A Study on Digital Therapy Intervention Strategies for Sub-healthy Cervical Spine Conditions among College Students: An Exploration of Design Methodology from Macro Environment to Micro Interaction

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Abstract— **There is growing concern regarding the poor health of the cervical spine in college-aged individuals and current interventions are failing to provide adequate levels of compliance, personalization, and adaptability to the various situations in which an intervention may be used. The purpose of this study is to identify the differences in the importance of digital therapeutics (DTx) functional requirements between 125 college student users and 5 rehabilitation professionals by utilizing the "Design Research Strategy Driven" (SDDR) methodology and employing Social-Economic-Technical (SET) analysis, Analytic Hierarchy Process (AHP), and t-test comparison of the data for revealing core tensions in need.Through the improved "Function-Behavior-Strategy" (FBS-S) model and expert workshops, an original "DTx Strategy Canvas" was constructed, comprising four major design principles, twelve core strategies, and thirty specific tactics. The results show that users place more emphasis on fun and motivation, while experts focus on clinical professionalism. The study verifies the effectiveness and innovativeness of the SDDR paradigm in guiding the design of DTx products for college students with suboptimal cervical spine health.**

Keywords—Suboptimal cervical spine health; Digital therapeutics; Design strategy; Strategy-driven design research; SET; Analytic Hierarchy Process (AHP); FBS-S

I. INTRODUCTION

A. Research Background

1) Epidemiological Status and Harm of Cervical Sub-health Issues Among College Students

Cervical sub-health, as a “ third state ” between physiological health and organic disease, is rapidly spreading among young people worldwide, becoming a serious public health challenge [1]. This issue is particularly prominent among university students, who face intense academic pressure, prolonged static study postures, and a deep reliance on digital devices. Numerous surveys have shown that over 70% of university students have experienced neck and shoulder pain or discomfort, with the incidence rate even surpassing that of some traditional desk-bound adult workers[2]. The emergence of this phenomenon goes against previous beliefs regarding the fact that "older people tend to experience most cervical issues," due to an increase in the number of younger people who are experiencing it, which is a negative sign.

The physiological aspect of cervical sub-health can lead to a variety of symptoms such as headache, dizziness and numbness in the upper limbs. These symptoms impact a student’s daily learning efficiency and quality of life. Further, disturbances to normal sleep patterns resulting from cervical sub-health will further increase the physical burden on students. In addition, long periods of being in a state of cervical sub-health increase the risk of developing potentially irreversible organic cervical conditions such as cervical disc herniation in adulthood [3]. Chronic pain and discomfort can cause feelings of anxiety and depression in university students. Psychological pain and physical pain place dual stressors on students’ overall health and quality of life and therefore represent a significant factor influencing their total well-being. Therefore, cervical spine sub-health represents not only a simple physical health problem, but also a multifaceted health issue that has both physiological and psychological components. As such, society, educational institutions, and the healthcare community need to pay greater attention to cervical spine sub-health and provide more effective preventive and treatment measures.

In addition, lifestyles in modern society- like long-term usage of smartphones and tablets and the ongoing head downwards position have increased incidence of cervical sub-health. Most students at a university do not adequately correct their posture or get enough rest when studying or relaxing; this places an additional load onto their necks. In addition, there is no education or awareness of cervical health that is systematic and will help to solve these issues quickly or effectively. Future initiatives and research should focus on intervening on the major lifestyle habits of university students like correcting poor posture, training for good posture, providing adequate psychological support and how to maintain their overall physical and mental health[4][5].

2) Dilemmas and Research Gaps in Existing Intervention Methods

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Current methods of intervention have serious limitations. While traditional physiotherapy is effective, it does come with high time and financial costs that are greatly influenced by specific treatment locations; thus, it is extremely difficult to meet the actual demand from university students needing adequate access to these regular/frequent interventions. Many health apps currently available in app stores provide interventions via stretching videos and check-connected reminders but due to the extremely homogenous nature of the content, no personalized follow-up, and an overall dull and unexciting user experience – there are extremely low rates for adherence – creating challenges in developing sustained, effective healthy behaviours [6].

Fundamentally, most current intervention attempts suffer from a "design shortcut" issue—that is, solutions are hastily introduced without a deep understanding of the nature of the problem or user needs, lacking systematic and scientific strategic support. In response to this situation, this study aims to fill the research gap by constructing a framework for systematic proactive strategy exploration, thoroughly analyzing the core of the issue, and thereby providing highly targeted, personalized, and easily sustainable intervention programs for the university student population.

B. *Overall Conceptual Model and the "Digital Therapeutics" Paradigm*

1) Systematic Presentation of the Problem: The "Human-Technology-Environment" Interaction Model

To thoroughly clarify the root causes of the issue, this study constructs a top-level conceptual model based on the "Human-Technology-Environment" interaction (see Figure 1), systematically revealing the formation mechanism of suboptimal cervical spine health among college students. The model indicates that this problem results from the dynamic interaction and negative cycle among three key elements: unhealthy behavioral habits and cognitive biases regarding health ("Human"); the hijacking of attention and physical discipline imposed by "Technology"; and the intensification of academic pressure along with non-ergonomic study facilities in the "Environment." As a result, many college students do not exhibit good posture or have a basic understanding of how to be healthy through their studies or daily lives. These two "human" variables create an increase in potential harm to themselves. However, smart devices, mobile apps and computer technology draw students' focus away from their body and diminish their ability to move naturally or make adjustments to their bodies, contributing to a disciplinary type of effect on their bodies. Additionally, environmental contributors such as excessive strain from high academic competition combined with poorly designed or furnished study areas also contribute to the physical load on the cervical spine. All three variables work together to create a negative cycle which results in an increased prevalence of sub-health states in the cervical spine of college students. This model provides a systematic approach for understanding cervical spine health problems in college students and establishes a theoretical framework for future intervention strategies.

