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Development of Innovative 3D Spherical Retrieval System and Virtual Reality for Insomnia Prescriptions in Traditional Chinese Medicine †

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Abstract: Insomnia is prevalent in modern society, and traditional Chinese medicine is gradually replacing Western medicine in its treatment. This study utilized insomnia symptoms and prescriptions from the "Dictionary of Chinese Medicine Prescriptions" to establish a 3D TCM spherical retrieval system, which intuitively displays the relationship between TCM prescriptions and insomnia symptoms. It enhances public and student interest in learning about TCM. Survey results indicate that the system effectively improves public knowledge of TCM and supports the United Nations Sustainable Development Goal 4: Quality Education.

Keywords: traditional Chinese medicine (TCM); spherical-type retrieval system (SRS); AI; MR; SDG 4; telemedicine

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1. Introduction

Insomnia is a common symptom in modern individuals. In adults over the age of 35, the one-year incidence of acute insomnia is 27%, with nearly 20% of patients experiencing persistent sleep disturbances. Chronic insomnia significantly impacts one's quality of life, leading to impaired memory, lack of concentration, reduced work efficiency, emotional instability, and adverse effects on interpersonal relationships and social satisfaction. Chronic insomnia increases the risk of certain diseases and exacerbates the severity of existing conditions, including allergic diseases, asthma, cardiovascular diseases, metabolic syndrome, mental disorders, dementia, and sepsis [1]. Given the prevalence of insomnia symptoms and their serious impact on health, effective insomnia treatment has become an important medical concern.

Many patients choose alternative therapies, especially traditional Chinese medicine (TCM), known for its holistic and constitution-nourishing approach, to treat insomnia. According to statistics, insomnia was most diagnosed among patients seeking treatment at the TCM Department of Taipei Veterans General Hospital in 2002 [2]. The insurance database shows a gradual increase in the number of people seeking Chinese medicine treatment for insomnia from 2002 to 2004 [1]. This indicates widespread attention among Taiwanese patients to the application of TCM in the treatment of insomnia.

Considering the diversity in the composition and application of Chinese herbal formulas used in TCM for treating insomnia, numerous studies have been conducted to clarify their efficacy and scope of application. For instance, Taipei City Hospital published a study summarizing Chinese herbal formulas used for treating insomnia in Taiwan from 2003 to 2006, as shown in Table 1 [3].

Table 1. Medications used to treat sparse treatment in Taiwan (2003−2006) [3].

Chinese Herbal Formulae	Ingredients	n (%)
Jia-Wey-Shiau-Yau-San	Angelica sinensis, Atractylodes macrocephala, Paeonia lactiflora, Bupleurum chinense, Poria cocos, etc.	2485 (6.71)
Suan-Tsao-Jen-Tang	Ziziphus jujuba, Anemarrhena asphodeloides, Ligusticum wallichii, Poria cocos, Glycyrrhiza uralensis	2284 (6.17)
Tian-Wang-Bu-Xing-Dan	Rehmannia glutinosa, Panax ginseng, Poria cocos, Polygala tenuifolia, Acorus gramineus, etc.	1630 (4.40)
Qing-Xin-Lian-Zi-Yin	Nelumbo nucifera, Poria cocos, Astragalus membranaceus, Panax ginseng, Ophiopogon japonicus	1032 (2.79)

Table 1 provides statistical data on the most commonly used Chinese herbal medicines and formulas for insomnia, serving as a reference for clinical physicians. Although this data allows doctors to understand commonly used formulas, it does not delve into the relationship between different symptoms and the use of Chinese herbal formulas. Therefore, it does not provide individualized treatment approaches for different patients, nor does it comprehensively reflect the diversity of Chinese herbal formulas for treating insomnia. Additionally, there is a lack of an excellent retrieval system, and it does not visually present relevant information on TCM treatments for insomnia symptoms and medicines. To address the inefficiency of retrieval in Table 1, we established a 3D visualized spherical retrieval system (SRS) to improve the efficiency of retrieving TCM symptoms and medicines. Furthermore, by creating a virtual reality sphere (VRS), the public's learning interest in TCM can be increased in a novel and engaging way. This effort is related to the United Nations Sustainable Development Goal 4: Quality Education. Regardless of whether the users are TCM professionals or not, they can use the developed system to query information on TCM-related symptoms, corresponding Chinese medicines, and prescriptions.

