pregnancy complications	Lyall *et al.* (26)	2012	Pregnancy complications and obstetric suboptimality in association with autism spectrum disorders in children of the nurses' health study II	Questionnaire	WOS, Scopus, PubMed
	Da Costa *et al.* (27)	1998	A prospective study of the impact of psychosocial and lifestyle variables on pregnancy complications	Interviews and questionnaire	WOS, Scopus, PubMed
Self-care practice	Aboulkhair Farag *et al.* (28)	2022	Effect of Educational Session on Knowledge, Self-Care Practices and Perception Regarding Gestational Weight Gain among Advanced Age Pregnant Women	Quasi experimental design	Research Gate
	Boonpongmanee *et al.* (29)	2003	Resourcefulness and Self-Care in Pregnant Women With HIV	Predictive model testing design	WOS, Scopus, PubMed
	Bamanikar and Kee (30)	2013	Knowledge, Attitude and Practice of Oral and Dental Healthcare in Pregnant Women	Cross-sectional descriptive and analytical study	PubMed
	Moawed *et al.* (31)	2014	Knowledge and oral health care practices among Saudi pregnant women	Cross-sectional survey	Scopus
Nutrition	Hrolfsdottir *et al.* (32)	2016	Maternal diet, gestational weight gain, and inflammatory markers during pregnancy	Cross-sectional analysis	WOS, PubMed
	Vahter (33)	2009	Effects of Arsenic on Maternal and Fetal Health	Narrative description	WOS, PubMed
	Doyle *et al.* (34)	2017	Determinants of dietary patterns and diet quality during pregnancy: a systematic review with narrative synthesis	Literature review	WOS, PubMed
	Chen *et al.* (35)	2024	Effects of an mHealth intervention on maternal and infant outcomes from pregnancy to early postpartum for women with overweight or obesity: A randomized controlled trial	A randomized controlled trial	WOS, Scopus, PubMed
Pregnancy complication, self-care practice	Da Costa *et al.* (27)	1998	A prospective study of the impact of psychosocial and lifestyle variables on pregnancy complications	Interviews and questionnaires	WOS, Scopus, PubMed
	Islam and Sultana (36)	2019	Risk factors for pregnancy related complications among urban slum and non-slum women in Bangladesh	Questionnaires	WOS, Scopus, PubMed
	Aboulkhair Farag *et al.* (28)	2022	Effect of Educational Session on Knowledge, Self-Care Practices and Perception Regarding Gestational Weight Gain among Advanced Age Pregnant Women	Quasi experimental design	Research Gate

Table 2 (*continued*)

Table 2 (*continued*)

Issue	Author	Year	Title	Methods	Source
Self-care practice, DTA	Boonpongmanee *et al.* (29)	2003	Resourcefulness and Self-Care in Pregnant Women With HIV	A randomized controlled trial	WOS, Scopus, PubMed
	Moawed *et al.* (31)	2014	Knowledge and oral health care practices among Saudi pregnant women	Questionnaires	WOS, Scopus
	Omidvar *et al.* (37)	2018	Associations of psychosocial factors with pregnancy healthy life styles	Questionnaires	WOS, Scopus, PubMed
	Baharom (38)	2017	Player-centric emotional design for digital games: an empirical exploration in visual aesthetics	Mixed methods	Research Gate
DTA, storytelling	Collins (39)	2018	Creative Research: The Theory and Practice of Research for the Creative Industries	Not applicable	Research Gate
	Seeber *et al.* (40)	2015	A Design Thinking Approach to Effective Vaccine Safety Communication	DTA	Scopus, PubMed
	Petersen and Hempler (41)	2017	Development and testing of a mobile application to support diabetes self-management for people with newly diagnosed type 2 diabetes: a design thinking case study	DTA	WOS, Scopus, PubMed
	Fareed *et al.* (42)	2023	Developing and testing an integrated patient mHealth and provider dashboard application system for type 2 diabetes management among Medicaid-enrolled pregnant individuals based on a user-centered approach: Mixed-methods study	Mixed-methods study	WOS, Scopus, PubMed
	Fabri *et al.* (43)	2016	Using design thinking to engage autistic students in participatory design of an online toolkit to help with transition into higher education	DTA	Scopus
	Marko-Holguin *et al.* (44)	2019	A Two-Way Interactive Text Messaging Application for Low-Income Patients with Chronic Medical Conditions: Design-Thinking Development Approach	Design thinking process with qualitative approach	WOS, Scopus, PubMed
	Hou *et al.* (45)	2020	The Development of a Mobile Health App for Breast Cancer Self-Management Support in Taiwan: Design Thinking Approach	Design thinking process with qualitative approach	WOS, Scopus, PubMed
	Barber (46)	2016	Digital storytelling: New opportunities for humanities scholarship and pedagogy	Literature review	Scopus
Storytelling, narrative visualization	Segel and Heer (47)	2010	Narrative Visualization: Telling Stories with Data	Case studies	WOS, Scopus, PubMed
	Gershon and Page (48)	2001	What storytelling can do for information visualization	Case study	WOS, Scopus
	Mou *et al.* (49)	2013	From storyboard to story: Animation content development	Case studies	Research Gate
	Lichaw (50)	2016	The User's Journey: Storymapping Products That People Love	Not applicable	Google Books, WOS
	Buskermolen and Terken (51)	2012	Co-constructing stories: a participatory design technique to elicit in-depth user feedback and suggestions about design concepts	Case study with participatory study	Scopus
	Talgorn *et al.* (8)	2022	A Storytelling Methodology to Facilitate User-Centered Co-Ideation between Scientists and Designers	Case study with participatory study	WOS, Scopus
	Danko (52)	2006	Humanizing Design through Narrative Inquiry	Case study with exploratory study	Research Gate
	Bunning *et al.* (53)	2017	Developing the personal narratives of children with complex communication needs associated with intellectual disabilities: What is the potential of Storysharing	Case studies with post intervention study	WOS, Scopus, PubMed
	Woodward *et al.* (54)	2023	In the hands of users with intellectual disabilities: co-designing tangible user interfaces for mental wellbeing	Case study with co-design approach	Scopus