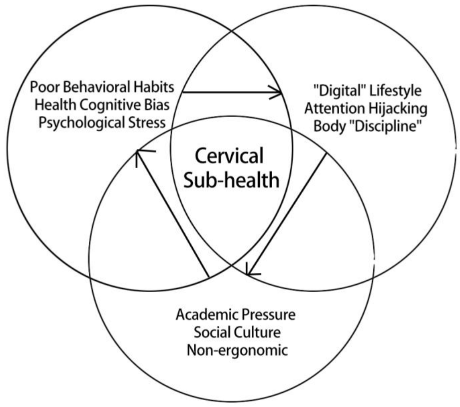

Fig. 1. The Top-Level Conceptual Model of "Human-Technology-Environment" Interaction

2) "Digital Therapeutics" (DTx): A New Paradigm of Interventions Based on Evidence-Based Medicine

Digital therapeutic solutions offer health-focused software tools that are developed using research from evidence-based medicine. With DTx, an individual using a digital therapeutic will achieve meaningful clinical results through scientifically validated software tools that can be used to overcome traditional intervention limitations (Dang et al., 2020). Unlike many other health-related mobile applications, digital therapeutics focus on providing rigorous therapeutic interventions at the level of being a "therapeutic". In order to do this, DTx have created a closed-loop intervention model that incorporates personal health assessments, adjustable intervention plans that adapt to changing conditions, and behavior change techniques. The DTx closed-loop intervention model adjusts content and intervention intensity based on the specific health and user-supplied feedback to provide targeted and sustainable interventions and therefore will achieve optimal health behaviour change and improvement in clinical measures. Additionally, DTx use a variety of theoretical and technological approaches from behavioural sciences such as cognitive behavioural therapy, motivational interviewing, and digital monitoring devices to provide a user experience with digital therapy from passive consumption of information to active involvement in treatment, which significantly enhances user adherence to the intervention and the effectiveness of the intervention. Therefore, digital therapies not only overcome traditional treatment method barriers of time, cost, and location, but they also provide users with corrections for the following issues found with existing health applications: homogeneity, lack of custodial guidance, and lack of user engagement. This indicates the wide applicability and significant advantages of DTx in the management of poor cervical health among university students.

"It is crucial, however, to clarify the scope of the present study in this context. A mature Digital Therapeutics (DTx) product necessitates rigorous validation through randomized clinical trials to substantiate its therapeutic claims. The primary aim of this research, as a foundational phase of development, is not to produce a market-ready, prescription-grade DTx. Rather, our objective is to construct a design strategy framework that is fundamentally evidence-oriented and possesses the foundational architecture to evolve into a DTx. Therefore, the term 'DTx strategies' throughout this paper should be interpreted as 'DTx-ready' or 'evidence-oriented wellness intervention' strategies. This framework is intended to bridge the gap between clinical principles and user engagement from the very inception of the design process, thereby paving the way for future clinical validation."

C. *Research Objectives, Content, and Technical Approach*

1) Research Objectives and Core Scientific Questions

The research focuses on proactive methods rather than creating an app and has two main objectives. The practical objective is to develop a systematic multi-dimensional framework that provides guidance for developing DTx products for cervical sub-health in university students. The theoretical objective is to create a new paradigm for the field of human-computer interaction of "Strategy Driven Design Research" (SDDR) to fill the current gap of either grand narrative or micro level optimizations within HCI research and to advocate for the use of a systematic strategic design process before UI/UX design through use of environmental scanning value trade-offs top level strategy development.

There are two key scientific inquiry questions (RQ) connected to those aims:

RQ1: In relation to social, economic, and technological influences, what factors contribute to cervical health DTx success for college students? What kinds of differences and "tensions" exist between users' and experts' prioritization of core DTx functions?

RQ2: How can quantified, and at times conflicting, demands be systematically transformed into specific, theoretically grounded, and actionable DTx design strategies?

2) Research Content and Technical Roadmap

A four-phase sequential exploratory mixed-methods approach was adopted, as shown in Figure 2, forming a logical chain from macro-environmental scanning to specific design strategies.

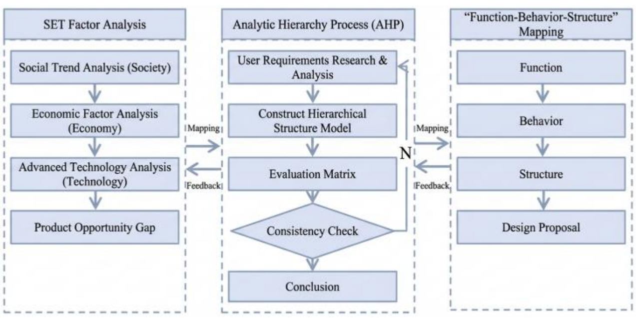

Fig. 2. SET-AHP-FBS-S Integrated Research Framework

II. Methodology

A. *Overall Research Design*

1) Selection and Justification of Mixed Methods Research Approaches

This study employs a sequential exploratory mixed-methods design of Qual→QUAN→Qual, aiming to comprehensively and systematically reveal the intervention needs and strategies for digital therapeutics (DTx) for cervical subhealth among college students through a multi-stage, multi-perspective research approach. This design pathway can be likened to the process of "geological exploration": first, a socio-economic-technology (SET) analysis provides a "broad aerial survey," delineating the core research scope and key influencing factors from a macro-level perspective; next, the Analytic Hierarchy Process (AHP) serves as "core sampling," quantitatively measuring the core needs and clarifying the weight and differences of demands between users and experts; finally, based on an improved "Function-Behavior-Strategy" (FBS-S) model, a process of "refining and purification" transforms quantified needs into concrete, operable intervention strategies, providing a scientific basis for subsequent product design. In order to reduce potential common method variance from self-report measures, this study developed multiple procedural control techniques for example randomizing the order of items on the questionnaire, encouraging respondents to provide anonymous responses, and including reverse coded items. These procedural controls were implemented to provide more valid and unbiased data, and add rigor and scientific validity to this study's findings.[7]

2) Operational Definition and Measurement of Core Constructs

To concentrate on the core student population who have subhealthy levels of cervical spine (neck) health, two measurement tools used—to define and measure the core construct of the cervical spine's "subhealth" well—were the Neck Disability Index (NDI) and Visual Analog Scale (VAS). The NDI is a self-report scale internationally accepted for assessing neck dysfunction and the degree to which individuals are limited in their daily activities; whereas, the VAS assesses the severity of perceived symptoms on a continuous scale of pain. While surveying student university samples, screening AHP questionnaire participants who had low NDI scores (5-14)[8] was the criteria for inclusion, thereby ensuring that the student sample would include only those students in suboptimal cervical spine health, and would therefore improve the relevance and representativeness of the findings of this research.