2. Data Preprocessing

We selected 72 commonly used symptoms and 72 prescriptions from the insomnia prescription retrieval table in the Dictionary of TCM Formulas (Tables 2 and 3) and encoded them. Subsequently, we established basic data tables for these symptoms and medicines and calculated their similarities in preparation for data clustering.

Table 2. "Insomnia" formulary retrieval table in the TCM formulary dictionary (partial) [1].

Insomnia	01439	03290	03638	03652	03868
04345	04507	06334	07895	08214	09232
09762	09780	10424	10425	10428	10484
84176	87089	87502	87503	87504	87508
87510	88909	93382	93644	93849	93851
94347	95208	95815	96008		

Before calculating the similarities, it is important to compute the common medicines between pairs of symptoms. The more common medicines there are, the more similar the two symptoms are. Given a set of medicines $M = \{m_1, m_2, \ldots, m_{72}\}$ and a set of symptoms $S = \{s_1, s_2, \ldots, s_{72}\}$, the number of common medicines (i.e., co-occurrence medicines for

a pair of symptoms) in the medicine set that can treat a pair of symptoms s and s' is calculated using (1) [4]. The computed results for common medicines are shown in Table 4. The data in Table 4 is then imported into the Orange software (Version 3.36.2) to cluster the 72 symptoms.

$$Co\text{-}medicine_{s,s'} = \sum_{m=1}^{72} \alpha_{m,s,s'}, \quad (1)$$

Table 3. Prescription page number table (partial) [1].

Number	Formula	Page
01439	Shi Wei Wen Dan Tang	168
03290	Ren Shen San	402
03638	Ren Shen Zhu Ye Tang	441
07895	Shang Xia Liang Ji Dan	1003
08214	Qian Li Liu Shui Tang	1041
09232	Xiao Suan Zao Tang	1176

Table 4. Co-medicine of symptom-to-symptom (partial) [1].

	s1	s2	s3	s4	s5
s1	0	0	0	0	0
s2	0	0	0	0	3
s3	0	0	0	1	0
s4	0	0	1	0	0
s5	0	3	0	0	0

3. Symptom Clustering

The k-means algorithm was used to cluster the symptoms. The k-means algorithm uses a greedy approach to improve clustering quality and approach a local optimum [5]. K-means is the most popular, simplest, and has low computational complexity among clustering algorithms [6]. Johannes et al. applied clustering methods to human grouping, while we clustered methods using data segmentation [7]. The purpose of clustering and solving in batches is to improve optimization efficiency and reduce the procurement and setup costs of computer hardware and software. We used the Orange software (https://orangedatamining.com/, accessed on 1 November 2023) for clustering. The process includes (1). data import, (2). setting attributes and target fields, (3). creating training and testing data, (4). building models, (5). evaluating models, and (6). examining predicted results (Figure 1) [8].

