Multi-sensor based IoT-driven community forest: a case study of E-health monitoring for environmental literacy in adolescents

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***Abstract*—In this paper, a community forest project was designed to integrate IoT and E-health acquisition device into digital art generation through a data visualization process and to intervene in adolescents' environmental literacy assessment, which was used to help them understand the state of themselves and the environment currently, and to stimulate reflection on their health and the health of the environment. Forty community-dwelling adolescents were recruited for the study and grouped into intervention-controlled experiments, which ended with questionnaire interviews. The outcome of experiments has shown that the experimental group, when combined with the advent of digital art, has significantly demonstrated an improvement in the assessment of environmental letters.The interview results showed that the participants were encouraged to exchange ideas and inspired to protect the environment through the digital art intervention. Our study focuses on the three axes of human health, environmental health, and environmental literacy, exploring the harmonious coexistence of the human-machine-environment trinity, and attempting to use digital art integrating health data as a link between the trinity, to develop a new approach to environmental education for improving environmental literacy of adolescents and promote sus-tainable development.**

Keywords—IoT; E-health monitoring; Environmental monitoring; Digital art; Environmental literacy

I. Introduction

A. The relevance and importance of E-health and multi-sensor based IoT

In today's digital age, the deeper integration of eHealth and Internet of Things (IoT) technologies is increasingly evident, bringing about a revolution in health administration and in the services for the care of human health. With the rapid development of sensor technology, data analytics, cloud computing and other fields, E-health systems have become more intelligent, efficient, and personalized. The rise of IoT has injected new vitality into E-health. With the development of a variety of sensors, the data collection range of IoT has been expanded, and IoT with integrated multi-sensors can realize multi-faceted monitoring of E-health, making the collection, transmission, and analysis of medical data more real-time and comprehensive [1]. E-health is no longer limited to traditional medical services but has expanded to a wider range of health management areas. Through the integration of IoT, along with sensors, mobile applications, and online suggestions, individual health data can be observed and recorded in real time, providing healthcare professionals with more comprehensive information, and making health monitoring more universal and intelligent [2]. The Internet of Healthy Things (IoHT), mentioned in the research review by Morais [3], has a huge potential to be applied to a variety of innovative solutions for healthcare. Through intelligent sensors and wearable devices, healthcare professionals are able to obtain real-time information such as patients' physiological parameters transmitted to a cloud database, and this highly real-time and all-encompassing information shifts from reactive healthcare to proactive and personalized health management, which makes it easier for individuals to achieve self-health management, provides more dimensional references for medical decision-making, and also allows for timely adjustments to the treatment plan or the provision of personalized advice [4].

B. Environmental hazard issues

As urbanization continues to grow, environmental pollution and citizen health issues become increasingly serious, and the density of population and changes in lifestyle habits begin to exert pressure on the effects of urbanization on human health [5]. Many studies have shown that exposure to environmental risks (e.g., polluting industrial activities) can harm the physical and mental health of people, increasing mortality, reducing life expectancy, and increasing health care costs [6]. In addition to air, water and soil, there is another invisible factor in environmental pollution: noise pollution. Sound, as one of the invisible environmental data, is constantly associated with environmental information and is an experience that people can continuously participate in and feel, but it is also the most easily neglected. Some studies have shown that people are more likely to lack awareness of noise pollution [7]. As urbanization accelerates, noise pollution should also be given more attention. Some studies have shown that children exposed to noise are not only affected in reading comprehension, but may also have increased ADHD scores, and in more severe cases, physical and mental health [8]. The "equivalent sound level" determines the energy of sound, so the louder the sound, the greater the effect on human health. Brief exposure to sounds above 120 dB without hearing protection can even cause physical pain. According to standards reported by the National Institute for Occupational Safety and Health (NIOSH), hazardous noise is defined as sound exposure exceeding an average time-weighted level of 85 dBA over an eight-hour workday [9].These parameters that can reflect the quality of the environment can also be realized through sensor enabled IoT to monitor environmental data and provide us with more insights into environmental health.

C. Current challenges to adolescents' environmental literacy and health

Improving these environmental issues and health problems requires people to have sufficient knowledge and attention to physical and environmental health, which needs

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to be supported by an adequate environmental literacy. Research has shown that environmentally conscious students usually have a positive attitude toward developments in the environmental field, an attitude that motivates them to exhibit environmentally friendly behaviors and have a positive view of environmentally friendly products [10]. Students can be agents of social change and may influence or "push" adults and their peers to engage in socially conscious activities, such as protecting the environment. Families and schools are two of the most important sources of information for youth, and without adequate environmental education at the source, environmental illiteracy will affect them [11]. The brain undergoes significant changes and developmental leaps during adolescence, which may profoundly affect decision-making [12]. It has been noted that by engaging students in in-depth, direct environmental science investigations of their local area, their confidence in researching and solving local problems can be boosted, as well as their belief in their ability to learn science and conduct scientific investigations [13]. Therefore, it is essential to recognize the progress of environmental literacy among adolescents.

D. *Reasons for adopting arts activity-based research*

The issue of improving environmental literacy among adolescents is challenging, and with the development of technology, it has begun to take on a variety of forms, with traditional methods such as curricular participation, scenario-based simulation, and mobile experiential [14].Over the years, researchers have focused more on the value of art in cultural expression, and art that fosters creativity and adapts to multiple forms of expression can effectively complement environmental education tools. The physical, multi-sensory, emotional, and creative qualities of artistic experiences have given rise to the concept of Artistic Environmental Education (AEE) as a way to attract a wider audience and increase participation in environmental education.Previous studies have consistently indicated that arts-based approaches can support environmental education by enhancing engagement, awareness, and pro-environmental behaviors [15].This suggests that the promise of arts activities in the field of environmental education is worth exploring further., which can benefit young students in various ways, increasing their ability to engage, understand, and make sense of complex issues, fostering an emotional connection to the world they live in, and providing them with memorable personalized art experiences.