3) Ethical Considerations and Informed Consent

The university's Institutional Review Board (IRB) has approved the research study (Approval Number: SS-2025-0012) and conducted it according to ethical guidelines. Each participant signed a form that provided information on the study's purpose, procedures, risks, and how their rights and interests would be protected (either in writing or electronically) before beginning the study. The data collected was anonymous to keep the identities of the participants private and to keep their personal data confidential. During this research project; the ethics of the study were maintained; the rights of all participants were respected, including their right to be part of the study voluntarily; the use of data was done legally and compliantly; and the research was conducted in a manner that respected and protected the participants involved in the research project.

B. *Phase One: Macro-Environmental Analysis Based on SET*

1) Definition of Analysis Dimensions, Data Collection, and Analysis

This section sets out the overall scope of the three-dimensional SET Analysis by focusing on three main areas of interest, or factors, which are socio-cultural factors; the economic environment; and the degree to which technological development has occurred. The purpose is to identify, from a macro perspective, all external environmental, or socio-economic-technology, factors impacting cervical sub-health and the need of college students for digital therapeutics in a systematic way. Data collection methods will use a triangulation methodology that combines literature review with in-depth interviews. Eight stakeholders will be invited to participate as key informants including institutions providing rehabilitation, mental health counseling, and college student representatives to ensure a wide variety of data sources are used for the interview portion of the research. Interviews will focus on several key themes such as cervical health status; intervention needs; technology acceptance; and environmental support. The analysis will adhere to the thematic analysis methods developed by Braun & Clarke (2006), through a series of analyses including coding, categorizing, and extracting themes to ensure that the analysis is systematic and that results are credible. This will form a solid basis for subsequent quantitative research and strategy development.

C. Phase Two: Demand Quantification and Tension Analysis Based on AHP

1) Construction of the AHP Hierarchical Model

Using the findings of the SET Analysis, a Three-Level AHP Model was developed (Figure 3) that has one Goal, Six Criteria and Twenty-Three Alternatives with specific indicators defining each level.

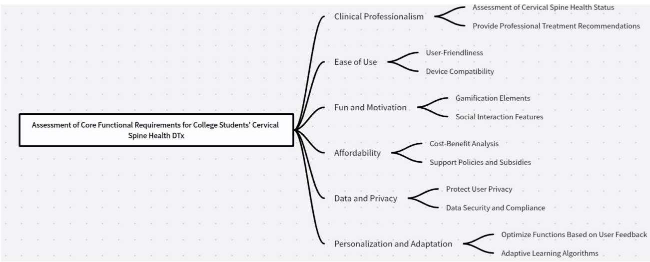

Fig. 3. AHP Three-Level Hierarchical Model

2) Questionnaire Design, Sampling Strategy, and Sensitivity Analysis

The AHP questionnaire was used to survey two groups of respondents, one of which contained 125 university students who were classified based on their status as users with a range of NDI scores from 5 to 14 (see Table 1). The second group included 5 experts from different fields. The results of each group were analyzed using yaahp software and a sensitivity analysis was completed to validate the conclusions of both groups.

TABLE I. BACKGROUND INFORMATION OF THE EXPERT PANEL (ANONYMIZED)

ID	Domain	Years Exp.	Title/Degree
E01	Rehabilitation Medicine	12	Chief Physician
E02	Rehabilitation Medicine	8	Associate Chief Physician
E03	Physical Therapy	15	Chief Therapist,PT,PhD
E04	Physical Therapy	10	Physical Therapist,MS
E05	Software Engineering	11	Principal Architect

*Note: The table contains de-identified background details about those involved in the Analytic Hierarchy Process (AHP) survey or the Focused Building Solution (FBS) workshop, including areas of specialty such as rehabilitation medicine, physical therapy, and software engineering. This interdisciplinary representation gives a wide range of disciplines represented.

D. Phase Three: Strategy Mapping Based on FBS-S

1) Construction of the FBS-S Model and Definition of the "Strategy-Tactics" System

Using the classical FBS model [9] as a reference point, an upgraded version of the FBS-S model (function-behavior-strategy) has been developed. Therefore, there are three levels related to the endpoint "S": design principles, design strategies, and design tactics (Figure 4), which allows for transitions from abstract requirements to concrete actions.

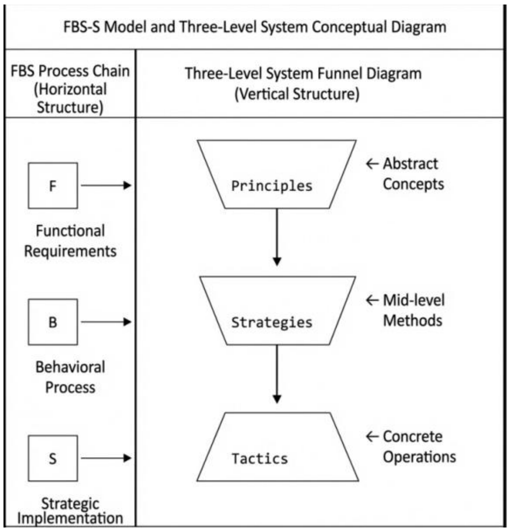

Fig. 4. Conceptual Diagram of the FBS-S Model and the Three-Tier System of "Principle-Strategy-Tactic"

2) Strategy Mapping Workshop and Triangular Mutual Verification

The research team went through a systematic process to complete the mapping of Function (F) to Behavior (B), then to Strategy (S) through a series of structured expert workshops. This process began with gathering the key behavioral targets based on the functional requirements identified during previous quantitative analysis of the study's results. From this point on, the mapping was completed by using the input from a group of expert participants who, through collaborative discussions and group brainstorming, produced a comprehensive set of actionable strategic plans. In order to validate the scientific rigor and credibility of the mapping results, a multi-faceted triangulation mechanism was used. On one side, triangulation among the researchers (Research triangulation) was used to provide the analysis process and conclusions with valid science. On the other side, participating experts were recruited to perform member checking of the strategy content to help ensure a reasonably good alignment between the identified strategies and the actual clinical and application needs. Also, theoretical frameworks and applied testing data through real-world case studies were integrated to validate the theory and practice of strategic design to ensure the strategies are both theoretically valid and practically doable. The use of this multi-dimensional validation mechanism greatly enhances the accuracy and practical utility of the strategy mapping, thereby creating a strong base on which to develop and implement future digital therapeutic products.