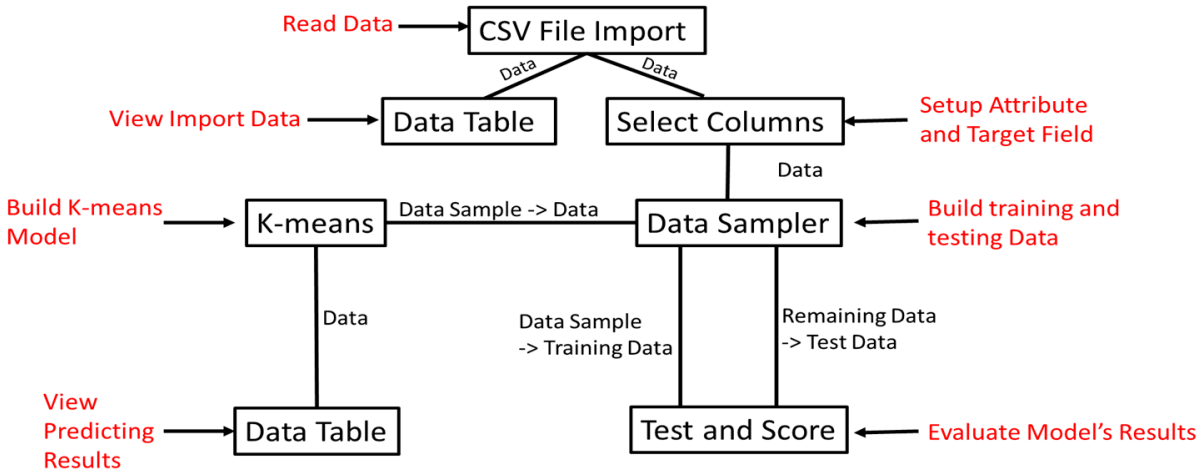

Figure 1. Procedure of k-mean clustering in Orange 3 [8].

We prepared a sphere with 144 grids. The 72 symptoms were divided into 3 clusters using the K-means algorithm and allocated to the upper hemisphere, while the lower hemisphere was allocated to the 72 medicines. Figure 2 shows the K-means clustering results for cluster C1. C1 contains 11 symptoms. Each symptom was assigned to one grid. To accommodate these symptoms, they were divided into 2 columns, with each column containing 6 grids, resulting in a total of $2 \times 6 = 12$ grids.

#	Symptom	Cluster	Silhouette
1	s31	C1	0.524702
2	s16	C1	0.565012
3	s21	C1	0.561783
4	s41	C1	0.475741
5	s44	C1	0.517913
6	s13	C1	0.466561
7	s14	C1	0.482402
8	s25	C1	0.462007
9	s43	C1	0.468212
10	s28	C1	0.560949
11	s40	C1	0.570792
12	s58	C1	0.610504

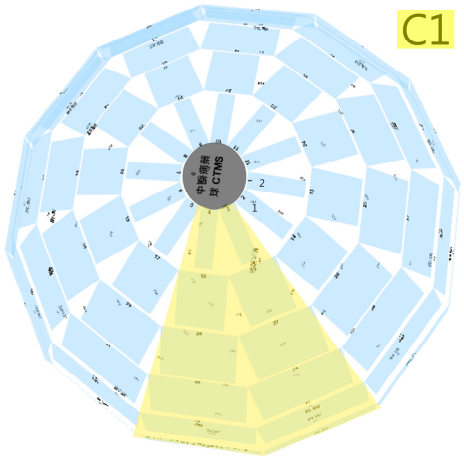

Figure 2. Distribution of cluster C1 on upper hemisphere. The Chinese text on the image is the name of this sphere: Traditional Chinese Medicine Syndrome and Medication Sphere.

The allocation results for the second cluster, C2, using K-means are shown in Figure 3. C2 contains 43 symptoms. To accommodate these symptoms, 8 vertical columns are used, each containing 6 grids, resulting in a total of $8 \times 6 = 48$ grids.

#	Symptom	Cluster	Silhouette
1	s58	C2	0.610504
2	s60	C2	0.601731
3	s59	C2	0.620185
4	s63	C2	0.642718
5	s71	C2	0.648413
6	s65	C2	0.643693
7	s67	C2	0.641931
…	…	…	…

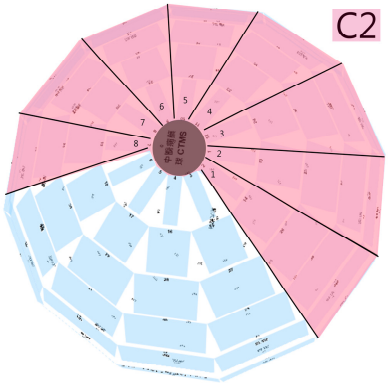

Figure 3. Distribution of cluster C2 on upper hemisphere. The Chinese text on the image is the name of this sphere: Traditional Chinese Medicine Syndrome and Medication Sphere.