E. *Study Motivation*

The above results demonstrate that arts-based environmental education is reliable and feedback-friendly. Nonetheless, the range of these artistic practices still tends to focus on more traditional media such as painting, photography, and material creation. In the context of art-based research, the world of digital art has been little explored. It is unclear whether digital art has a similar effect on environmental literacy, and digital art that incorporates digital health and environmental data is a research gap in the field. However, a recent review of research suggests that technology-based interventions show great potential in various areas of youth development [16]. Recent studies have shown that the emotional and social development of digitally native adolescents has a more significant influence on their own online actions, especially on social media and suggested games [17].Globally, smartphone ownership and Internet use have become widespread, especially among adolescents, making digital media a dominant channel for daily interaction.Adolescents are the main group of digital media users [18]. This study concluded that if adolescents are accustomed to interacting with the world through digital media, providing appropriate technological experiences can fulfill their care needs. There is a dearth of research on the impact of digital arts on environmental literacy, but in other fields of education, the use of digital arts is common and has obtained favorable outcomes. In the challenging environment we live in today, the rise of E-health and IoT provides us with unprecedented opportunities and challenges. As technology advances at a rapid pace, interpersonal connections and concern for the natural environment seem to fade, while health and environmental issues become increasingly prominent in the digital age. Against this backdrop, there is an urgent need for a new way to re-energize attention to health and the environment, and the combination of E-health and IoT offers a compelling path forward. Digital art, as an innovative form of expression, offers us a unique way to present E-health data. Through the digital art project, we aim to provide vivid and intuitive ways to present human health and environmental data, with adolescents as the focus of the investigation. Not only to let individuals better understand their own health conditions, but also to utilize the power of digital art to break the barrier of interpersonal communication in the digital age, and to motivate adolescents to take a more active interest in their own health and the environment. Through this study, we hope to revitalize awareness of the connection between health and the environment, and to push society forward towards sustainable development.

In the background of our study, we will further explore how to utilize these advanced technologies to explore the deep integration of E-health and IoT to enhance individual health management, and to apply them to environmental literacy assessment and intervention for adolescents.

II. MATERIALS AND METHODS

Our research will take human health, environmental health, and environmental literacy as the three axes, using environmental data combined with human health for segmented assessment and digital art generation, and presenting environmental health and human health with community forests. Figure 1 shows the Human- Machine-Environment trinity assessment system. The realization pathway is shown in Figure 2 for the connection configuration of experiment system.

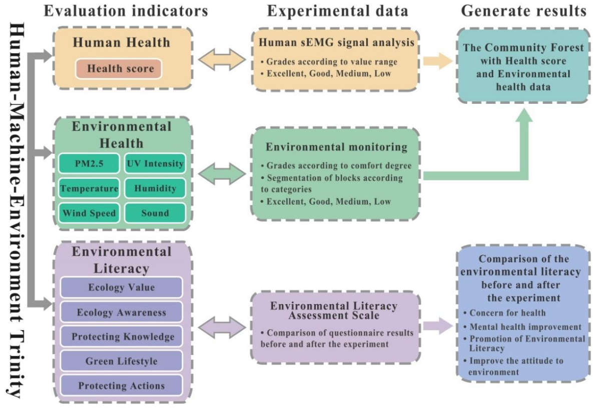

Fig. 1. Human- Machine- Environment trinity assessment system.

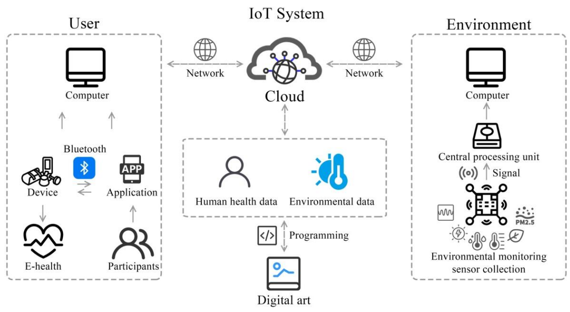

Fig. 2. Connection configuration of experiment system

A. The Sample of Participants

Samples were selected from Houchengqiao and Nanyangba communities in Xihu District, Hangzhou, with populations of 1013 and 1395, respectively. Participants were aged 13-17 years, residing in the community for over a year. This experiment selected 40 eligible participants from the applicants. Twenty of them were from Houchengqiao community and 20 from Nanyangba Community. The experimental site was set up in the nearby Youth Palace of Xihu District, Hangzhou. As the study was an investigative type of experiment, the exemption was obtained from the Ethics Review Committee of Hangzhou Seventh People's Hospital. Before the start of the experiment, we thoroughly informed and explained the steps and details of the experiment to the participants and obtained their and their guardian's informed and consent to disclose the results and some of their personal information. Data were processed using SPSS version 20, following principles suitable for correlation analysis in small-sample datasets.Participants were randomly divided into control (n=20) and experimental (n=20) groups. Demographic and basic sample characteristics are shown in Table 1. There was no variability in the demographic characteristics and environmental literacy scores among the groups.

TABLE I. DEMOGRAPHIC AND BASELINE CHARACTERISTICS OF SAMPLE.

