Smart Farm Teaching Aids Based on STEM Concepts

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Abstract. In view of the above-mentioned problems, this paper is based on STEM education and constructs teaching aids for smart farms, allowing students to practice the teaching aids developed by this paper in the field. The teaching aids of this paper are mainly based on the detection of farm and honeycomb status. Determine whether there are any abnormalities between the farm and the activity status of bees, such as: crop growth, bee reproduction, etc. Students can increase their interest in IT practical learning through teaching aid assembly and program operation. In addition, students should correct the teaching aid parameters during actual operation. Improving the recognition accuracy will further arouse students' interest in artificial intelligence theory learning and achieve STEM education concepts. This paper will mainly use traditional artificial intelligence practical teaching methods and the innovative teaching methods proposed by this paper for learning comparison. The teaching method will be evaluated through the T test method through front and back questionnaires, teaching evaluation and student achievement scores. Help show whether the teaching method of this paper has achieved the expected goal. This article aims to cultivate more talents through Artificial Intelligence of Things (AIoT) teaching aids, analyzing data using t-tests in Statistical Product and Service Solutions (SPSS). Therefore, the experimental results prove that the STEM 4.0 approach proposed in this study can enhance students' learning performance and willingness.

Keywords: Artificial Intelligence · Smart Farming · Interdisciplinary Teaching · STEM · Digital Transformation

1 Introduction

Concerning the teaching of Artificial Intelligence (AI) and multimedia theories, most students tend to be less willing to learn as they lack motivation or have learning disabilities. The possible reasons for this situation are their incomprehension of the concepts and definitions and limited computational skills. In the long term, students become afraid of mathematics and even choose to give up

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when encountering basic calculations. When students lack the ability for mathematical logic and proof and can only memorize formulas by route, they are likely to forget those formulas as time passes, making them fail to calculate. On the other hand, the complex mathematical theories in AI and multimedia studies can sometimes lower students' learning motivation; additionally, they might give up the entire course because these mathematical theories are the application foundation of these sectors. If learners want to be more creative in developing relevant applications, they must possess the inferential capacity to tackle mathematical theories and comprehend the full process.

This article focuses on smart agriculture and aims to cultivate interdisciplinary talents. Firstly, the study lists the relevant questions of smart agriculture for students to choose the ones they are interested in, allowing students to discuss the issues and solutions. Next, this research will create smart agriculture teaching aids for students to assemble, write programs, and derive mathematical reasoning for each module, expecting to achieve the goals of Science, Technology, Engineering, and Mathematics (STEM). By focusing on smart agriculture, the study will provide students with relevant teaching aids; the features of this article are: 1. The equipment utilizes Artificial Intelligence of Things (AIoT) sensors to detect the environmental factors in the farm, such as temperatures or humidity; 2. The system can identify various animal sounds during different periods, such as farm animals or bees, by wavelet transformation to process signals; furthermore, the equipment then analyzes the pitches, eigenfrequencies, and frequency distributions to build the condition eigenvalues of various farm animals or bees, helping AI identify the signals; 3. The system uses You Only Look Once (YOLO) to recognize objects, primarily checking whether there are hornets in beehives; meanwhile, as the high recognition rate of YOLO, the technique can be applied in animal husbandry to detect whether a pig is crippled or in other smart agriculture environments. Additionally, this research starts by creating the model of the proposed teaching aids and further asks the students to train the model and develop the recognition rate. This process allows students to encounter challenges during the practice and encourages them to discuss with teachers and understand the theories, stimulating students' learning motivation toward the mathematical theories in multimedia and AI.

2 Related Works

Reference [2] utilizes 3-D Computer-Aided Design (CAD) to create a model, design, and print 3-D products to improve students' spatial visualization, creativity, and problem-solving capacity. Applying 3-D CAD software and 3-D printing can influence creativity needs' perception when students resolve the issues they might encounter in their STEM careers. Reference [5] points out that the lower numbers of female participants in STEM courses has always been a popular research topic, and the research has found that the scarcity of female students enrolled does not always show a uniform distribution in STEM studies. In some subjects, such as computer, communications, electric, and electrical engineering, the number of female students does not increase but declines instead.