The remaining symptoms that were not assigned to C1 and C2 were allocated to cluster C3. Thus, the allocation results of the symptoms on the upper hemisphere are shown in Figure 4. Grids of the same color on the sphere indicate the same cluster. Symptoms that share common medicines have higher similarity, and those with higher similarity are more likely to be grouped. Symptoms s40, s16, and s21 have the highest number of common medicines and are indeed grouped. This demonstrates the high accuracy of using k-means clustering.

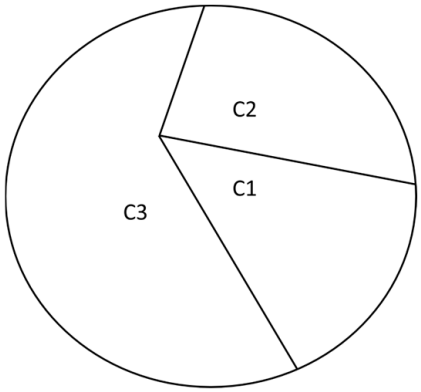

Figure 4. K-means clustering results in upper hemisphere.

Although the clustering results are highly accurate, dividing the symptoms into only three clusters does not adequately reflect the detailed characteristics of the symptoms and the specific functions of the medicines. Therefore, TCM practitioners need to categorize the symptoms into 12 categories, with each category assigned to the same vertical column. This approach makes it easier to search for and intuitively understand the main functions and directions of the medicines. Consequently, we reclassified the symptoms and medicines according to the recommendations of TCM experts. Finally, on the sphere, different colored grids represent different categories of symptoms and medicines.

4. TCM Database

After determining the positions of all symptoms and medicines in the sphere, we established a comprehensive TCM database containing all the data. Basic data tables for symptoms, medicines, and prescriptions were created with tables for grid numbers and coordinates on the sphere. The relationship between these tables was established. Figure 5 shows the snowflake schema diagram of the normalized relationships between the tables.

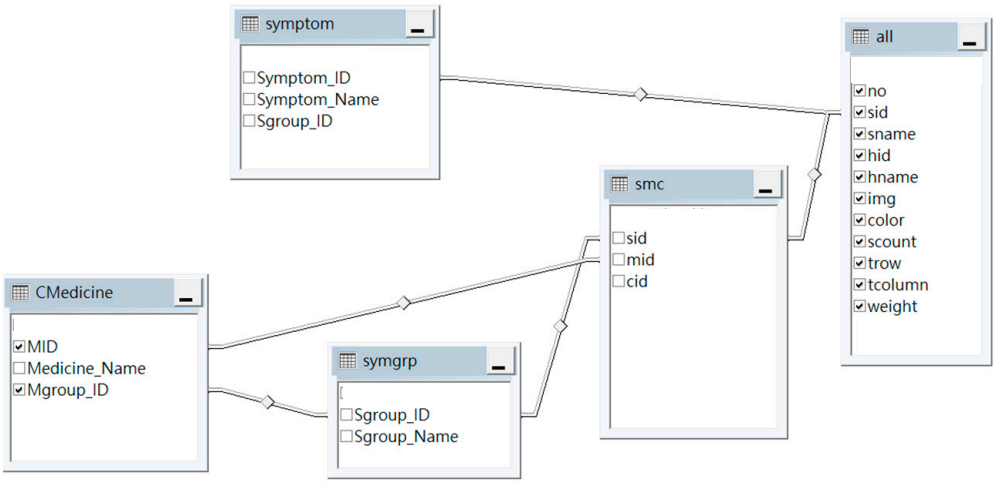

Figure 5. Entity-relationship diagram (ERD) of TCM database.