Variable Description	Control group (n=20)	Test group (n=20)	t	P
Age	14.40 ± 1.231	14.45 ± 1.538	-0.113	0.910
Gender (n, %)			0	1.000
Male	10 (50.0)	10 (50.0)		
Female	10 (50.0)	10 (50.0)		
Education attainment (n, %)			0.107	0.744
Junior high school	12 (60.0)	13 (65.0)		
Senior high school	8 (40.0)	7 (35.0)		
Environmental ethics	12.05 ± 2.025	11.90 ± 2.780	0.195	0.846

*Note. There was no conspicuous discrepancies in the distribution of each group regarding gender, level of education, and environmental ethics.

B. Experimental design

The subjects were stochastically allocated into the control cohort and the experimental cohort in an equitability of 1:1. The assignments were generated by an independent researcher using a computer-based program and were numbered sequentially. After screening, participants took an Environmental Literacy Scale assessment.

Once the experiment began, we collected health data and environmental data from local participants at the same time each week on Sundays, and then led the participants together to the juvenile hall for a 2-hour group session, which was held in a different venue at the juvenile hall for the two groups to prevent the two groups from coming into contact with each other and influencing the results of the experiment. The experiment was conducted weekly for 4 rounds, with each round of meeting discussion on a different topic, Subsequent to a four-week duration of the experiment, all individuals were solicited to once more complete the Environmental Literacy Scale, and the collected statistics were gathered. Figure 3 illustrates the procedures of experiment.

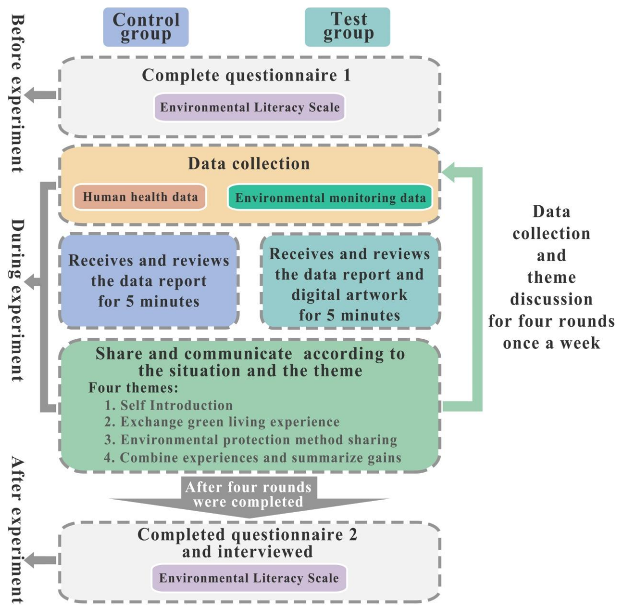

Fig. 3. Connection configuration of experiment system.

C. Measurement

1) Human health measurement and assessment system

Electromyography (EMG) is a neuromuscular signal acquisition method that involves the detection, monitoring, and analysis of bioelectrical potentials generated by motor units within muscle tissue during voluntary or involuntary movements. Due to its non-invasive nature, EMG allows for safe and continuous monitoring and has been widely applied in human health-related studies.With advances in flexible sensors, signal processing techniques, and machine learning methods, surface electromyography (sEMG) has been increasingly used to characterize physiological states and support the assessment of neuromuscular and functional health conditions. sEMG-based analysis can provide informative indicators for health evaluation and decision support.

In this study, an integrated health data acquisition system was employed to collect and analyze sEMG signals from the human hand. The system consists of a wearable signal acquisition device, a mobile application,and a cloud-based data processing platform. The collected sEMG signals were processed to generate quantitative health evaluation results based on a multi-dimensional assessment framework. Among the generated indicators, the total health score was selected as the representative measure of overall health status for subsequent analysis. Figures 4 and 5 illustrate the algorithm model matching process and an example of the health evaluation report, respectively.

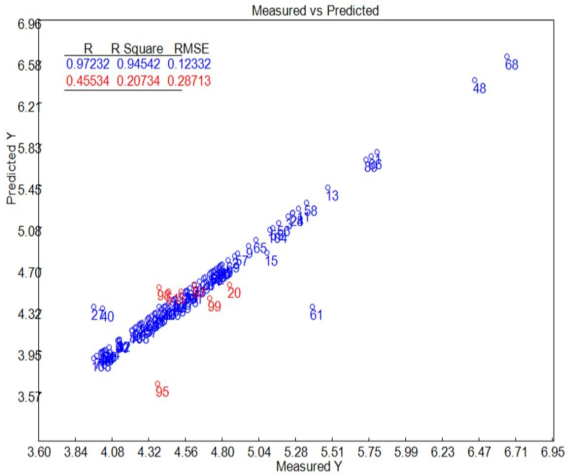

Fig. 4. Algorithm model matching of TCM-AI.

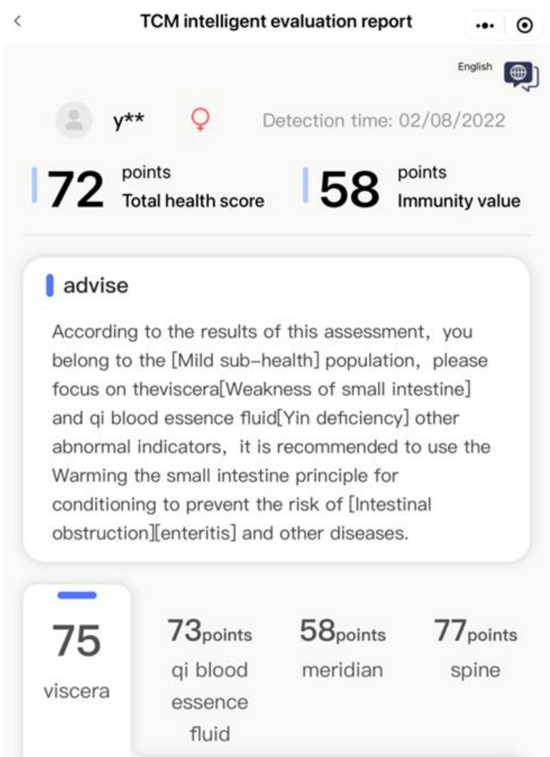

Fig. 5. TCM intelligent evaluation report sample.