Table 2 (*continued*)

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Issue	Author	Year	Title	Methods	Source
Narrative visualization co-creation	Dash (55)	2021	An exploratory study on design process in architecture: Perspective of creativity	Case study	Scopus
	Barkman (56)	1985	The Storyboard Method: A Neglected Aspect of Organizational Communication	Not applicable	Scopus
	Gershon and Page (48)	2001	What storytelling can do for information visualization	Case study	WOS, Scopus
	Naicker *et al.* (57)	2020	Restorying lived lives in educational research: Storyboarding as a creative space for scholarly thinking in narrative analysis	Case study	WOS, Scopus
	Vertelney and Curtis (58)	1990	Storyboards and Sketch Prototypes for Rapid Interface Visualization	Not applicable	Research gate
	Mottet and Jones (59)	1988	The poster session: an overlooked management tool	Case study	WOS, Scopus, PubMed
	Truong *et al.* (60)	2006	Storyboarding: An Empirical Determination of Best Practices and Effective Guidelines	Empirical study with formative studies	Scopus
	Fraser (61)	2003	Project storyboards: catalysts for collaborative improvement	Case studies	Research gate
	Krause (62)	2018	Storyboards Help Visualize UX Ideas	Not applicable	External papers from Nielsen Norman Group
	SlideModel (63)	2022	What is a storyboard and how to use it in product design	Not applicable	External papers from Nielsen Norman Group
	Mou *et al.* (49)	2013	From storyboard to story: Animation content development	Case study	Research Gate
	Bran (64)	2010	Message in a bottle Telling stories in a digital world	Qualitative research	WOS, Scopus
	Talgorn *et al.* (8)	2022	A Storytelling Methodology to Facilitate User-Centered Co-Ideation between Scientists and Designers	Qualitative research using case study with multidisciplinary workshops	WOS, Scopus
Co-creation, storyboarding strategy for visualizing pregnant women's demands in development of mhealth apps	Sander and Stappers (65)	2008	Co-creation and the new landscapes of design	Case study	Research Gate
	Isa and Liem (66)	2021	Exploring the role of physical prototypes during co-creation activities at LEGO company using case study validation	Case study	WOS, Scopus
	Naicker *et al.* (57)	2020	Restoring lived lives in educational research: Storyboarding as a creative space for scholarly thinking in narrative analysis	Case study	Research Gate
	Lottier (67)	1986	Storyboarding Your Way to Successful Training	Not applicable	WOS

Table 2 (*continued*)

Table 2 (*continued*)

Issue	Author	Year	Title	Methods	Source
Storyboarding strategy for visualizing pregnant women's demands in development of mhealth apps	Seeber *et al.* (40)	2015	A Design Thinking Approach to Effective Vaccine Safety Communication	Case study with DTA	Scopus, PubMed
	Truong *et al.* (60)	2006	Storyboarding: An Empirical Determination of Best Practices and Effective Guidelines	Case study	Scopus
	Dederichs *et al.* (68)	2022	Piloting an Innovative Concept of e–Mental Health and mHealth Workshops With Medical Students Using a Participatory Co-design Approach and App Prototyping: Case Study	Case study	WOS, Scopus, PubMed
	Vertelney and Curtis (58)	1990	Storyboards and Sketch Prototypes for Rapid Interface Visualization	Not applicable	Research Gate
	Gershon and Page (48)	2001	What storytelling can do for information visualization	Case studies	WOS, Scopus
	Mou *et al.* (49)	2013	From storyboard to story: Animation content development	Case study	Research Gate
	Hayes and Childress (69)	1999	Fairy tales of storyboarding	Case study	Scopus, PubMed
	Naicker *et al.* (57)	2020	Restorying lived lives in educational research: Storyboarding as a creative space for scholarly thinking in narrative analysis	Case study	Research Gate
	Limke *et al.* (70)	2022	Case Studies on the Use of Storyboarding by Novice Programmers	Qualitative research with case studies	WOS, Scopus
	Manning (71)	1998	Understanding Comics: The Invisible Art	Not applicable	WOS, Scopus
	Truong *et al.* (60)	2006	Storyboarding: An Empirical Determination of Best Practices and Effective Guidelines	Qualitative research-semi-structured interview	Scopus

DTA, design thinking approach; MFA, maternal-fetal attachment; WOS, Web of Science.

the synthesis summary and analyze the likelihood of storyboards visualizing user needs in developing mHealth apps for pregnant women. Key synthetic extracts are formed using the Eagle system by following the steps in the point of departure (POD) tree diagram and documenting the synthesis process.

Results

The 63 articles adopted multiple approaches to solving the issue of visualizing UDs in developing a mHealth app for pregnant women through a storyboarding strategy. Six of the 69 in *Table 2* were reanalyzed in the "mHealth apps for pregnant women" and "visualize user demands" sections. Gershon and Page's research [2001] was cited three times in this study, and Mou *et al.*'s research [2013] was quoted in the storytelling and UDs visualization section (48,49). Vertelney and Curtis's research [1990] was mentioned in the "narrative visualization" and "storyboarding strategy" sections (58). Naicker *et al.*'s research [2020] was cited in the "co-creation" and storyboarding strategy" section (57). Truong *et al.*'s research [2006] was cited in the section of "co-creation and storyboarding" (60).