5. Retrieval System

After the TCM database was established, an online interactive SRS was created to help users query the corresponding medicines for TCM symptoms. This SRS uses technologies such as ASP.NET, JavaScript, Three.js, and Microsoft's SQL Server. It is built on a three-tier architecture. Users can access the system via a computer, smartphone, or tablet. The system's designed functions include the following: (1) query filtering based on symptoms or medicines; (2) zooming in and out and panning the sphere; (3) clicking on images on the sphere opens new pages with detailed information; (4) selecting a symptom from the dropdown menu to display the prescriptions for that symptom and rotating the sphere to position the symptom at the front center; (5) highlighting the relevant symptoms and corresponding medicines on the sphere in red when hovering the mouse over the menu, the hover function is triggered; and (6) visual analysis charts for prescriptions, such as word clouds and tree diagrams.

The URL for the completed TCM SRS is https://ctm.splab.fju.edu.tw/Ctm.aspx (Accessed on 22 February 2025). The website interface is shown in Figure 6. This URL automatically detects the access device, and if it is a mobile device (smartphone or tablet), the system automatically switches to the mobile version of the webpage. The mobile version interface is shown in Figure 7.

Figure 6. TCM SRS.

Additionally, for the desktop version, we developed an interactive highlight function (Hover). When users move the cursor over a symptom or medicine in the menu, the corresponding medicine names and their related symptom numbers on the sphere indicate the symptoms treatable by that medicine. Similarly, when the cursor hovers over a symptom, the background color of the symptom and its corresponding medicine numbers turn red on the sphere. This highlight function received high praise from participants during the survey (Figure 8).

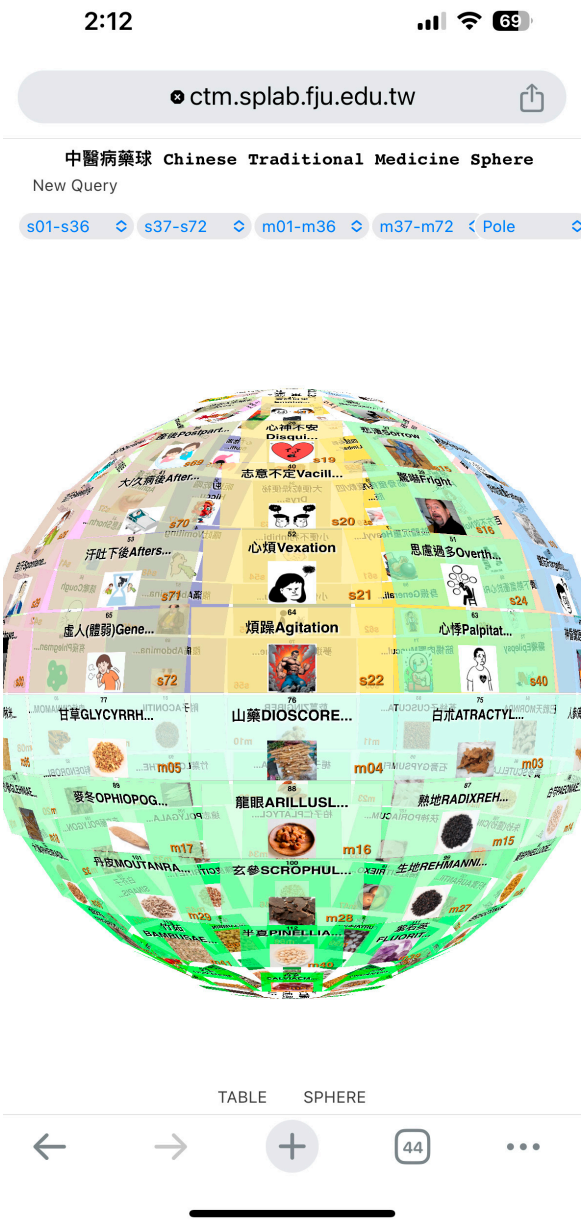

Figure 7. Mobile version of TCM SRS.