III. RESULTS

A. SET Analysis Results

The results of the theme analysis (Kappa = 0.83) using inter-coder reliability indicated that the macro-environment factors can be identified as key contributors and were summarized into a SWOT cross-analysis matrix format (see Table 2). This provides an environmental basis on which to build future strategies.[10]

TABLE II. SWOT CROSS-ANALYSIS MATRIX WITH STRATEGIC DIRECTIONS

	Opportunities- O1, O2, O3	Threats- T1, T2, T3
Strengths- S1, S2, S3	Strategic Direction of SO (Growth Strategy): Leverage the digital-native user base (S2) and favorable policy environment (O1) to rapidly capture the large market of "latent demand" (S1).	Strategic Direction of ST (Defensive Strategy): Leverage technological advantages (S3) to build competitive barriers and address market competition (T1) and privacy concerns (T2).
Weaknesses- W1, W2, W3	Strategic Direction of WO (Turnaround Strategy): Utilize artificial intelligence technology (O3) and the concept of "prevention over treatment" (O2) to overcome the "knowing-doing gap" (W1) and trust barriers (W2).	Strategic Direction of WT (Defensive/Survival Strategy): Given the uncertainties surrounding trust (W2) and payment models (T3), explore a minimum viable product (MVP) entry point centered on "non-intrusive monitoring".

*Note: The macro-environmental factors identified through the integrated SET matrix analysis are cross-analyzed with internal and external factors to clarify the four major strategic directions, providing macro-level guidance for DTx strategy formulation.

B. AHP Analysis Results

1) Analysis of Guideline Layer (Layer B) Weights: The "Demand Tension" Between Users and Experts(Table 3)

TABLE III. COMPLETE COMPOSITE WEIGHTS OF ALL ALTERNATIVES FOR THE EXPERT GROUP

Expert Group	B1 Professionalism	B2 Convenience	B3 Fun	B4 Economy	B5 Privacy	B6 Personalization
B1 Professionalism	1.00	3.25	5.12	7.50	4.08	2.16
B2 Convenience	0.31	1.00	1.88	4.21	1.35	0.73
B3 Fun	0.20	0.53	1.00	2.25	0.67	0.40
B4 Economy	0.13	0.24	0.44	1.00	0.28	0.19
B5 Privacy	0.25	0.74	1.50	3.57	1.00	0.59
B6 Personalization	0.46	1.37	2.50	5.26	1.69	1.00

Let the product of each row in the judgment matrix be denoted as Mi:

$$\prod_{j=1}^{m} a_{ij} \ (i = 1,2,\ldots, m) \tag{1}$$

In the formula, a_{ij} is the element in the i-th row and j-th column of the judgment matrix; m is the number of factors.
2)Calculate the geometric mean ωi of the elements in each row of the judgment matrix:

$$\omega_i = \sqrt[m]{M_i} (i = 1,2,\ldots, m) \tag{2}$$

Normalize the geometric mean to obtain the relative weights:

$$w_i = \frac{\omega_i}{\sum_{i=1}^{m} \omega_i} \tag{3}$$

To ensure the accuracy of the judgment matrix and maintain consistency among experts during the evaluation process, the maximum eigenvalue λmax is calculated, and a consistency check is performed on the judgment matrix.
4)The calculation of the maximum eigenvalue is shown in equation (4).

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(C_{\omega})_i}{\omega_i} \tag{4}$$

In the formula: represents the i-th component of vector After obtaining the maximum eigenvalue, calculate IC, see equation (5).

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{5}$$

In the formula: IC is the consistency index; λ_{max} is the maximum eigenvalue; n is the order of the judgment matrix. After obtaining the maximum eigenvalue, calculate RC as shown in Equation (6).

$$R_c = \frac{I_c}{I_R} \tag{6}$$

In the formula: RC is the consistency ratio; IR is the random consistency index. [11]

To determine whether there are issues with the constructed matrix and whether the matrix has passed the consistency test, judgment must be based on the RC.

Generally, when RC is less than 0.1, it indicates that the judgment matrix has passed the consistency test. If RC is greater than or equal to 0.1, it indicates that there is a problem with the judgment matrix.

The AHP results reveal a significant "demand tension" (Table 4), and define the "tension index = |user group weight - expert group weight|" to quantify the difference. An independent samples t-test shows that the difference in weights between the two groups is extremely significant for "clinical professionalism" ($p < 0.001$) and "fun and motivation" ($p < 0.001$), and significant for "ease of use" ($p < 0.05$).

The AHP results reveal significant "demand tension" (Table 4), defined by the "tension index = |user group weight - expert group weight|" to quantify the difference. An independent samples t-test shows that the two groups have highly significant differences in weights for "clinical professionalism" ($p < 0.001$) and "interest and motivation" ($p < 0.001$), and a significant difference in "ease of use" ($p < 0.05$).