It can be noted that these articles, which were cited many times, were closely related to our study. The section on mHealth apps for pregnant women includes several themes: fetal health tracking, the management of nutrition weight, and pregnancy complications. Regarding the storyboarding issue, the subthemes are co-design, narrative visualization, and co-creativity. Many studies adopted more than one research methodology, such as case studies and mixed methods.

What are the key components in developing mHealth apps for pregnant women?

More and more women search the internet for health information during pregnancy, and their search action aims to assess the health of the fetus and themselves (72). Study has shown that women use pregnancy apps during their first pregnancy and switch to maternal health apps after giving birth (73). The health information that pregnant ladies are searching for includes body fetal health tracking, nutrition, pregnancy complications, monthly checkups, physical

training, and emotional and sleeping management (74).

mHealth apps features

Fetal health

Fetal development and its associated outcomes during pregnancy have garnered significant attention among researchers. Scaioli *et al.* [2015] highlighted the importance of understanding fetal health, as it remains a highly searched topic by pregnant women (19). Furthermore, Farrant and Heazell [2016] reveal a concerning statistic that 46–50% of women experience decreased fetal movements and abnormal fetal status before a diagnosis of stillbirth (20). This highlights the criticality of focusing on fetal health as a primary research area. However, the authors did not focus on the methods of e-Health to address this issue.

Prenatal stress

Norbeck and Tilden conducted a prospective, multivariate study on life stress, social support, and emotional disequilibrium in pregnancy complications (21). The author highlighted that life stress and pregnancy complications, as well as emotional issues, have a significant impact on fetal health (21). Omowale *et al.* [2022] stated that the daily stress during pregnancy includes social inequalities in education, health care, and income, and the government should pay more attention to achieving maternal health equity (75). Regarding the methods to decrease prenatal stress, Norbeck and Tilden [1983] mentioned that social and family support for pregnant women is important (21). Abdelmalak *et al.* [2024] argued that mHealth apps could potentially reduce existing healthcare inequities with comparable internet penetration and education because they can act as one of the methods for pregnant women in poor areas to reduce prenatal stress (22).

Maternal-fetal attachment (MFA)

One influential factor in promoting healthy behaviors during pregnancy is MFA, which encompasses the interactions and emotional connection between women and their unborn children (23). They emphasized that lower MFA levels are associated with reduced engagement in healthcare practices during pregnancy and a higher likelihood of adverse outcomes. Hassan and Hassan [2017] researched the predictors of MFA among pregnant women, and they argue that the visualization of fetal details helps women build healthy MFA among pregnant women and their unborn fetuses (76).

However, Smith *et al.* [2020] researched the relationship between digital media use during pregnancy, maternal psychological well-being, and MFA (25). They highlighted no evidence of a relationship between digital media use and MFA. However, their research only focused on the relationship between digital media use during pregnancy, psychological well-being, and MFA. Thus, our study agrees with Alhusen *et al.* [2012] and Hassan and Hassan [2017] because their research directly points to the relationship between women and their unborn children and the method to strengthen the bond (23,76). However, they did not mention the design perspective on this issue. Furthermore, though Ross and Gao [2016] researched the development of a user interface for mobile health apps for women, they did not focus on the pregnant women issue (24). Therefore, this study focuses on the design perspective to visualize fetal details to help build MFA among pregnant women and their fetas.

Nutrition

Hrolfsdottir *et al.* [2016] researched maternal diet, gestational weight gain, and inflammatory markers during pregnancy (32). They highlighted that nutrition during pregnancy is widely recognized as a crucial factor affecting fetal development, with nutrients transmitted to the fetus through the placenta. Various studies support that inadequate nutritional supply during fetal development can affect physical health and cognitive abilities in adulthood (33,34). While these authors highlighted the link between maternal nutrition and fetal health, they did not address strategies for guiding pregnant women in achieving a nutritious diet. Chen *et al.* [2024] conducted a randomized controlled trial on the effects of a mHealth intervention on maternal and infant outcomes from pregnancy to early postpartum for women with overweight or obesity (35). According to Doyle *et al.* [2017], young pregnant women who have a low education level or do not adhere to general health advice are at a higher risk of inadequate dietary intake (34).

Chen *et al.* [2024] highlighted that mHealth helped women with obesity to successfully manage their GWG and body weight before childbirth and newborns' birth weight (35). Though our research agrees with them, they did not focus on the design approach to developing mHealth apps for pregnant women on the nutrient issue. Therefore, this study will focus on evidence-based interventions, providing pregnant women with nutritional information to foster healthy dietary practices and promote optimal fetal development.

Pregnancy complication

Pregnancy complications were related to many aspects; the serious symptoms would influence the health of pregnant women and fetuses. Lyall *et al.* [2012] stated that women

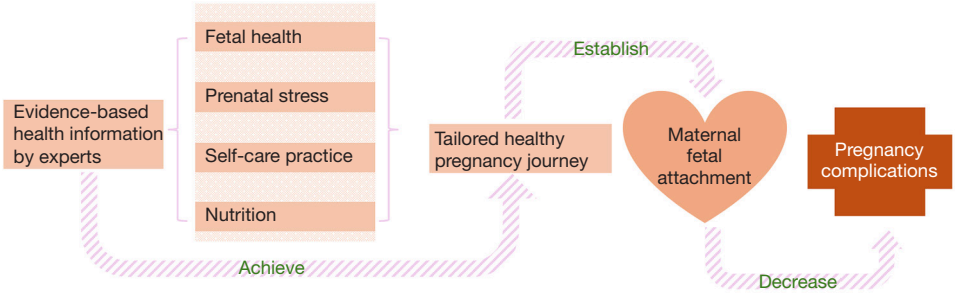

Figure 2 Proposed conceptual framework for MFA. MFA, maternal-fetal attachment.

who have pregnancy complications were more likely to give birth to a baby with autism (26). Da Costa *et al.* [1998] conducted a prospective study of the impact of psychosocial and lifestyle variables on pregnancy complications, and they highlighted that the primary women were more likely to experience gestational and intrapartum complications than multiparous women (27). This research was supported by Islam and Sultana [2019]. They researched the risk factors for pregnancy-related complications among urban slum and non-slum women in Bangladesh (36). The authors highlighted that preterm births, primiparas, unwanted pregnancies, and low economic status may increase the risk of complications during pregnancy, and the research highlighted that the lower the pregnancy complications, the lower the death for pregnant women. Thus, it is very important for women who are on their first pregnancy, an unwanted pregnancy, and with lower family income to have evidenced and accurate health information sources to decrease the pregnancy complications risk. Therefore, our research will focus on the target group to conduct the research.