Figure 8. Highlight related objects (red) on the top menu.

The query interface design of this study allows users to find related medicines and prescriptions from symptoms or to find treatable symptoms from Chinese medicines. The query interface is shown in Figure 9.

Figure 9. Query user interface.

For consultations with patients in remote areas or those needing telemedicine, such as during the COVID-19 quarantine, we designed a telemedicine video consultation feature. Doctors need to click the "Video Consultation" button, and the system automatically activates the webcam. This allows TCM doctors to observe the patient's complexion, examine their tongue, and inquire about their symptoms, as shown in Figure 10.

Figure 10. Telemedicine video consultation.

6. VRS

To enhance user interaction and increase interest in TCM, we developed a TCM VRS that users can immerse in using VR glasses or head-mounted devices. The system was developed using the Oculus Unity SDK and is compatible with Meta Quest 3 devices. The designed features of the VRS are as follows.

6.1. Spherical Information Display

In a 3D VR environment, a 3D spherical structure and 144 information panels about TCM are constructed.

6.2. Dynamic Double-Sided Browsing

Based on the user's position, whether inside or outside the sphere, the information panels dynamically adjust to display on the front or back, providing an optimal browsing experience.

6.3. Smart Dragging

Users can use the right-hand joystick and ray to drag information panels and rotate the sphere. To prevent the information panels from tilting or flipping during rotation, the sphere automatically aligns the selected information panel to an easy-to-read orientation, ensuring a smooth browsing experience.

6.4. Position and Size Adjustment

To allow users to browse and operate in their preferred way, the left-hand joystick can be used to adjust the sphere's position and size. The left-hand joystick's X button is used to set the sphere's center position on the ground at the user's feet, the Y button is used to set the sphere's center at the front of the left-hand controller, and the left-hand joystick is used to scroll up and down to adjust the sphere's size.

Figure 11 shows the development results and actual testing of the VR sphere. It includes a photo from one of the classes featuring the VRS experience. We involved a total of 4 classes where students engaged with the TCM VRS. Most students experienced VR for the first time and found the VRS extremely enjoyable. Students expressed interest in purchasing their own VR headsets, making it a perfect blend of education and entertainment.

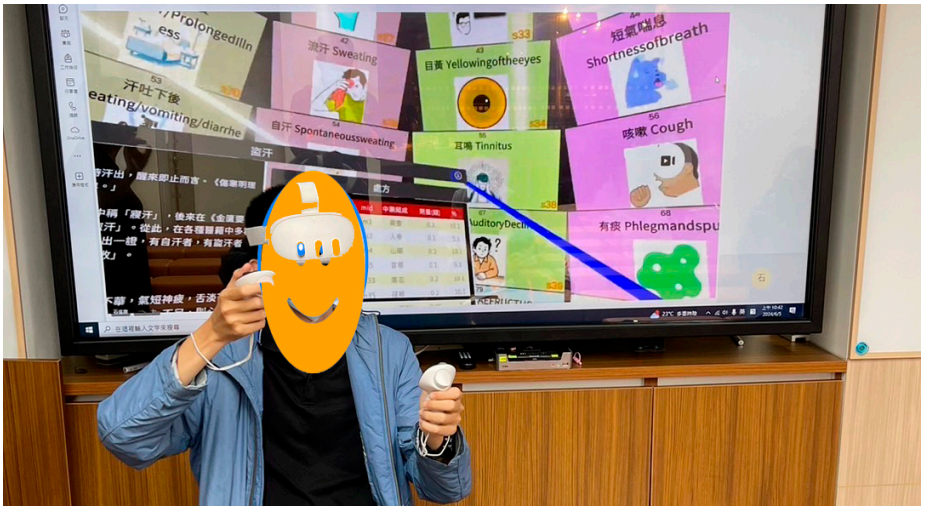

Figure 11. TCM VRS.