The experiment result of Reference [6] reveals that many pieces of research focused on discussing and evaluating the appropriateness and effectiveness of Virtual Reality (VR) supported teaching applications. Moreover, some studies point out the learning outcomes, positive viewpoints of user experience, and the improvement of perceived availability; yet, only limited research measures students' learning performance. The current scope review aims to encourage instructional designers to develop innovative VR applications or integrate existing methods into their teaching. On the other hand, Reference [1] mentions that Japanese high school students in STEM subjects expect to work in scientific and technical sectors but lack the motivation for learning English as a second language (L2), weakening their current L2 learning capability and the ability to communicate globally during their career in the future. Finally, the summary of the research states that it seems to have a close correlation between students' English learning motivation and gaining high scores in standardized English language tests, obtaining employment, and striving for promotions in occupational hierarchies; however, these external motivations in L2 learning is never stronger than the positive image of using English directly in the future.

While setting STEM as the basic foundation, this study aims to arouse students' interests in mathematic theories by practicing experiments. In Reference [8], the research states that the graduates who adopted STEM education in the United States tend to have higher work capacity and ability; meanwhile, students who participate in STEM education have better wages and job positions. Therefore, some universities further changed their educational entrance examination methods by including STEM scores in the rating scale, hoping to increase students' interest in practicing STEM. Reference [7] argues that although the United States has introduced STEM education proactively, the country's mathematical ranking still falls to 35; the reason is probably due to the interference of parents in selecting STEM courses. Hence, apart from implementing STEM education, governments and schools also need to provide educational propaganda and win support from parents. By integrating and summarizing the best practice papers that focused on identifying, sharing, and evaluating experiences and items, the articles in Reference [3] intend to foster diversity and gender equality in STEM subjects in academia and the professions. The experiment in Reference [4] anticipates filling the educational gap by evaluating the quality of teachers' predictions (labelled expert prediction). In the experiment, 43 elementary teachers predicted students' step-by-step actions whilst solving Ill-defined Problems (IDPs) through a Light Path Task (LPT); next, the experiment compared the quality with machine predictions executed by sequential pattern mining techniques. In the meantime, the experiment also collected students' lines of action data from 501 fifth- and sixth-grade students aged between 11 and 12.

Based on the concept of STEM 4.0, our research empowers students to team up and explore more problems and solutions independently. Summarizing the above literature reviews completes the research and teaching of this article, and the developed smart agriculture teaching aids allow students to extend to more topics.

3 The Proposed Scheme

3.1 Research Method

Setting STEM 4.0 education as the foundation, the course in this study separates students into controlled and experiment groups, and the course process is shown in Fig. 1. Firstly, we explore various topics for students to choose from, and the students will discuss the questions of the topic accordingly. As the course agenda is about farms, students need to acquire interdisciplinary knowledge of agriculture and stock farming. On the other hand, teachers will conduct the traditional didactic teaching to students in the controlled group and teaching aid assembling and programming to the other group. In the experiment group, the teacher will provide a 30-minute discussion time in each class; when students encounter questions, teachers can offer theoretical teaching, encouraging students to discover issues through practical experiments and stimulating a higher interest in learning theories and knowledge.

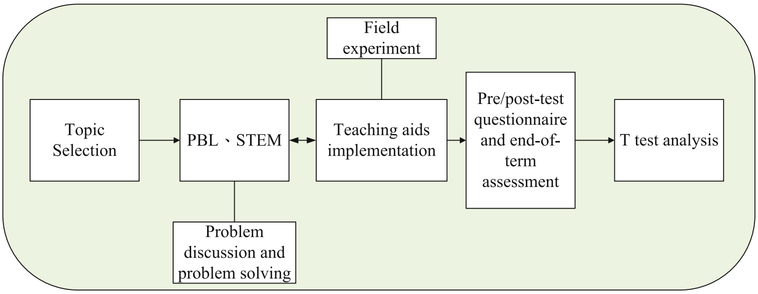

Fig. 1. Teaching Mode.

We will conduct pre-, post-, and final evaluation questionnaires to analyze the course effectiveness of the experiment; next, a t-test will be utilized to examine the performance, verifying whether the teaching model proposed in this study can achieve the expected teaching goal. Moreover, we will use a questionnaire to understand students' practicing interest in those teaching aids and check if they fully absorb the theories. Apart from confirming the performance of teaching aids, we will also take students to visit and do actual experiments in the field, testing those teaching aids' usability. Finally, the t-test results from all questionnaires allow us to learn the difference between the two groups and check students' satisfaction with the course design.