Self-care practice

Self-care practice variables for pregnant women involve a range of behaviors and activities to promote their physical and mental well-being during pregnancy. A large number of scholars researched the issue. The study conducted by Aboulkhair Farag *et al.* [2022] suggests that women who maintain their health during pregnancy and postpartum are more likely to have improved delivery outcomes and long-term health. However, existing research predominantly focuses on self-care practices during pregnancy, types of care services, and interventions related to care service courses (28). Boonpongmanee *et al.* [2003] stated the potential of learned resourcefulness in reducing depression and promoting prenatal self-care practices among pregnant Thai women (29). Bamanikar and Kee [2013] emphasize the importance of intensive dental health education in improving oral and dental health, leading to positive pregnancy outcomes (30). Moawed *et al.* [2014] stressed the crucial role of midwives in enhancing perinatal outcomes and maternal dental health through risk factor screening and education on prevention strategies (31). Aboulkhair Farag *et al.* [2022] demonstrated that educational sessions positively impact knowledge, self-care practices, and perception of proper weight gain during pregnancy among advanced-age pregnant women (28). Moreover, Omidvar *et al.* [2018] propose addressing psychological risk factors during pregnancy, including home and social support, social interaction needs and entertainment, and pregnancy ecology, which significantly influence pregnant women's psychological well-being (37).

As shown by Bamanikar and Kee [2013] and Aboulkhair Farag *et al.* [2022], educating pregnant women about pregnancy care is a good practice. Our research agrees with the two viewpoints and provides pregnant women with pregnancy care education knowledge through the mHealth app so they can get health care services.

Thus, we merge and screen the valid highlight points of the article in a systematic and synthesized way to filter and merge them to answer the RQ. Finally, we will create a research sentence of no more than 40 words, and the logistic research sentence includes phenomenon, cause, and effect (77).

By providing health information on fetal health, prenatal stress, self-care practice, and nutrition, we aim to help women achieve a tailored, healthy pregnancy journey for establishing MFA and reducing pregnancy complications (see *Figure 2*).

mHealth apps development strategy

Design thinking approach (DTA)

DTA and research tools incubate ideas and create

innovative solutions within teams and as individuals (38,39). Product development stakeholders can participate in the design process and engage their creative ideas on users' requirements (78).

The design thinking process includes empathizing, defining, ideating, prototyping, and testing. Empathizing involves user involvement. The prototype phase involves quickly producing many prototypes, while the ideation phase involves brainstorming and problem-solving. Last, the test phase can involve final implementation. From a design standpoint, design thinking can help make sense of things (39).

(I) DTA in mHealth development

Collins [2018] researched the design-thinking approach to effective vaccine safety communication, and he highlighted that the design-thinking approach (understanding, observing, point of view, ideating, prototype, and testing) can generate ground-breaking ideas by muti-disciplinary teams' expertise and different points of view towards effective vaccine safety communication among parents (39). Seeber *et al.* [2015] conducted a design thinking case study on developing and testing a mobile application to support diabetes self-management for people with newly diagnosed type 2 diabetes (40). The author highlighted that the app was developed using a design-based approach that included three major phases: inspiration, ideation, and implementation. The thinking process used in developing and implementing the mHealth apps was crucial to creating value for users (41).

However, Seeber *et al.* [2015] and Petersen and Hempler [2017] are focused on the DTA for end users to create value for them, and they did not mention the participatory requirements of these end users (40,41).

In 2023, Fareed *et al.* conducted an evidence-based framework for creating inclusive and personalized mHealth solutions, designing a solution for Medicaid-eligible pregnant women individuals with uncontrolled type 2 diabetes. In their research, they argued that the user-centered design (UCD) engages stakeholders based on principles of UCD and iterates with stakeholders to refine intervention that could help Medicaid-enrolled pregnant individuals with uncontrolled type 2 diabetes, the solutions with an inclusive and personalized evidenced development framework (79).

Thus, our research agrees with Fareed's [2023] viewpoint because they mentioned the UCD approach to generating personalized, evidence-based information for pregnant women. However, they did not focus on pregnant women with health conditions; they focused only on the UCD approach. Our research will focus on the DTA to engage stakeholders caring about end-UDs in developing mHealth apps for pregnant women to generate personalized, evidence-based information.

(II) DTA could engage stakeholders' creativity

Fabri *et al.* [2016] conducted research by using design thinking to engage autistic students in the participatory design of an online toolkit to help with the transition into higher education, and they highlighted that the five-step DTA engaged multiple stakeholders at different points, including empathies, define, ideate, prototype, and test, and the design thinking proved a suitable framework for involving Autism students in the creation of solutions that serve their needs (43). In addition, Marko-Holguin *et al.* [2019] conducted a design-thinking development approach on a two-way interactive text messaging application for low-income patients with chronic medical conditions (44). The author highlighted that design thinking (empathy, identifying needs and defining the needs-based outcome through a shared viewpoint across multiple stakeholders, user ideation through a multidisciplinary team approach, creating a prototype, and testing the prototype) can develop a tool to meet the engagement needs of patients with complex health care needs and be user-friendly for health care staff. Fabri *et al.* [2016] and Marko-Holguin *et al.* [2019] mentioned the DTA as the DTA to engage stakeholders in developing mHealth apps for end users and satisfying their participatory needs (43,44).