TABLE IV. COMPARISON OF WEIGHTS, RANKING, AND TENSION INDEX BETWEEN USER GROUP AND EXPERT GROUP AT THE CRITERION LAYER (LAYER B)

Number	Criteria	User Group (Weight / Ranking)	Expert Group (Weight / Ranking)	Tension Index	p-value
B1	Clinical Professionalism	0.129/4	0.405/1	0.276	<0.001
B3	Fun and Motivation	0.312/1	0.081/4	0.231	<0.001
B2	Ease of Use	0.245/2	0.146/3	0.099	<0.05
B5	Data and Privacy	0.055/6	0.123/5	0.068	>0.05
B6	Personalization and Adaptation	0.166/3	0.203/2	0.037	>0.05
B4	Affordability	0.093/5	0.042/6	0.051	>0.05

2) Scheme Level (C Level) Combined Weight Analysis: Priority of Specific Functional Requirements

The analysis of combined weights (Table 5) shows that "C2.2 Unobtrusive/Background Posture Monitoring" and "C6.1 Solution Generation Based on Initial Assessment" are the only "consensus items" that simultaneously made it into the Top 5 lists for both groups, thus serving as key bridges connecting user and expert needs.[11]

TABLE V. COMPARISON OF THE TOP 5 COMBINED WEIGHTS AT THE SCHEME LEVEL

Rank	User Group Top 5 (Belonging Criteria)	Weight	Expert Group Top 5 (Belonging Criteria)	Weight
1	C3.1 Gamification / Challenges / Badge System (B3)	0.115	C1.1 Evidence-Based Rehabilitation Program Library (B1)	0.178
2	C2.1 Minimalist UI and Interaction Flow (B2)	0.098	C6.1 Initial Assessment-Based Program Generation (B6)	0.095
3	C3.2 Social Elements (Friends, Ranking, Team Up) (B3)	0.089	C1.3 Rehabilitation Outcomes Quantitative Report (B1)	0.088
4	C2.2 Non-Intrusive / Background Posture Monitoring (B2)	0.081	C6.2 Dynamic Program Adjustment Based on Process Data (B6)	0.064
5	C6.1 Program Generation Based on Initial Assessment (B6)	0.075	C2.2 Non-Intrusive / Background Posture Monitoring (B2)	0.059

3) Sensitivity Analysis

The results of the sensitivity analysis (Figure 5) show that even when the weight of the “Interest and Incentive” (B3) criterion is manually adjusted, the experts’ prioritization of core professional items such as the “Evidence-based Rehabilitation Program Library” (C1.1) remains stable, without any fundamental reversal. This demonstrates that the study’s conclusions regarding the “Tension of Needs” and the “Consensus Bridge” are highly robust.

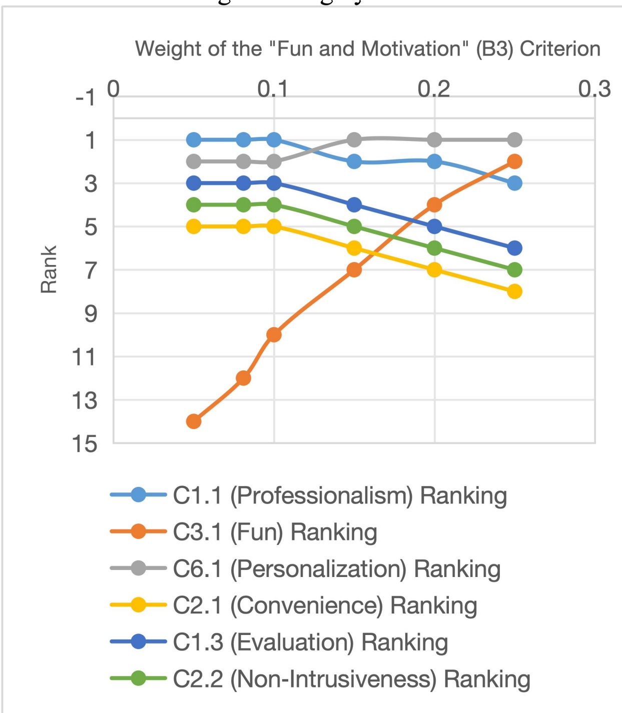

Fig. 5. Sensitivity Analysis Chart of the "Fun" Criterion by the Expert Panel

C. FBS-S Mapping Results

After completing the qualitative scan of the macro-environment (SET) and the quantitative weighting of core requirements (AHP), the final stage of this study aims to transform these analytical results into a set of concrete, practice-oriented design strategies. By conducting a structured expert workshop — triangulated as described in Section 2.4.2 — we used the high-weight functional requirements (Functions) identified through AHP as inputs. These were systematically mapped to user and system behaviors (Behaviors), and ultimately distilled and refined into a "DTx Strategy Canvas" (Strategies) featuring a three-tiered system of "Principles – Strategies – Tactics."

1) Construction and Presentation of the “DTx Strategy Canvas”

The "DTx Strategy Canvas" (Table 6), developed through FBS-S mapping, comprises four core design principles, twelve design strategies, and thirty specific tactics. It is systematically integrated according to intervention journey stages and design hierarchy, providing a comprehensive blueprint for product development.