3.2 The Design of Teaching Aids

The structure of designed teaching aids is demonstrated in Fig. 2. To enhance the preciseness, we start the process by sorting the teaching aids. Next, we separate the teaching aids' sound and image and use YOLO to recognize objects; to increase the accuracy, we have collected videos directly from farms to separate the sound and video. After collecting enough data, we implement feature extraction, training, and testing on the images. In the meantime, using wavelet transformation as the foundation, we recognize the sound by its frequency, eigenvalue, and pitch period. Finally, as we aim to detect future environmental factors in this research, we utilize the Internet of Things (IoT) to obtain data on current environmental factors and judge if there are abnormal conditions. Additionally, this article employs machine learning to process and recognize the conditions of the ongoing topics, hoping to improve the model's accuracy and data ownership.

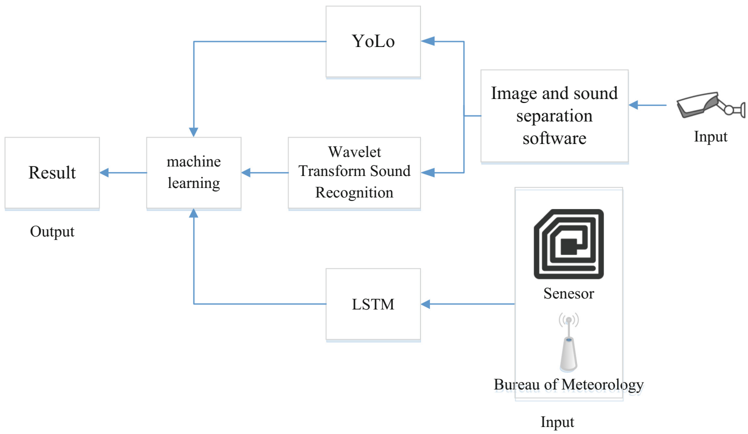

Fig. 2. Schematic diagram of teaching aids.

3.3 The Design of Sound Recognition Teaching Aids

The sound recognition technique in this research utilizes the frequency domain. Firstly, based on the auditory model to divide input signals into 24 sub-band signals, the decomposition tree structure consists of six hierarchies. As the highest frequency will not be over 8 KHz; thus, according to the Nyquist Sampling Rate, we set the sampling frequency to be 16 HKz, which is 0 to 16 KHz in the human audibility range. Afterward, we use wavelet transformation to construct 24 sub-band signals, $X[n]$, based on the human auditory range; after gaining the audio frame, we can get $x[i]$, where i represents each different frame. Each wavelet packet transformation of the frame can further build 24 sub-band signals, $w_{j,m}(k)$, where j means the hierarchy of the tree structure, m represents the 24 sub-band signals, respectively, and k shows the length of the sub-band signal; therefore, we select 24 sub-bands for further steps. Meanwhile, the function of the Teager Energy Operator (TEO) is to strengthen stable or semi-stable signals and attenuate other unstable signals; it is an extremely effective nonlinear algorithm that extracts signal energy through mechanical and physical methods. There are two ways of expression in continuous and discrete signals; the TEO calculation in continuous signals can be shown as the first- and second-order functions of the signal $x[i]$, and the formation is as follows:

$$\varphi_c\left[x[i]\right] = \left(\frac{dx[i]}{dt}\right)^2 - x[i]\frac{d^2x[i]}{dt} \tag{1}$$

On the other hand, the differential is used to replace derivative operations in discrete signals, and the formula is illustrated below:

$$\varphi_D\left[x[n]\right] = x^2[n] - x[n+1]x[n-1] \tag{2}$$

In this study, the TEO output is $t_{j,m}(k)$, and MASK means to smooth the waveform and reduce sawtooth waves. The formula is as below:

$$T_{j,m}(k) = t_{j,m}(k) * H_j(k) \tag{3}$$

In the formula, $H_j(k)$ represents the Hamming window, and the length is $256/2^j$. As sound recognition primarily judges the eigenvalues of sound; hence, our study measures the pitch, timbre, and sonorant (frequency distribution). Firstly, we utilize Mel-frequency Cepstrum to calculate timbre. Next, because we use wavelet transformation to calculate the frequency distribution of the sound; thus, there is no need to obtain each sound's frequency by triangular bandpass filters. As a result, this research applies discrete cosine transform to derive Mel-frequency cepstral coefficients, and the formula is as follows:

$$C_m^i = \sum_{j=0}^{J-1} \cos(m\frac{\pi}{J}(k+0.5))\log_{10}(T_{j,m}(k)) \tag{4}$$

where C_m^i represents Mel-frequency cepstral coefficients, and the calculation of differential cepstral coefficient is shown below:

$$\Delta C_m(t) = \frac{\partial C_m(t)}{\partial t} = \frac{\sum_{\tau=-M}^{M} \tau \cdot C_m(t+\tau)}{\sum_{\tau=-M}^{M} \tau^2} = \frac{\sum_{\tau=1}^{M} \tau \cdot (C_m(t+\tau) - C_m(t-\tau))}{2 \cdot \sum_{\tau=1}^{M} \tau^2} \tag{5}$$

In the formula, C_m^i and $\Delta C_m(t)$ mean the sound's timbre eigenvalues. Next, we need to calculate the pitch period of the sound, and the formula is as follows:

$$P_{j,m} = \prod_{j=0}^{n-1} X[j] \tag{6}$$

Table 1. Post-analysis

	Number	Minimum	Maximum	Sum	Average Deviation	Standard	Variation
@1 I possess the capacity for practical execution	35	2.0	4.0	95.0	2.714	0.5725	0.328
@2 I possess teamwork abilities	35	1.0	4.0	89.0	2.543	0.6572	.432
@3 I possess communication skills, including group communication in discussing coursework and presentation reports	35	2.0	4.0	87.0	2.486	0.5621	0.316
@4 I possess data collection capacity	35	1.0	4.0	90.0	2.571	0.6081	0.370
@5 I possess problem-solving abilities	35	2.0	4.0	92.0	2.629	0.6897	0.476
@6 I possess innovation capability	35	2.0	4.0	96.0	2.743	0.6572	0.432
@7 I possess a logical thinking capacity	35	2.0	4.0	92.0	2.629	0.5470	0.299
@8 I possess the ability to analyze problems	35	2.0	3.0	90.0	2.571	0.5021	0.252
@9 I possess employability	35	1.0	4.0	95.0	2.714	0.6217	0.387
@10 Overall speaking, this course benefits the improvement of professional expertise	35	2.0	3.0	90.0	2.571	0.5021	0.252
Valid N (Listwise)	35						

This article plans to utilize wavelet transformation to convert frequencies first; then, combined with deep learning, we use the timbre, pitch, and sonorant to recognize the sound, enhancing the accuracy of sound recognition.

4 Experiment Results

This article evaluates the effectiveness of the proposed method by pre- and post-questionnaire and the final teaching assessment. Table 1 demonstrates the post-analysis result, Table 2 presents the pre-analysis result, and Table 3 shows the integrated analysis. Furthermore, a t-test is conducted to check the significance of the research, and the data in Table 4 has proved that our proposed approach has statistical significance, showing the feasibility of our study.

Table 2. Pre-analysis

	Number	Minimum	Maximum	Sum	Average Deviation	Standard	Variation
@1 I possess the capacity for practical execution	35	2.0	5.0	131.0	3.743	0.7413	0.550
@2 I possess teamwork abilities	35	3.0	5.0	146.0	4.171	0.5681	0.323
@3 I possess communication skills, including group communication in discussing coursework and presentation reports	35	3.0	5.0	147.0	4.200	0.6325	0.400
@4 I possess data collection capacity	35	4.0	5.0	152.0	4.343	0.4816	0.232
@5 I possess problem-solving abilities	35	4.0	5.0	153.0	4.371	0.4902	0.240
@6 I possess innovation capability	35	3.0	5.0	137.0	3.914	0.6122	0.375
@7 I possess a logical thinking capacity	35	3.0	5.0	133.0	3.800	0.6325	0.400
@8 I possess the ability to analyze problems	35	3.0	5.0	137.0	3.914	0.6585	0.434
@9 I possess employability	35	3.0	5.0	131.0	3.743	0.6108	0.373
@10 I anticipate gaining sufficient support from this course	35	4.0	5.0	157.0	4.486	0.5071	0.257
Valid N (Listwise)	35						