2) Environmental data monitoring system

Environmental pollution poses complex and long-term risks to human health, characterized by delayed effects, multifactorial influences,and challenges in establishing clear causal relationships. Through systematic environmental health monitoring, investigation, risk assessment, and preventive control, the adverse health impacts of polluted environments can be effectively mitigated.

With the continuous development of intelligent and networked sensor technologies, radio communication and Internet of Things (IoT)technologies have been widely applied in environmental data acquisition systems. These systems enable the real-time monitoring of multiple environmental parameters, including wind speed, wind direction,temperature, humidity, noise, barometric pressure, light intensity,particulate matter concentration (PM2.5), and carbon dioxide (CO_2)levels, thereby supporting comprehensive environmental quality assessment.

Our study draws on previous experiences and designs an environmental data monitoring system that connects sensors, controllers, machines, and the environment through communication technologies such as the Internet, which can collect PM2.5 concentration, humidity, wind speed, light intensity, noise, temperature, and six environmental parameters. The required sensor modules mainly include PM2.5 sensor, humidity sensor, wind speed sensor, light sensor, noise sensor, and temperature sensor. Various types of temperature sensor technology on the market are relatively mature and can meet the system's use requirements. As shown in Figure 6 for the environmental monitoring sensor module, Table 2 presents the specifications of the sensors.

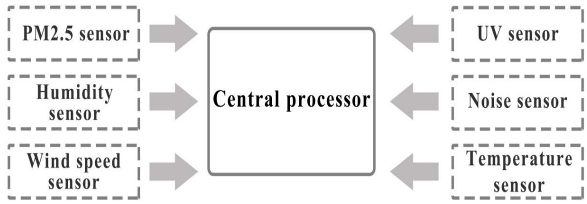

Fig. 6. Environmental monitoring sensor module

TABLE II. SPECIFICATION OF THE SENSORS.

Sensor type	Model	Measuring range	Measurement accuracy	Working conditions
PM2.5 sensor	PM2008 MSE	0~1000μg/m³	± 10μg/m³ (≤ 100μg/m³) ± 10% (> 100μg/m³)	-10~50℃ 0~95%RH
Humidity sensor	HAT_UB	0~95%RH	±2%RH	-40~85℃ 0~95%RH
Wind speed sensor	W410C2	0~5m/s	FS0.02%	-40~80℃ 0~95%RH
UV sensor	JXBS-3001-UV	0~150W/m²	±3%W/m² (@25℃)	-40~80℃ 0~100%RH
Noise sensor	JHM-NS02	30~130dB	±1.5dB	-10~60℃ 0~90%RH
Temperature sensor	HAT_UB	-40~85℃	±0.3℃ (@10~55℃)	-40~85℃ 0~95%RH

3) Output of community forest

Numerous efforts have explored the monitoring of data and its expression through visual forms, particularly in the domains of environmental and physiological information.

Visual representations of environmental noise, air quality, and other parameters enable intuitive understanding of complex data. Similarly, physiological signals such as respiration,heart rate, and stress-related indicators can be transformed into visual,acoustic, or optical forms, serving as intuitive representations of an individual' s health or stress state and supporting self-awareness and self-regulation.

Some interactive visualization approaches further extend this concept by mapping individual physiological states into shared visual contexts,allowing users to perceive both personal and collective conditions. Such approaches demonstrate the potential of data-driven visualization to support reflection, emotional regulation, and social awareness.However, studies that generate digital art directly from physiological health indicators derived from surface electromyography (sEMG) remain limited. Moreover, visualization approaches that integrate both physiological and environmental data are still scarce, and the potential of digital art generated from combined health and environmental data to enhance environmental literacy has not been sufficiently explored.

In this study, multimodal data are used to generate a community forest composed of multiple visual blocks, with each block representing different aspects of community health. Health data and environmental data are collected through a TCM-AI system and an environmental monitoring system, respectively, and mapped to a unified visual correspondence scheme for constructing the community forest. The overall process is summarized as a framework and algorithmic model for visualizing adolescents' health conditions and their surrounding environmental states. To enhance visual clarity and emphasize key elements, the conceptual framework of the community forest is illustratedin Figure 7.

Depending on the pleasantness of the data, different levels of data will take different forms in the community forest. Different data will need to be assessed using different thresholds for individual blocks, while some indicators, such as noise, will need to highlight the impact effects of audiovisual isomorphisms, so the cumulative effect of different blocks will be used to measure the impact results. As well as considering whether any individual indicator is above or below the threshold, the overall impact of the indicator needs to be considered. We used the software Processing as a programming drawing tool. The input of data allows the program to select the corresponding block and the corresponding grade of the picture (excellent, good, medium, low) and synthesize a complete digital art effect picture by superimposing them, the healthier the data, the greener the picture. The framework structure of health levels is shown in Figure 8, and part of the code synthesis is displayed in Figure 9.