In 2020, Hou *et al.* conducted research through the DTA in the development of a mobile health app for breast cancer self-management support in Taiwan (45). The author highlighted that the DTA could reduce the gap between end users and developers and help facilitate disease self-management for Taiwanese women with breast cancer.

Therefore, our research will use the DTA of DTA to develop mHealth apps for pregnant women to fulfill their participatory requirements and get their real needs and wants.

The process of conceptual framework formation

This study explores the DTA to develop mHealth apps for pregnant women to foster healthy behavior through enhancing MFA. This paper records the critical health information for women during pregnancy to determine what components need to be included in the mHealth apps for pregnant women to guide health behavior. The results show that exploring the health information, including fetal health, stress management, pregnancy complications,

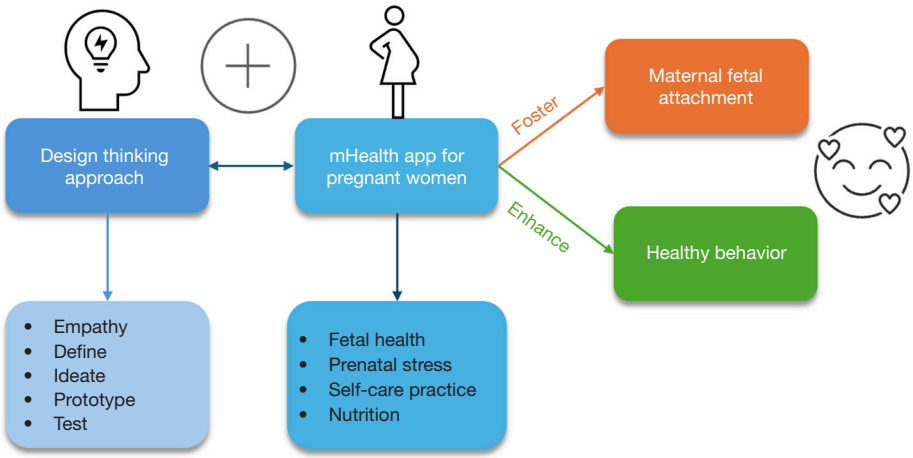

Figure 3 Proposed conceptual framework for DTA of mHealth apps. DTA, design thinking approach.

nutrient diet, and physical exercise, and applying them in developing mHealth apps to enhance MFA and foster health behavior. The study proposes to explore the DTA to engage stakeholders' creative ideas in mHealth apps for pregnant women. The DTA (e.g., empathize, define, ideate, prototype, and test) can involve end users in the mHealth apps to involve their user needs and experience and make sense of things. The results show that the user-centered thinking approach can identify the end user's experience and, through multi-stakeholder involvement, satisfy the involvement of end users. To sum up, this study proposes to focus on analyzing the health information critical to know for pregnant women and the UCD DTA to involve pregnant women in the mHealth apps for engaging stakeholders' creative ideas (see *Figure 3*).

What is the best storyboarding strategy for developing mHealth apps for pregnant women?

Storytelling

Storytelling can be defined as the social and cultural activity of sharing stories (80). It is one way of sustaining core relationships in society, family, and community because storytelling can reflect narrative thinking. It gives an account of a series of events, facts, etc., given in order and connects the notion of a chain of causally related events (47).

Traditional storytelling is rooted in human culture, physiology, and psychology (81); according to the author, storytelling has even been referred to as "the world's second-oldest profession" and an important part of human culture. By sharing their experiences or emotions, speakers can feel more comfortable and express their thoughts (49). A well-told story conveys great quantities of information in relatively few words in a format that the listener or viewer easily assimilates (46).

Storytelling can be used in research to imagine, map out, and communicate product or service experiences and in early testing with story prototypes to uncover latent constraints and desirables (50). Thus, co-storytelling has been used as a participatory design technique to stimulate in-depth user feedback on early concepts or ideas for future applications (51). According to Talgorn *et al.* [2022], stories can be used as experiential artifacts for user-centered innovation and as boundary objects for cooperative ideation and co-creation (8). Though, Talgorn *et al.* [2022] regards the story as the UCD approach in product design for co-creation, they did not mention the application in mHealth apps to cooperate with end users. Thus, our research will focus on the storytelling approach as the UCD to be integrated in the mHealth apps to co-creation with end users.

Like designing, stories are a creative process of selecting and organizing chaotic events to show how diverse elements form meaningful experiences (52). According to Danko [2006], the six common elements of narrative outlined above can be distilled into four key elements: voice, setting, action, and resolution. The voice is the narrator's underscoring of the significance and meaning of the action. The setting is the time and place, which introduces the situation and characters. The action is the dilemma using a sequence of events. The resolution is what happens at the end of the story. Moreover, Bunning *et al.* [2017] argued that the story episode, denoting a particular moment in time, exhibited

a coherent narrative structure comprising an introduction, conclusion, pivotal moment, climax, an allusion to emotions or significance, and a high point (53).

However, according to our literature review on the storytelling tools method, only Danko [2006] and Bunning *et al.* [2017]—the only two articles provided the details of the storytelling key element; the other research only focused on the functions of storytelling from the perspective of education, design process, and even management. Thus, in our research, we will use the four storytelling elements: introduction (voice), conclusion (resolution), pivotal moment (setting), action (an allusion to emotions or significance), and a high point (52,53).

Narrative visualization

Gershon and Page [2001] put forth the conceptualization of information visualization. It is the process of converting data, knowledge, and information into a format in which the human visual system is required to perceive the contained information (48). The use of visual, creative methods helps maintain engagement and promote idea generation (54).