TABLE VI. DTx STRATEGY CANVAS FOR SUB-HEALTHY CERVICAL SPINE IN COLLEGE STUDENTS

Principle	Strategy	Design Tactics
(P1) Dynamic Intervention Rhythm	1.1 Background Posture Tracking	• Using the phone's front camera, with user authorization, the computer vision API silently performs head pose estimation while reading or video applications are running in the foreground. • Allows users to customize monitoring periods (for example, "enable only from 9 a.m. to 5 p.m., Monday to Friday"). • Provides a quick entry to "pause monitoring," for example, through the drop-down notification bar.
	1.2 Contextual Micro-Intervention Reminders	• When poor posture (e.g., head forward tilt > 20°) is detected for more than 5 minutes, a visual halo appears at the top of the screen, transitioning from clear to blurry to simulate "vision degradation." • Trigger gentle, relaxing sound effects such as water droplets or wind chimes, instead of alarm sounds. • When connected to Bluetooth earphones, spatial audio technology can be used to deliver soft voice prompts such as "A bit to the left" or "Lift your head" near the user's ears.
	1.3 Periodic Professional Training Guidance	• During "break" periods such as 10:30 and 15:30 daily, push notifications are sent to guide users through a 10-minute "Cervical Spine Refueling" session. • Training content is automatically matched to the day's monitoring data; if the left-side muscles are tense, targeted stretching exercises are prioritized. • Users are allowed to synchronize their training plans with the mobile phone calendar to form a fixed schedule.
(P2) Endogenous Gamification Paradigm	2.1 Narrative Rehabilitation Journey	• When users enter the App for the first time, they select a "Guardian Beast" (e.g., Phoenix, Qilin), whose growth is bound to the user's rehabilitation journey.• Rehabilitation training is packaged into storylines such as "Exploring the Unknown Map" or "Restoring Ancient Ruins". Each completed training session lights up a section of the map or grants a "Ruins Fragment".• Key rehabilitation milestones (e.g., 7 consecutive days of adherence, a 2-point decrease in NDI score) trigger special cutscenes or unlock new "Guardian Beast" appearances.
	2.2 Social Incentives Based on Team Collaboration	• Users can invite 2-4 real-life friends (roommates, classmates) to form a "Guardian Team".• The team collectively "raises" a virtual plant, which requires members to "water" and "fertilize" it daily by completing training tasks.• A team-exclusive "Cheer Board" (chat area) is provided, where team members can send pre-set encouraging stickers or phrases.• When the team collectively achieves a goal (e.g., 1000 minutes of cumulative training), all members can unlock special App themes or avatar frames for use.
	2.3 Playful Presentation of Expert Knowledge	• As users "explore the map", they will "collect" knowledge cards, which will provide information about health tips, such as "how to adjust your screen height". • An event called the "Cervical Health Quiz" is conducted on a weekly basis as a mini-game where you can get a chance to water by answering correctly. • All 3 components of training—stretching, strength, and relaxation—have been categorized into attributes during play as “Attack”, “Defense”, and "Recovery" respectively. Therefore, users will be able to create more strategic plans for the way they perform their workouts.
(P3) Multi-modal Adaptive Engine	3.1 Initial Assessment Combining Subjective and Objective Measures	• Guide users to complete the NDI/VAS subjective scales. • Activate the camera and use AR technology to draw auxiliary lines on the screen, guiding users to perform neck Range of Motion (ROM) tests in 6 directions such as nodding, shaking the head, and lateral flexion. The system automatically records the maximum angles. • Integrate subjective and objective data to generate a "Cervical Health Radar Chart" including dimensions such as "Pain Index", "Flexibility", and "Muscle Strength".
	3.2 Dynamic Difficulty Adjustment Based on Progress Feedback	• The system analyzes the standard of the user's training movements in real time via the camera and provides real-time voice feedback such as "A bit higher" and "Hold it". • If the user completes a strength exercise with high quality for 3 consecutive days, the system automatically increases the number of repetitions from 12 to 15. • If the user reports a significant increase in VAS pain score on a given day compared to the previous day, the system automatically replaces the next day's plan with gentler stretching and relaxation exercises.
(P4) Participatory Data Ethics	4.1 Hierarchical Privacy Authorization and Data Dashboard	• On the authorization page, users are given the autonomy to choose whether to grant permissions such as "Camera for posture monitoring" and "Health data for algorithm optimization" via clear toggle switches. • The "My Data" page has a graphical dashboard of daily metrics; for instance, examples of data points are "Head-Down Duration" and "Compliance to Training". The information is used to modify the user's personal plan. • You can find the functionality to export all your data with a single click and the capability of deleting your account permanently and all the associated data, both within your account settings.
	4.2 User Feedback via "Group Reports"	• You are given a weekly report regarding the state of cervical health known as a Cervical Health Report. Last week's average head down time for students at XX College fell approximately 12% compared to other department's averages. Your input has made a difference. • Under strict data desensitization and anonymization, seasonal reports such as: "The peak time for cervical spine pressure is at the end of the semester, so be sure to balance working with resting." will be published. • Participating users have the opportunity to select whether or not they wish to make available de-identified data they generate through using their devices to support university public health research projects that publish research results regularly.

2) Core Design Principles, Strategies, and Validation

TCore design principles consist of: dynamic intervention rhythms, endogenous gamification paradigm, multimodal adaptive engine, and participatory data ethics. All strategies undergo cross-validation via behaviour change theory and market competitors to insure both theoretical validity and practical innovation (Table 7).

TABLE VII. TRIANGULAR CROSS-VALIDATION MATRIX OF CORE DESIGN STRATEGIES

Core Strategy	Supporting Theory	Novelty in Practice
Strategy 1.1: Background Posture Tracking	Fogg Behavior Model: Promote behavior by lowering the "ability" threshold (no active operation required).	Posture & Neck requires manual, session-based monitoring where the phone must be placed on the chest, limiting its use to dedicated times. Keep lacks this feature entirely. Our proposed 'always-on, imperceptible' approach offers a significant advantage in ecological validity.
Strategy 2.2: Social Incentives Based on Team Collaboration	Self-Determination Theory (SDT): Enhance intrinsic motivation by satisfying users' need for "relatedness".	Keep utilizes leaderboards and time-limited group challenges, which can induce social pressure and demotivation for lower-performing users. A cooperative, "nurturing" model based on real-world peer groups is not a primary feature in major apps, marking a novel approach to social engagement.
Strategy 3.2: Dynamic Difficulty Adjustment	Flow Theory: Match challenges to skills to maintain the user's flow state.	Cervical Spondylosis Yoga provides static video libraries. While Keep offers courses with different difficulty levels, it lacks a mechanism for "day-to-day" dynamic adjustment based on a user's real-time performance and subjective feedback (e.g., pain scores).
Strategy 4.2: User Feedback via "Group Reports"	Social Identity Theory: Enhance users' sense of group belonging and altruistic motivation.	No similar functions exist in mainstream competitors, demonstrating high practical novelty.

IV. DISCUSSION

The core objective of this study is to explore systematic digital therapeutics (DTx) intervention strategies for the widespread issue of cervical subhealth among university students. We first conducted a thorough analysis of the research problem through a combined SET-AHP-FBS point of view, rather than proceeding directly with functional development as done in many of the previous studies. The dataset we present contains not only separate points of data but also provides three perspectives of a combined set of macroenvironmental factors, measurable tensions, and creative strategies. In this chapter, our intention is to go beyond stating "what we found" and focus on considering "why this is important," describing this from three viewpoints: 1) the significance of our major findings in their theoretical and practical application, (2) the benefits of our proposed "DTx Strategy Canvas" compared to existing options, (3) and the methodologic contribution to the design research community.