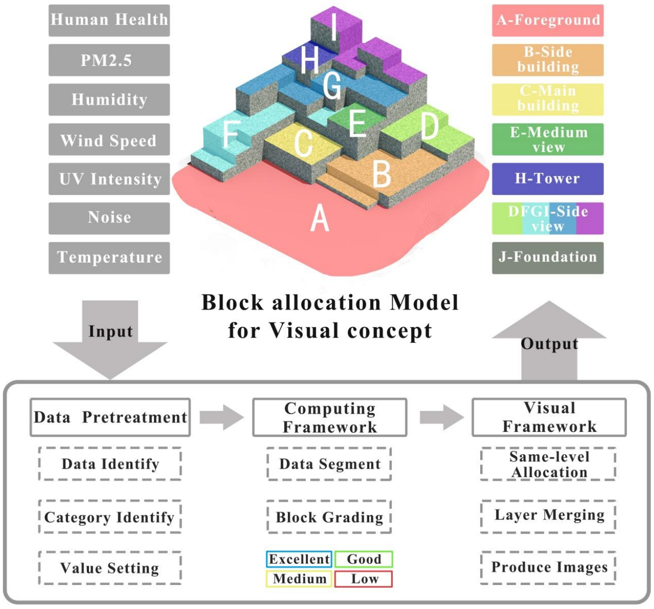

Fig. 7. Visual conceptual framework of the community forest.

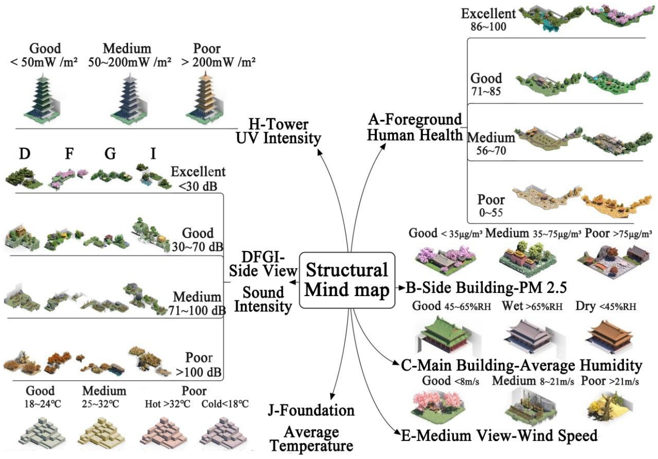

Fig. 8. Health grade structure framework.

```
PGraphics canvas;
int canvasWidth, canvasHeight;

int separation;

String inBase;
String outBase;
String tmpBase = "tmp";

String outAbsPath;

String[] categoryList;
String[][] candidateList;
String[] imageList;

HashSet<String> tmpPath;

PImage[] inImage;

Logger logger;

String[] filter(String[] input)
{
  if(input == null)
  {
    return new String[0];
  }

  List<String> list = new LinkedList(Arrays.asList(input));

  // list.removeIf(s -> s.charAt(0) == '.');

  Iterator<String> itor = list.iterator();
  while(itor.hasNext())
  {
    if(itor.next().charAt(0) == '.')
    {
      itor.remove();
    }
  }

  String[] output = new String[list.size()];
  list.toArray(output);
```

Fig. 9. A portion of the synthesis code.

4) Environmental Literacy Assessment Scale (ELAS)

Environmental literacy is commonly understood as a multidimensional construct related to individuals' understanding of environmental issues,their attitudes and values toward the environment, and their willingness to engage in pro-environmental behaviors. From a behavioral perspective,environmental literacy is often associated with environmental knowledge,attitudes, responsibility, concern, and action. Psychological and ethical perspectives further emphasize intrinsic values, care for nature, and moral responsibility toward the environment, highlighting the complex relationship between cognition, emotion, and behavior in environmental engagement.

In this study, environmental literacy was measured using a structured Likert-scale questionnaire designed to assess adolescents' awareness,attitudes, and behavioral tendencies related to environmental protection.The scale consisted of five dimensions: (1) awareness of the value of the environment (E-V); (2) awareness of the impact of the environment on health (E-A); (3) knowledge of environmental protection (P-K); (4) practice of a green lifestyle (G-L); and (5) actions taken to protect the environment (P-A). Each dimension was assessed using two items, resulting in a total of ten questions. Responses were recorded on a five-point scale ranging from "strongly disagree" to "strongly agree." Scores for each dimension were calculated as the average of the corresponding items, with higher scores indicating stronger environmental awareness, recognition,and engagement in pro-environmental behaviors. The overall scale showed good internal consistency (Cronbach's α = 0.886), indicating that it is suitable for assessing adolescents' environmental literacy.

5) Experimental satisfaction

To improve the reliability of data analysis and to supplement the quantitative survey, participants were interviewed and recorded at the end of the experiment with their informed and consent. The interview questionnaire included: 1. Activity satisfaction; 2. Atmosphere satisfaction; 3. Monitoring result satisfaction; 4. Social satisfaction; 5. Cognitive change degree; 6. Behavioral impact degree; 7. Mental health regulation.

III. RESULTS

A. Sample description

Figure 10 and Figure 11 display the environmental literacy assessment scale before and after the experiment, with different colors representing the proportion of people at different points.

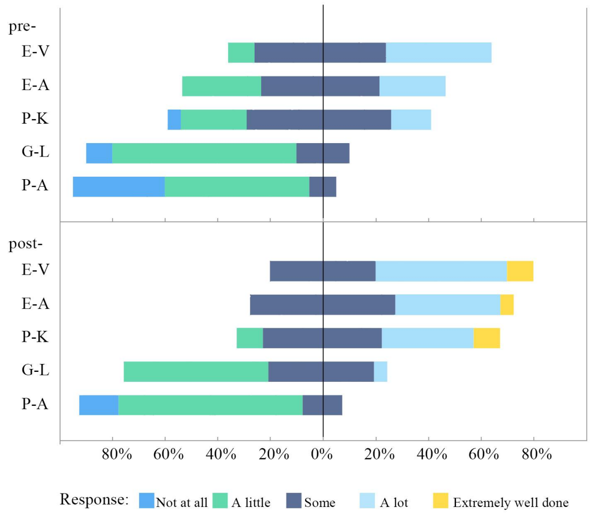

Fig. 10. Assessment of environmental literacy before and after the experiment(Control group)