Hence, to establish a connection between the client's specifications and the designer's thought process, it is essential to employ visual language and communication that facilitate the client's comprehension of the expert's technical expertise in its basic form (55). Also, while creating a visually depicted production may be challenging, images are frequently the most effective means of communicating the significance of a set of instructions (56).

However, an effectively narrated story communicates vast amounts of knowledge using comparatively few words, thereby employing a format readily assimilated by the audience or observer. Like visuals, it contains substantial information that a reviewer can rapidly comprehend. Nevertheless, images are prone to uncertainties that may necessitate declarative statements to clarify them (48).

Using storyboards as a visual aid for comprehension could illuminate the data interpretation and meaning formation process through narratives (57). A storyboard is a visual depiction of the script consisting of a series of individual images, each symbolizing a unique event or narrative aspect. It helps to illustrate the interaction between the user and the computer (58). Storyboards function as early sketches that depict actions sequentially. They can also provide an initial user interface description and are essential for production planning and debate. Storyboards are frequently employed as a means of communication. They are implemented to enhance the prominence of information, whether in a conference, workshop, or the workplace (59).

Truong *et al.* [2006] conducted research on storyboarding through an empirical determination of best practices and effective guidelines (60). They highlighted that the use of text, inclusion of people, level of detail, number of panels, and representation of the passage of time are very important elements of a storyboard. However, the study demonstrates they are being successfully used in the human-computer interaction (HCI) class. Thus, in our research, we will integrate the storyboarding elements into the early design phase of mHealth apps to visualize UDs.

Storyboard is an effective means of sharing information (61,63). The series of storyboards are often used to describe a fragment of the user journey and several of them may be needed to capture the different branches. The author also stated that a storyboard is meant to tell a story and to form a shared understanding, rather than a polished, refined artifact. The author supported the solid point by creating a storyboard that should be quick and straightforward, and the important content is the experience and interactions, not the overall look and feel. A researcher from Nielsen Norman Group proposed the storyboard process: (I) conduct customer/user research; (II) document the current UE; (III) strategize the new UE; (IV) sketch the basic story; (V) notes and scripts; and (IV) review and iterate (62). However, in Mou *et al.*'s [2013] and Bran's [2010] research, digital tools and software have made storytelling easier and more convenient for people of all ages to create (49,64). They all agreed that digital storytelling covers all the elements of traditional stories, even if can be regarded as the modern extension of the ancient art of storytelling which is now interwoven with digitalized stills.

Fraser's [2003] and Krause's [2018] opinions are supported in our research because storyboards provide a visual narrative that generates empathy and communicates the context in which a technology or form factor will be used (61,62). Our research using storyboards aims to easily and understandably get the narrative experience visualization from end-users.

In summary, our research integrates storyboards into the early design phase of mHealth apps to visualize UDs in a narrative and empathetic way.

Co-creation

Definition

Sanders and Stappers [2008] took co-creation to refer to any act of collective creativity, i.e., creativity that two or

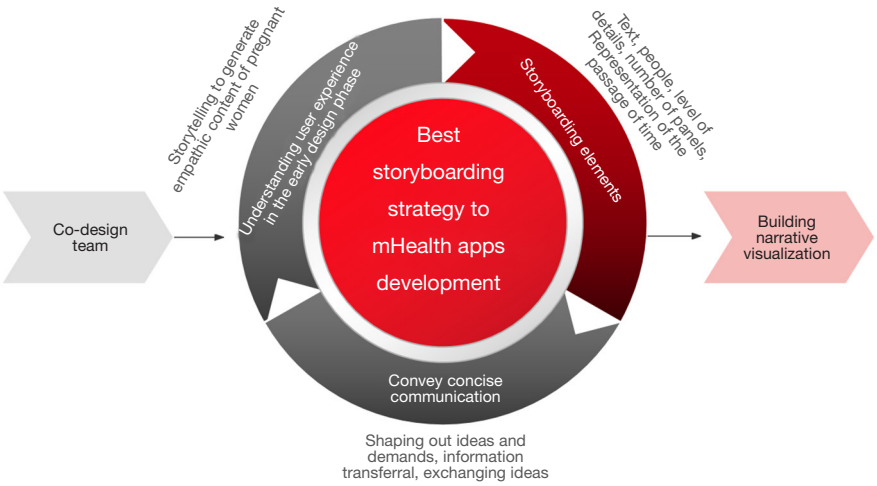

Figure 4 The proposed conceptual framework for storyboards strategy of mHealth apps development.

more people share, and co-design is a specific instance of co-creation (65). In their study, they also regard co-design in a broader sense, referring to the creativity of designers and people not trained in design working together in design development. In 2022, their viewpoint was supported by Talgorn *et al.* [2022]. In Talgorn's [2022] research, co-creation is a collaborative innovation where ideas are shared and improved with experts and stakeholders (8). Thus, end users, as experts in the field of use of their products, have their own language to express their feelings and emotions about the product; in our research, the product can be described as a mobile app. Thus, co-creation with them could reach the product's target and improve its UE.

Storyboarding can better understand the use of physical prototypes concerning knowledge integration and experience and expertise sharing in the co-creation process (64,66). UCD or DTA have grown tremendously to drive interdisciplinary creative ideation, place the user perspective at the center of the creative process in the early stages of innovation, boost innovativeness, and reduce cognitive bias.

Talgorn *et al.* [2022] researched a storytelling methodology to facilitate user-centered co-ideation between scientists and designers. The author highlighted that participatory storytelling has the potential to facilitate multidisciplinary collaboration and bring user-centered thinking to non-design stakeholders to envision user needs in future scenarios and new ecosystems (8). However, the research did not mention how to co-create with end-users to meet their needs. Therefore, our research will focus on co-creation with end-users to meet their needs through storytelling.