A. Implications of the Core Findings: Building a "Bridge of Consensus" Amidst the Tension Between "Fun" and "Professionalism"

Through both the Analytic Hierarchy Process (AHP) and the statistical significance shown by the t-value of less than .001, we were able to quantify and statistically validate the significant "tension" between users' and experts' perceptions or demands for DTxs. Users generally want "fun and motivation" (0.312) while experts want "clinical professionalism" (0.405), which results in a paradoxical and fundamental disconnect in the design of digital health products. While the tension described above is not new, it was never quantified until now with the creation of the "Tension Index". The Tension Index has allowed us to provide you with the first objective, quantifiable measure of a relationship that has historically been only a subjective perception. The high Tension Indices of "clinical professionalism" (0.276) and "fun and motivation" (0.231) reveal the degree of the disconnect.

As a consequence, two distinctly different mental models emerge from the previous sentence.[12] Users adopt a "consumer model," as they exist in an environment full of extremely optimized and instantly gratifying apps, such as games, social networking sites and short videos, with "attention" being viewed as a finite quantity. They judge an app's success based upon whether it was "fun" or "easy to use," and on whether it will provide them with a sense of enjoyment when they are using it. Clinical efficacy is a delayed reward that requires effort on the part of the user, therefore it is not nearly as attractive to the user. On the other hand, experts adopt a "clinician model," as they are most concerned about both "efficacy" and "safety;" therefore every intervention must be justified by an evidence-based medicine model. For experts, fun is only a "means to improve adherence," not an "end to be pursued." As such, sacrificing professionalism for entertainment is placing the cart before the horse, and may actually be viewed as "irresponsible."

However, more important than this tension's rise is the consensus-building magic that can span that divide. The data available to us indicate that "seamless/background posture monitoring" (C2.2) and "plan generation based on initial assessment" (C6.1) were the only two Top 5 rankings common to both groups—the consensus items. The practical consequences of such are quite important: "seamlessness" acts as the gateway to the user's desire for "convenience," while "personalization" is the key to the expert's focus on "effectiveness." For any DTx product attempting to balance "fun" and "professionalism," the keys will likely be the perfect integration of "seamless monitoring" and "precision personalization." While the former lowers the threshold for user involvement, the latter assures the scientific basis for the start of interventions. This explains how our Principle One: Dynamic Intervention Rhythm and Principle Three: Multimodal Adaptive Engine became the nucleus of the entire strategic framework.

B. The Advantages of the "DTx Strategy Canvas": From "List of Functions" to "Systematic Intervention"

Currently, the majority of health-related apps available use a "feature list" approach - a listing of disparate functions such as "your own library of videos", "Certificate of Completion", and "See How You Stack Up Against Everyone Else". The major flaw in this design is how each of these features acts as an isolated point rather than being interconnected; therefore, failing dramatically in the creation of a closed-loop feedback process for the purpose of transforming long-term user behaviours. In conclusion, the culmination of this research is the "DTx Strategy Canvas" illustrated in Figure 5. The reason that this document stands out is because it enables the creation of a paradigm shift in the movement away from conventional "feature list" to "weather systematic change".[13]

To begin with, the canvas itself is "process driven" rather than "feature driven". The horizontal axis of the canvas (Perception & Assessment, Intervention & Training, Feedback & Motivation, and Maintenance & Generalization) provides a complete overview of what happens throughout the entire cycle of behavioral change for all users. Therefore our approach is also "contextual" in nature. A perfect example of this is Strategy 4.2 (giving users a "group report" as a source of feedback), which can be identified under the Maintenance & Generalization phase because the main value in the "group report" is to instill a sense of connection with other users and motivate users again when there is no longer novelty or excitement to be gained from their use of the product.

Secondly, the framework is based on theory, not on experience. As shown in our "Triangulated Validation Matrix" (Table 7), each of the core strategies represented in the canvas has solid theoretical support. For example, strategy 2.2 (social motivation via team collaboration) is not only about making training enjoyable, but is based on a profound insight from Self-Determination Theory (SDT) regarding relatedness, which explains why social team competition is more effective than just having individual leaderboards. Strategy 3.2 (dynamic difficulty adjustment) is also derived from Flow Theory, which aims to maintain a dynamically balanced state between challenge and skill, thereby keeping participants highly engaged and in a state of flow (i.e., transforming monotonous training into an enjoyable experience). Theory-driven design for our operational strategic system creates a foundation that is free of arbitrary or anecdotal input, yet possess considerable capacity for scientific interpretation and predictability.

Ultimately, the goal is to create a "harmonized tension" rather than creating a "unilateral compromise". The whole strategy canvas (particularly Principle 2: Endogenous Gamification Paradigm) is built around incorporating "fun" into the entire experience continuum while preserving the basic element of "professionalism". A great example of this is Strategy 2.1 (narrativizing the rehabilitation Efforts), which does not change the professional rehabilitation efforts (the core); however, it provides them with new "meaning" and "intent" using an engaging storyline, causing the individual's motivation for performing that action to change from "I 'have to' do this action" to "I 'want to' perform this action to continue my story". This represents a creative and uncompromising solution to the core conflict that has been identified by the AHP.

"We acknowledge that, on the surface, some of our proposed strategies, such as the 'Endogenous Gamification Paradigm,' may appear similar to features found in high-end wellness applications. The substantive distinction, however, lies in the design's underlying motivation and ultimate objective. Our strategies are not engineered AgNOstically for entertainment. Instead, they employ 'engagement' as a therapeutic modality — a carefully selected instrument, grounded in established behavioral theories like Self-Determination Theory (SDT), fatores to enhance long-term adherence to a clinical regimen. For instance, every milestone within the 'Narrative-based Rehab Journey' must be strictly mapped to a validated, stage-specific goal of a recognized rehabilitation protocol (e.g., McKenzie Method exercises). This principle — of making engagement subservient to clinical professionalism — is precisely what distinguishes our framework from conventional wellness apps and marks its first deliberate step toward the rigor of genuine Digital Therapeutics."

C. Methodological Contribution: A New Paradigm of Design Research Linking the "Macro" and the "Micro"

This study has the goal of creating a tangible set of practical strategic systems, but it also aims to explore and validate a methodological framework that can help create complex "Product-Service Systems." Our integrated SET-AHP-FBS-S framework brings together these two dimensions by connecting "macro-level environmental insights" to "micro-level interaction design," providing fresh perspectives for traditional design research — especially in areas such as Human Computer Interaction (HCI) that are concerned with Long Term Behavior Change.