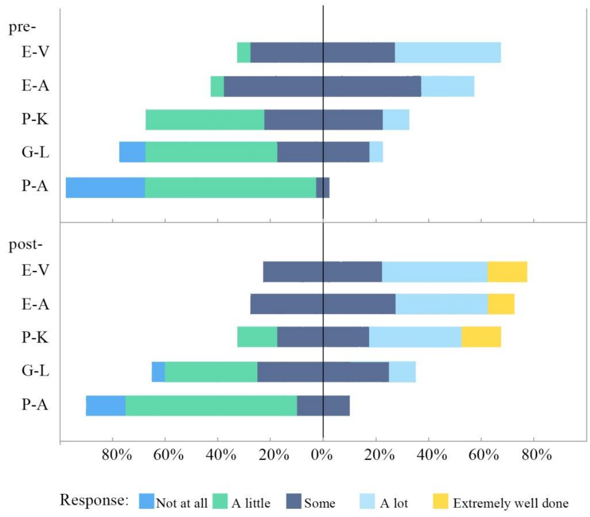

Fig. 11. Assessment of environmental literacy before and after the experiment (Test group).

Comparing Figures 10 and 11, the environmental literacy assessments of both the control and test groups improved and were particularly significant in terms of Ecology Value (E-V), Environment Awareness (E-A), and Protecting Knowledge (P-K), but the degree of improvement varied. Further data analysis is required for specifics. In the following, a paired t-test will be applied to compare the improvement in environmental literacy between the two groups before and after the experiment.

TABLE III. ANALYSIS OF ENVIRONMENTAL LITERACY ASSESSMENT BEFORE AND AFTER THE EXPERIMENT.

Item	Control group (a) pre Control group (b) post			Test group (c) pre Test group (d) post			PD	t	p
Scale	M±SD (a)/(b)	Min	Max	M±SD (c)/(d)	Min	Max	(a)(b) /(c)(d)		
E-V	3.125±0.455	2	4	3.175±0.674	2	4	-0.350±-0.094	-3.036	0.007**
	3.47	3	5	3.575	3	5	-	-	0.0

	5±0.550			±0.545			0.400±0.13	4.292	00***
E-A	2.975±0.380	2	4	2.750±0.596	2	4	-0.300±-0.145	-2.349	0.030*
	3.275±0.525	2	5	3.250±0.618	3	5	-0.5±-0.022	-5.627	0.000***
P-K	2.325±0.654	1	4	2.525±0.697	1	4	-1.075±-0.198	-6.582	0.000***
	3.400±0.852	2	5	3.300±0.715	2	5	-0.775±-0.017	-6.049	0.000***
G-L	2.125±0.686	1	3	1.925±0.545	1	3	-0.375±-0.021	-2.881	0.010**
	2.500±0.707	1	4	2.275±0.595	1	4	-0.350±-0.051	-4.765	0.000***
P-A	1.500±0.487	1	3	1.525±0.550	1	3	-0.250±-0.063	-2.703	0.014*
	1.750±0.550	1	3	1.775±0.573	1	3	-0.250±-0.023	-4.359	0.000***

* NOTE. *P< 0.05, **P< 0.01, ***P< 0.001.

Abbreviations. EV= Environment Value, awareness of the value of environment; EA= Environment Awareness, awareness of the impact of environment on health; PK= Protecting Knowledge, knowledge of protecting the environment; GL= Green Lifestyle, practice of a green lifestyle; PA= Protecting Actions, actions to protect the environment; M= mean; SD= standard deviation; PD= pairing difference; Control group = experimental group without digital art; Test group = experimental group that included digital art.

Table 3 compares the results of the environmental literacy scale in the two groups before and after the experiment, and the mean scores of each item tended to increase after the experiment, indicating that both groups of the experiment had a positive impact on environmental literacy, which helped to enhance people's environmental health literacy, especially in the area of Protecting Knowledge, and that both groups showed statistically significant progress (p(ab) P-K = 0.000***, t = - 6.582; p(cd) P-K = 0.000***, t= -6.049). However, the two groups differed in the degree of improvement on other items.

For the control group, a more statistically significant difference was demonstrated in Environment Value and Green Lifestyle (p(ab) E-V = 0.007**, t= -3.036; p(ab) G-L = 0.01**, t= -2.881). Statistically significant differences were also demonstrated in Environment Awareness, Protecting Actions (p(ab) E-A = 0.03*, t = -2.349; p(ab) P-A = 0.014*, t = -2.703). It indicates that the control group plays a certain intervention role in Environment Awareness and Protecting Actions, but the effect is not more significant than that of Environment Value and Green Lifestyle.

For the test group, the results of the Environmental Literacy Scale showed statistically significant improvements in all directions besides Protecting Knowledge (p(cd) E-V = 0.000***, t= -4.292; p(cd) E-A = 0.000***, t= -5.627; p(cd) G-L = 0.000***, t= -4.765; p(cd) P-A = 0.000***, t= -4.359), which suggests that the test group showed significant improvements in all aspects of environmental literacy.

B. Results of interview discussions

Upon the conclusion of the community forest experiment project, follow-up questionnaire interviews were administered to the participants, which were recorded using a digital recorder, and the details of the texts were thematically categorized according to context through data processing. A heat map of satisfaction with the interview results for two groups is shown in Figure 12.