Table 3. Integrated Analysis

	Test	Number	Average	Standard Deviation	Standard Error of the Mean
@1 I possess the capacity for practical execution	1.0	35	3.743	0.7413	0.1253
	2.0	35	2.714	0.5725	0.0968
@2 I possess teamwork abilities	1.0	35	4.171	0.5681	0.0960
	2.0	35	2.543	0.6572	0.1111
@3 I possess communication skills, including group communication in discussing coursework and presentation reports	1.0	35	4.200	0.6325	0.1069
	2.0	35	2.486	0.5621	0.0950
@4 I possess data collection capacity	1.0	35	4.343	0.4816	0.0814
	2.0	35	2.571	0.6081	0.1028
@5 I possess problem-solving abilities	1.0	35	4.371	0.4902	0.0829
	2.0	35	2.629	0.6897	0.1166
@6 I possess innovation capability	1.0	35	3.914	0.6122	0.1035
	2.0	35	2.743	0.6572	0.1111
@7 I possess a logical thinking capacity	1.0	35	3.800	0.6325	0.1069
	2.0	35	2.629	0.5470	0.0925
@8 I possess the ability to analyze problems	1.0	35	3.914	0.6585	0.1113
	2.0	35	2.571	0.5021	0.0849
@9 I possess employability	1.0	35	3.743	0.6108	0.1032
	2.0	35	2.714	0.6217	0.1051
@10 I anticipate gaining sufficient support from this course	1.0	35	4.486	0.5071	0.0857
	2.0	35	2.571	0.5021	0.0849
Valid N (Listwise)	35				

Table 4. Integrated Analysis

	T	Degrees of Freedom	Significance (two-tailed)
@1 I possess the capacity for practical execution	6.497	68	0.000
@2 I possess teamwork abilities	11.091	68	0.000
@3 I possess communication skills, including group communication in discussing coursework and presentation reports	11.986	68	0.000
@4 I possess data collection capacity	13.511	68	0.000
@5 I possess problem-solving abilities	12.186	68	0.000
@6 I possess innovation capability	7.716	68	0.000
@7 I possess a logical thinking capacity	8.288	68	0.000
@8 I possess the ability to analyze problems	9.594	68	0.000
@9 I possess employability	6.982	68	0.000
@10 I anticipate gaining sufficient	15.870	68	0.000

A pre- and post-questionnaire was conducted before and after the course. We also operated the t-test in SPSS to analyze data. The analytic result shows that our data is an F-distribution, and the obtained value of F means statistical significance if the F-value is lower than 0.05; in other words, the statistical result proves that the teaching model and aids can enrich students' learning performance. The pretest reveals that the top three personalities among the participants are innovation, hands-on execution ability, and employability, presenting that students expect to focus on personal development like innovation and practical execution capacity. On the other hand, the posttest shows that the top three abilities students expect are: this course benefits the improvement of professional expertise, I possess problem-solving abilities, and I possess data collection capacity. Finally, the integrated analysis indicates that the average difference between the pre- and post-questionnaire is two to four, demonstrating the discrepancy between the experimental and control groups. The result also illustrates that students possessed expectations toward the course content before experimenting, and the class improved students' learning performance. Furthermore, the t-test analysis illustrates that participants significantly improved each evaluation item after the class, particularly the three sub-statements in question four: I possess data collection capacity, problem-solving abilities, and communication skills, including group communication in discussing coursework and presentation reports, present high significance. This result proves that the study can indeed enhance students' performance. The t value of the integrated analysis is 15.87, showing a high significance. As a result, the analyses indicate that apart from enriching students' learning capacity, they have also improved their teamwork and practical abilities through participating in the course.

5 Conclusion

Universities have been promoting interdisciplinary education; consequently, apart from acquiring professional skills in the major subject, students are required to gain additional knowledge in other sectors. This project focuses on STEM 4.0 education and encourages students to develop self-directed learning, cultivating their problem-seeking and problem-solving abilities. By taking the STEM 4.0 concepts as the key concept, this project creates an initial model, attracting students to collect, train, and test data spontaneously, guiding students to understand relevant mathematical theories during the process and increasing their interest in learning the background knowledge. Aside from developing teaching aids, the course is designed to foster AI and smart agriculture talents, benefiting talent cultivation in the technology industry. The experiment result has proven that students possess high acceptance toward the designed course, which is feasible to boost students' learning enthusiasm for mathematics. Meanwhile, we will also discuss blockchain technology to record students' full learning performance and special topic conditions, enhancing the analysis of students' learning progress and special topic performance.

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