Application

According to Talgorn *et al.* [2022], the story is the boundary object for co-ideation between designers and scientists. Thus, on the left side of the story is design expertise, including mindset and language, and on the right side is scientific expertise, including mindset and language (8). We supported this viewpoint; however, our research will focus on the story as a boundary for co-ideation between designers and end-users.

Approach

Referring to the co-creation approach in the design process, Sanders and Stappers [2014] proposed alternative methods and tools to analyze people's needs, wants, and design problems in human-centered design (82). They proposed a co-creation process where designers and stakeholders are involved in creative acts of making by involving probes, toolkits, and prototypes during pre-design and design development process. In addition, Sanders and Stappers's [2014] research was supported by Isa and Liem's [2021] research; the authors highlighted the iterative co-creation process, in which every step was a closed circle; once arrived at a certain status of design, the process will go to the next phase (66).

Therefore, our research will engage users' real demands through storytelling and visualize them by storyboarding them in a co-creation process (see *Figure 4*).

What is the storyboarding strategy for visualizing pregnant women's demands in developing mHealth apps?

Storyboarding has been studied in education, management,

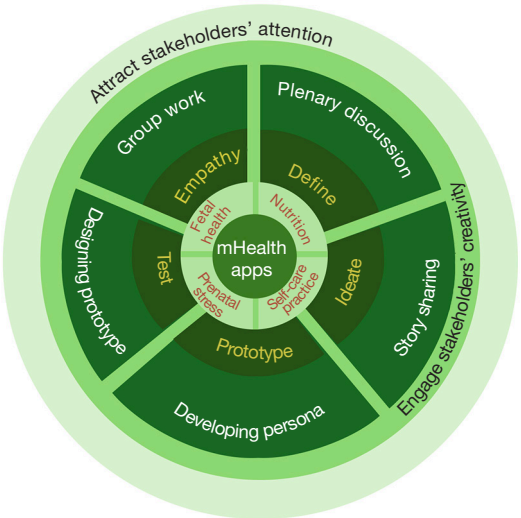

Figure 5 The proposed conceptual framework for co-creativity.

and healthcare (40,57,67,69), and it is the best practice and is an effective guideline (60). Limke *et al.* [2022] applied storytelling to healthcare as a collaborative design tool (70). Dederichs *et al.* [2022] and Manning [1998] use storyboarding as a design thinking creation tool to visualize user background information (68,71). Gershon and Page [2001] and Vertelney and Curtis [1990] both highlighted that storyboarding could improve the co-creative in the co-design work (48,58). In addition, Mou *et al.* [2013] argue that storyboarding could shorten the creative process and spark new ideas (49).

Although, Gershon and Page [2001] and Vertelney and Curtis [1990] mention the storyboarding strategy for information visualization, they do not focus on developing mHealth apps (48). As well as Fraser [2003], the authors only focused on the storyboard strategy application in teamwork and did not mention the application in mHealth app development (61). Thus, our research aims to use a storyboard strategy in design thinking to visualize health information for pregnant women and engage co-design teams' creativity in developing mHealth apps.

Our research is the same as Gershon and Page [2001], Mou *et al.* [2013], and Manning [1998]; they are all focused on the information visualization strategy (48,49,71). From the authors' perspective, storyboarding can be a creative tool to visualize UDs, shape participants' ideas, and convey new ideas to others. In addition, by employing multiple perspectives to share new ideas, the storyboard can attract participants' attention, stimulate interest (57), allow creativity to surface many ideas in a short time (67), and decrease the dilemmas of ambiguity (62). Thus, we agree that storyboarding can be used as a creativity tool in co-design teams to reflect UE and decrease the development cost because it can allow teams to alter their designs easily (70).

Therefore, according to Dederichs *et al.* [2022], our research will conduct face-to-face workshops, which include group work, plenary discussions, story sharing, developing personas, and designing prototypes of mHealth apps (68). In addition, during the storyboarding phase, we agree with Truong *et al.* [2006] that the storyboard elements should include text, people, level of details, number of panels, and representation of the passage of time (60). As we can see from *Figure 5*, the research will use a DTA flow (understand, observe, point of view, ideate, prototype, and test).

Discussion

This section discusses how the literature review's analyses resulted in mHealth apps, Storyboarding, and visualizing UDs.

mHealth apps play a great role in prenatal care for pregnant women; they can help pregnant women track their fetal and maternity health and query all kinds of health information. However, the lack of evidence information in mHealth apps is a pain point. In our research, we tried to solve the problem using the DTA through Co-Design activities. It incorporates obstetricians' views and recommendations into developing mHealth apps promptly. UCD principles enable the end-UE to be delivered throughout. The result of the study is similar to that of Yu *et al.* [2023] (72,83); the studies point out that UCD can be integrated into the mHealth apps for pregnant women to increase the evidenced contents of mHealth apps (72,83). However, in our study, we argue that storyboarding is an efficient design strategy to visualize UDs and increase the evidence-based information of mHealth apps. We explore ways to solve the problem by combining storyboards with a DTA.

In past research, storyboarding has been used in many fields, such as education, management, and healthcare. The role of storyboarding includes stimulating creativity, reflecting the use experience, and decreasing communication barriers. In our research, we apply storyboarding to visualize user background information, including user scenarios and user flow. What's more, we presented them as cartoon-like sketches in artificial intelligence (AI) tools. We bring storyboarding into the Co-Design activities so that the multidisciplinary team members can discuss and

Figure 6 POD tree diagram for the visualization use experience through storyboarding strategy. POD, point of departure.

finalize the UDs through the storyboarding of cartoon-like sketches. The information architecture, wireframe, and low-fi prototype will be generated during the Co-Design workshop. Storyboarding plays an important role as an intermediary communication tool.