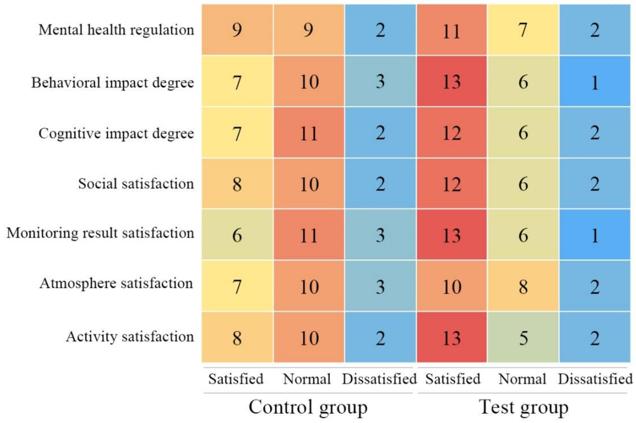

Fig. 12. Map of satisfaction with the interview results for two groups.

According to the recorded results, we found that many participants were not very enthusiastic about the traditional education mode, and they felt normal. They did not pay much attention to physical health and environmental health. Therefore, in the test group, they were delighted with such a novel model and had a higher level of satisfaction. During the experiment, participants have reported stress relief through communication with others, have gained some awareness of the importance of physical health and environmental health, and have tried to adopt the practice of green lifestyle. We also found that the activities of the control group required an outgoing member to drive the atmosphere, and data reporting could not be of much use. However, with the aid of the community forest digital artwork, the test group was able to have a more vivid and graphic understanding of the data and had more topics to discuss in their exchanges. They were looking forward to the new artwork and at the same time their determination to improve their health and the environmental health to present the artwork in a better way became stronger.

In addition, we learned that it did not take long for the participants to open or establish rapport through exchanging information about their respective community forests. They also mentioned that in their interactions with other participants, theirs felt a sense of ease and pleasure from the vibrant atmosphere. In the experiment, participants projected their emotions onto the scene of the community forest was the most common way of observing the digital artwork as they were exposed to the community forest artwork, they made subtle observations and gained perceptions of the changing digital artwork, projected their emotions or feelings about the environment through the community forest. These also become a good starting point for unfolding a narrative personal story. The emotions they see in the faces of others, they know are significant and symbolic to them, and thus may provide a way to "reconnect" with their own emotions. They were eager to share their community forest work and knowledge with others, looking forward to new work, creating a contagious interest in taking part in the course. Participants gained distraction, anxiety relief and a reduction in self-defense through digital forest activities. Some participants talked about how their participation in the program provided a break from the pressures of their busy studies, a sense of freshness of circulation and a shift in focus, as well as a reduction in stress when viewing the community forest, and began to increase their concern for the environmental health of their community, which was helpful for interactions amongst the participants and for the improvement of their environmental health literacy.

Furthermore, emotional contagion is readily available when a group of people are discussing the same topic together, and some participants have good social skills themselves, which provide a greater impetus to the project and ease the social pressure on others. However, for the members of the control group, it is difficult to draw direct attention to a purely numerical change, and the participants would be more inclined to reach the goal of the activity from the point of view of interacting with people. However, we cannot exclude those who are resistant to strangers due to social anxiety, and it takes them a longer time to really participate in the activity.

The results, as shown in Tables 3 and Figures 9 and 10, indicate that the control group had a certain effect on the improvement of environmental literacy, but the degree of improvement is not universal, while the test group took the community forest as the carrying body, stimulated the participants from a visual perspective, so that the participants could more deeply appreciate the importance of the ecological environment, and had a greater effect on the improvement of environmental literacy and a wider generalization .

Compared with traditional environmental education activities, community forests are more relaxed and natural, and have a higher degree of acceptability and participation, do not require participants to endure too much pressure and discomfort, and at the same time do not have too high a threshold, which aids in drawing a larger audience to engage in them. The project also exhibits a high degree of interactivity, which can help participants better understand their emotional state, and communicate with others to share their inner world, thus achieving better results.

IV. Discussion

This study applied digital art, which incorporates digital health and environmental data, to the improvement of environmental literacy in adolescents. Quantitative findings indicated that the experimental group demonstrated statistically significant enhancement across all items of the environmental literacy scale post-experiment. The overall improvement was markedly superior to that of the control group, with participants in the experimental group showing increased willingness to adopt a green lifestyle and engage in activities promoting environmental health. As shown in Figure 13 the Test group has the highest satisfaction rate in terms of Cognitive impact degree and Behavioral impact degree, both reaching 65%, which is higher than the Control group by 116.67% and 85.71% respectively.

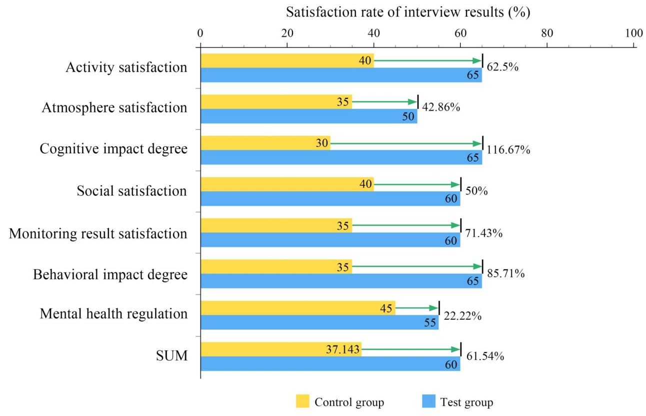

Fig. 13. Satisfaction rate of interview results for two groups.

The results indicate that digital art – based visualization can effectively stimulate deeper reflection on health and environmental issues by providing an intuitive and emotionally engaging medium for interpretation. In the qualitative analysis, the use of the community forest demonstrated clear advantages. As shown in Figure 13, the test group achieved a 55% satisfaction rate in mental health regulation, representing a 22.22% improvement compared to the control group. Participants reported that the community forest offered a relaxing and immersive environment that supported emotional expression,mood sharing, and self-reflection. It also provided a platform for communication and interaction, helping participants better recognize and respond to their own health conditions and challenges.