There exist two active trends in HCI research. The first is a macro, ethnographic method that is apposite to the study of sociology and anthropology, and provides rich cultural understandings, but often does so without being able to inform clear design decisions. The second is a micro, experimental psychology based method that focuses on usability and/or A/B testing, and optimizes an individual button or method of interaction but does so without a strong understanding of the product's strategic direction.

Both perspectives will be incorporated into our framework. The SET analysis functions as a "telescope," assessing design challenges from broad social, economic, and technological viewpoints so that we can, from the beginning, identify strategic factors determining a product's future. These factors include, but are not limited to, "policy benefits," "privacy risks," and "willingness to pay." The AHP serves as a "microscope," converting macro-level insights into measurable metrics and measuring the subtle yet critical differences among the unique needs of stakeholder groups in unprecedented detail. The FBS-S model functions as a "magician" by offering a well-structured method for converting hard numerical weights into a creative, vibrant, and theory-based "principles-strategy-tactics" framework.

The AHP method measures users' "stated" preferences from rational models while DTx has to deal with many irrationally expressed or displayed "revealed" preferences. Because of this, we do not consider the AHP results to be the best representation of user behavior, but rather a projection of what users see as their "ideal selves". The purpose of the FBS-S workshops and strategy canvas is to identify how we can create designs (such as narratives, social incentives and other irrational methods) to bridge the gap between users' "aspirations" of being healthy versus their "reality" of inability to continue a healthy lifestyle. Thus, our methodology addresses the conflict between "rational expectations" and "irrational behaviors."

To further crystallize the methodological contribution of the Strategy-Driven Design Research (SDDR) paradigm proposed herein, it is instructive to situate it in relation to established design research methodologies, namely Design Thinking and Research-through-Design (RtD).

Distinction from Design Thinking[14]: Design Thinking, as popularized by firms like IDEO, is a fundamentally divergent process centered on user empathy, ideation, and rapid prototyping. Its output is often a wide array of early-stage concepts. In contrast, the SDDR paradigm is markedly more convergent and structured. It mandates an explicit, quantitative trade-off analysis of multi-stakeholder requirements (not limited to the user) via tools like AHP. Consequently, its primary output is not a divergent set of ideas, but a highly structured, internally coherent 'strategy system.' If Design Thinking excels in the 'zero-to-one' phase of exploratory innovation, SDDR provides a rigorous framework for the 'one-to-ten' phase of strategic system building.

Distinction from Research-through-Design (RtD)[15]: The core tenet of RtD is the creation of a tangible artifact (e.g., an interactive prototype), which itself serves as the process and medium of inquiry, generating new theoretical knowledge. The knowledge generated is often tacit, embodied in the artifact and revealed through interaction. SDDR differs fundamentally in its primary deliverable, which is not a physical artifact but an explicit, linguistic 'strategy canvas.' The knowledge it produces is codified and structured. SDDR places its emphasis on the critical phase prior to costly prototype development, focusing on building the 'strategic constitution' that will guide all subsequent design and engineering efforts.

In summary, SDDR is not intended to supplant these canonical methodologies. Rather, it offers a distinct pathway tailored for complex socio-technical systems, one that uniquely prioritizes upfront strategic trade-offs and structured strategy generation before committing to form-giving and implementation.

V. CONCLUSION

A. Research Summary

This study employs a multi-phase mixed methods approach to systematically investigate DTx intervention approaches as they relate to high risk for poor cervical spine health among university students. Quantitatively, this research describes the differences and conflicting sets of needs between DTx users and their rehabilitation providers, and presents an integrated solution, known as the "DTx Strategy Canvas." Qualitatively, this research integrates multiple sources of data through Social, Economic and Technical (SET) analysis, Analytical Hierarchy Process (AHP), and expert workshops to identify the core needs of the university population for managing cervical spine health, thereby advancing both theoretical and practical connections. The DTx Strategy Canvas provides the framework for the design of DTx products and services, consisting of four overarching design principles, twelve fundamental strategies, and thirty distinct tactics, characterised by their high degrees of relevance and operability. Furthermore, this study presents a novel approach to design research through the introduction of the "Strategy-Driven Design Research" (SDDR) paradigm, which offers a systematic methodological basis for designing multifaceted products that are intended to accomplish an aggregate health outcome, thus advancing both the theoretical and practical aspects of design research.

B. Research Limitations

This research has three primary drawbacks. First, the sample for the AHP study was primarily taken from universities in one specific region. Therefore, a limited sample size and geographic coverage may limit generalization from the findings. Future investigations will need to add to and expand the variety of samples to verify the applicability of the findings. Second, the workshop for creating expert strategy generation carries a risk of creating "group-think" issues that could result in the leaders not having sufficient variety of strategy options or being disproportionately influenced by individuals with strong opinions. Future research will also need to include more diverse representatives of the field and repeat several rounds of workshops to accomplish the goal of having scientific rigor and the greatest number of strategy options include. Finally, the DTx Strategy Canvas has been proven using multiple methods, but it is not yet ready for use in a practical sense; therefore, systematic evaluation needs to be performed on the developed prototypes and empirical studies to confirm the integrity of the proposed strategies and their effectiveness.

C. Future Prospects

Future research will progress in two directions: First, we will continue to develop and establish digital therapy prototypes based on the 'DTx' devised in the present study through the yet-to-be-completed usability study. The primary goal is to increase user's engagement and encourage adherence by designing digital therapies with optimal interactions and individually customized capabilities. Second, through either quasi-experimental or randomized controlled trial studies, we will assess the evidence supporting the clinical effect and behaviour change of faculty and students enrolled in DTx programs as an intervention for improving cervical spine health among college students. It is of paramount importance that all health interventions are integrated into user's daily lives in a manner that achieves the goal of "all things become healthful without noise"; in other words, significant and effective cervical spine health can be maintained over time by the delivery of naturally occurring, continuous, and sustainable behavioural guidance while also improving the overall health status of the college student population.

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