7. Survey Result

We designed two types of questionnaires. The first questionnaire survey was carried out for professionals in TCM, students, and TCM doctors to gather their opinions on the TCM SRS and to conduct tests. A total of 38 questionnaire responses were received [1]. The second questionnaire survey was conducted for students majoring in information systems and interdisciplinary English programs, including three international students, office workers, and IT professionals. The 12 survey questions are shown in Table 5. We provided on-site demonstrations and operations of the SRS and VRS, allowing the participants to experience the systems and compare them with traditional 2D table queries. Finally, the participants filled out a 12-question feedback questionnaire. A total of 66 valid responses were received.

A total of 41 students accounted for 61% of the number of participants. A total of 11 (17%) were industrial and commercial staff. Five teachers accounted for 8%.

We conducted a student's *t*-test to compare the significance between two sets of data using TCM SRS and TCM Prescription Dictionary 2D Tables. The *t*-test results for Question 10, "TCM Sphere is easier than TCM Prescription Dictionary 2D Tables to find corresponding Chinese medicine and prescriptions (formulas) for insomnia symptoms",

and Question 11, "I find TCM Sphere more interesting and enjoyable than TCM Prescription Dictionary 2D Tables", were a t-statistic of −3.110 and a *p*-value of 0.002. This indicates a significant difference in the evaluations between using TCM SRS and TCM Prescription Dictionary 2D Tables, as the *p*-value is less than 0.05. The null hypothesis was rejected, meaning the means between the two are different. These results suggested that participants perceived a significant difference in the ease of finding corresponding Chinese medicine and prescriptions (formulas) for insomnia symptoms and in the level of interest and enjoyment, favoring TCM SRS. The survey results for the 12 questions are shown in Table 6.

Table 5. A total of 12 survey questions.

No.	Question
1	The TCM Sphere left a deep impression on me.
2	The TCM VR Sphere allows users to immerse themselves in a virtual sphere or shrink it to browse like a globe. It is a novel and interesting interactive way to browse knowledge.
3	The TCM VR Sphere left a deep impression on me.
4	The TCM Sphere makes it easier to find TCM symptoms and related items compared to the TCM Prescriptions Dictionary in 2D table format.
5	The hover highlight function of the TCM Sphere on the computer version allows me to immediately know the correspondence between symptoms and Chinese medicines.
6	Searching visually with the TCM Sphere is more efficient than text-based search.
7	The TCM VR Sphere is interesting and fun.
8	The visual TCM Sphere can filter out uninteresting symptom items.
9	The TCM Sphere website and VR can increase my knowledge of TCM.
10	The TCM Sphere makes it easier to find insomnia-related Chinese medicines and prescriptions compared to the TCM Prescriptions Dictionary in 2D table format.
11	I find the TCM Sphere more interesting and fun than the TCM Prescriptions Dictionary in 2D table format.
12	The TCM Sphere is very valuable as a reference.

Table 6. Average scores of survey questions.

Question	Avg Score
Q11	4.47
Q2	4.44
Q7	4.41
Q12	4.29
Q3	4.23
Q5	4.21
Q8	4.2
Q9	4.17
Q1	4.11
Q10	4.06
Q4	4.02
Q6	3.91
AVG	4.21

In addition, interview results with TCM practitioners and professionals revealed that the SRS and VRS developed in this study serve as tools to assist TCM students in their studies, stimulating their interest in learning. However, due to differences between the medication sources and those currently in use, adjustments are needed for clinical application. Future system filtering using "AND" aligns with physicians' prescribing habits [1]. Additionally, TCM practitioners suggested that the VRS is interesting and recommended adding a feature for "synchronous consultation between physician and patient in a VR environment" to expand its applicability.

8. Conclusions

To address the challenge of retrieving information from 2D tables, we developed the TCM SRS. The TCM SRS is more user-friendly for finding symptoms corresponding to medications compared to traditional 2D tables. Additionally, to promote TCM knowledge, we introduced the VRS. VRS increases public and student interest and contributes to sustainable development.

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