Compared with conventional data reports, the community forest visualization was perceived as more vivid, intuitive, and emotionally resonant. This form of representation was more effective in eliciting emotional engagement,stimulating concern, and encouraging communication among community members.As a result, it contributed to stronger group cohesion and increased motivation to actively engage in health-related and environmental practices,thereby supporting the enhancement of environmental literacy and the adoption of green lifestyles.

Overall, the findings suggest that integrating digital visual art as an auxiliary medium in health and environmental education is both feasible and effective. Increased engagement and positive learning attitudes enabled participants to actively interact with and further develop their digital artworks, transforming the visualization process into a participatory and evolving experience. Through the community forest digital artworks, the study promoted adolescents' awareness of personal health and environmental health, enhanced their environmental literacy and sense of cultural identity, and contributed to sustainable development. This approach demonstrates a high degree of originality and advancement in combining digital art with community health and provides valuable insights for future research in related fields.

There are several limitations in this study that should be acknowledged.First, the human health data used for digital art generation were derived from sEMG signals. The detection results may be influenced by environmental conditions and individual differences, which limits measurement accuracy. In addition, the current data analysis technique may require further optimization and should not be regarded as the only or optimal solution for health data interpretation. Second, the study primarily focused on enhancing environmental literacy,while the detection of environmental hazards was relatively limited.Apart from PM2.5, other important environmental indicators, such as water quality and soil quality, were not included, resulting in incomplete environmental data coverage.Furthermore, differences in landscape preference were observed among participants, suggesting that aesthetic and emotional responses to environmental visualizations may vary depending on individual factors such as age, cultural background, and educational experience. As a result, the findings may not be directly generalizable to other age groups or populations.In addition, environmental literacy was assessed using self-reported questionnaires, which may introduce subjective bias. Objective or behavior-based evaluation methods should be incorporated in future studies to strengthen the rigor of assessment.Finally, the relatively short experimental duration and the limited,homogeneous sample size may affect the generalizability and reliability of the results. Future research should involve longer-term studies, larger and more diverse participant groups, and customized research protocols for different regions and populations to further validate and expand the findings.Although the results indicate a positive effect of integrating digital art with human and environmental health on adolescents ’ environmental literacy, further investigation is needed to examine the sustainability and long-term impact of this approach. Longitudinal and follow-up studies would be particularly valuable in assessing lasting behavioral and attitudinal changes. While this study focused on adolescents, broader social and environmental benefits may be achieved through community-wide participation and collaborative engagement.

Despite these constraints, initial research indicates that community forests positively contribute to enhancing environmental literacy among adolescents. In the future, we will be working on a new and improved project on community forests, which aims to promote community health and well-being through community health data collection activities, and to improve the environmental literacy of residents in general. The project will contribute to the maintenance of physical and environmental health, and to the improvement of the community forest as an art form, as well as to the improvement of a friendly and green environment in the community. Specifically, we will collect human health data and environmental monitoring data on a community basis and analyze these data to generate digital art that reflects the overall health of the community. At the same time, we will invite community residents to participate in the creation of digital artworks to promote cultural exchange and artistic creation in the community. All digital artworks created by the community will be voted and ranked online, and the best works will be selected to become NFT projects for sale. 20% of the funds obtained will be used for online community management, and 30% will be used for offline community refurbishment, renovation, and construction to improve the community's service facilities and residents' well-being. Furthermore, future research could also further expand the application scenarios and value of digital art by considering the introduction of artificial intelligence technology and virtual reality technology to intensify the immersion and interactivity of digital art pieces, and to improve the degree of participation and user experience. In addition, the project has made new advances in the application of E-health and IoT, encourage community adolescents to participate in actions for environmental protection and sustainable development, form common values and cultural identities, and enhance community cohesion. This will further realize the aim of harmonious coexistence of the Human-Machine-Environment trinity, which is highly socially valuable and practically significant.

V. Conclusion

This study utilized IoT to acquire E-health and combined the human health and environmental literacy to generate digital art and develop a sustainable method of intervention for environmental literacy. A controlled experiment and questionnaire interviews verified the positive impact of community forest digital artworks on environmental literacy among adolescents. The results of the experiment showed that community forest digital can assist adolescents with socialization, help them understand their health conditions, and significantly improve adolescents' environmental literacy assessments. Although the application of digital art in community health interventions and environmental education still needs further investigation and improvement, the study's findings offer fresh perspectives and a certain theoretical and practical basis for the application of E-health and IoT in this field, and offer some insights and references relevant to subsequent studies.

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The following abbreviations are used in this manuscript (Table 4):

TABLE IV. Abbreviations

MDPI	Multidisciplinary Digital Publishing Institute
IoT	Internet of Things
ADHD	Attention Deficit and Hyperactive Disorder
NIOSH	National Institute for Occupational Safety and Health
AEE	Artistic Environmental Education
CEPS	Children's Environmental Perception Survey
SPSS	Statistical Product and Service Solutions
EMG	Electromyography
ALS	Amyotrophic Lateral Sclerosis
TCM	Traditional Chinese Medicine
LTD.	Company Limited
APP	Application
ELAS	Environmental Literacy Assessment Scale
TPB	Theory of Planned Behavior
EE	Environmental Ethics
PEB	pro-environmental behavior
EV	Environment Value
EA	Environment Awareness
PK	Protecting Knowledge
GL	Green Lifestyle
PA	Protecting Actions
M	Mean
SD	Standard Deviation
PD	Pairing Difference
NFT	Non-Fungible Token

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