In our research, we analyzed the DTA applied to the development content of mHealth apps, evaluated the best design process for developing mHealth apps using storyboarding, and identified the storyboard elements for visualizing the UDs (pregnant women). To highlight the needs for this study, our research analyzes and discusses six step-by-step for each section.

The research sequence was designed as described to evaluate the strengths and weaknesses of various combinations of perspectives and propose the most appropriate direction for the larger study. Referring to the POD tree diagram in *Figure 6*, this section further synthesizes the preliminary results to form a potential theoretical proposition for future research.

Through the research and discussion in the "What are the key components in developing mHealth apps for pregnant women?" section of the study, the study concluded that analyzing specific measures to keep healthy behaviors for pregnant women in a design perspective, such as Empathy, Define, Prototype, and Test. As well as the health information that is critical to know for pregnant women, such as enough sleep, nutrient diet, physical activity, and stress management) to foster maternal attachment (visualized fetal assessment). Therefore, they should enhance their healthy behavior (enhancing self-care practices and maintaining healthy pregnancy lives). See POD1. In this section, on the best storyboarding strategy for developing mHealth apps for pregnant women, this study concluded that storytelling to generate

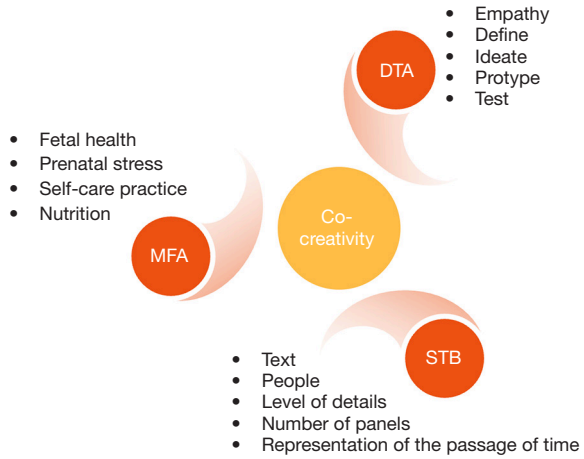

Figure 7 A proposed conceptual framework for visualizing UDs to engage co-creativity. DTA, design thinking approach; MFA, maternal-fetal attachment; STB, storyboarding; UD, user demand.

user background information, such as pregnant women's empathic content, conveys concise communication for the co-design team. Concise communication includes shaping out ideas and demands, information transferal, exchanging ideas, and constructing narrative visualization design narrative flow, such as (graphical elements and the interface, users: interactive exploration) (see POD2). The synthesis of POD1 and POD2 found the integration approach, which involves design thinking with storyboarding into the early design phase of mHealth apps, could make the co-design team understand the UE. In addition, build narrative visualization for enhancing MFA towards achieving healthy behaviors for pregnant women. Therefore, storyboarding as a design thinking way to develop mHealth apps could enhance the visualization information for pregnant women and co-design teams.

In the "What is the storyboarding strategy for visualizing pregnant women's demands in developing mHealth apps?" section, this study found that storyboard elements should include text, people, the level of details, the number of panels, and a representation of the passage of time. Though reflecting UE visual information, the storyboarding could attract stakeholders' attention and engage co-creativity. See POD3. After synthesizing POD2 and POD3, this study found that integrating storyboarding elements into the early design phase of mHealth apps could display UE and convey concise communication ways to engage co-creativity.

Go through the POD tree diagram; after synthesizing POD4 and POD5, this study found that the cartoon-like sketches storyboarding could be used in the co-design workshop to attract co-creativity to develop mHealth apps which can lead to health behavior for pregnant women. See POD7. After synthesizing POD5 and POD6, this study found that integrating the DTA (empathy, define, prototype, and test) into the mHealth apps could build tailored health behavior mHealth apps for pregnant women. See POD8.

As the conclusion of this synthesis exercise between POD7 and POD8, this study found that by applying a DTA with storyboarding elements into the early design phase of mHealth apps to understand the UE and engage stakeholders' creativity. In this way, it builds tailored health behavior for pregnant women. Based on POD9, this study posits a potential design framework for developing mHealth apps for pregnant women by integrating a DTA with storyboarding into the co-design team to reflect UE and engage stakeholders' creativity. *Figure* 7 shows the subsequent proposed conceptual framework.

Conclusions

This paper evaluates the key components of generating creative ideas through storyboarding in developing mHealth apps for pregnant women.

The study included a development strategy for mHealth apps, storyboarding elements, and visualization of UDs. Regarding the design strategy of mHealth apps for pregnant women, the study found that using the DTA to develop mHealth apps could foster maternal attachment and enhance their health behaviors. In addition, we found that sleep management, nutrient diet, physical exercise, and stress management are the most frequent search for health information for pregnant women. Storyboarding includes text elements, people, level of details, number of panels, and representation of the passage of time. Our research has shown that storytelling can gather empathetic information about pregnant women, which can then be utilized to communicate UDs and experiences to the co-design team. This approach helps in creating narrative visualization.

Moreover, in discussing the strategy to engage co-creativity, we found that integrating the DTA with storyboard elements in developing mHealth apps for pregnant women could attract stakeholders' attention and engage their co-creativity. Further synthesis of the above results concludes that the conceptual framework for storyboarding could engage stakeholders' creativity in developing the mHealth app. The proposed conceptual framework recommends that applying the DTA with

storyboarding elements in the mHealth app development could visualize UDs towards engaging stakeholders' creativity. The research results are significant because they help stakeholders develop mHealth apps to visualize pregnant women's demands and engage stakeholders' creativity. This study recommends further research into how storyboarding with DTA can visualize UDs and engage stakeholders' co-creativity. This study contributes to integrating UDs and experience in the early design phase of mHealth app development and shortens the development process.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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