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Interactive realization of business English Classroom Based on communication technology and data fusion

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Abstract Timely and effective interactive feedback between teachers and students in classroom teaching is of great significance for the improvement of students' learning motivation, classroom efficiency and teaching quality. This paper designs a smart classroom interactive teaching system based on ZigBee technology. And with the help of smart classroom interactive analysis coding system to test the application effect of interactive teaching system in business English classroom. After testing, the system in this paper can effectively improve the interactive flexibility of the smart classroom and shorten the time to open the system interface compared with the Flanders interactive analysis system based on event records and the classroom interactive teaching system based on 5G wireless communication, which can provide a guarantee for the learning and teaching efficiency of students and teachers. Taking the teaching of business English course as an example to test the system, the system in this paper helps to stimulate students' interest in learning, promote students' active learning, improve students' classroom participation, and enhance students' performance in business English. The study combined with students' classroom performance data proves that the interactive teaching system based on communication technology can improve the effect of teacher-student interaction and feedback in the business English classroom.

Index Terms ZigBee technology, interactive analytic coding system, smart classroom, business English

I. Introduction

With the rapid development of economic globalization, English has become a language tool for many people to communicate. Business English teaching in colleges and universities has become more and more important, which outputs high-level English talents for the society and promotes efficient communication among all social classes [1]. Among the many social environmental factors in school teaching, interpersonal relationships are the most important, and promoting the smooth development of classroom interpersonal relationships and strengthening teacher-student interactions have become an important goal of classroom reform [2]. However, due to the influence of various factors, at this stage, many college students are not active enough to learn, used to passively accept the teacher's lectures, this traditional teaching method restricts the all-round development of students and hinders the effective implementation of teaching reform [3]-[5]. The deeper significance of teacher-student interaction lies in the fact that the knowledge, experience and experience formed by communication are transferred to the students in a special way, so that the students can make progress through continuous learning and become useful talents with all-round development of comprehensive quality [6]-[8]. In business English classroom teaching, teachers should take effective measures to attract students to learn actively and interact with teachers positively [9].

With the application of information technology and various classroom interaction platforms, a diversified classroom teacher-student interaction mode has gradually been formed [10]. The various resources and emerging functions presented under the support of communication technology and data convergence also provide more possibilities for teaching optimization in the modern university English classroom, and make the classroom interaction ecology gradually change qualitatively [11]-[13]. Relying on these information resources and platforms, the business English professional classroom brings great convenience to classroom teaching, creates a personalized, digital and intelligent teaching environment, and gradually forms and builds a brand-new classroom ecological environment [14]-[16]. Therefore, it is important to explore the status quo and existing problems of teacher-student interaction mode in university business English professional classroom under the background of informationization, analyze the reasons for its emergence and put forward corresponding solutions to build a good classroom interaction ecology, so as to improve the teaching quality and efficiency of business English professional classroom [17]-[20].

Traditional teaching focuses on imparting knowledge to students, in the form of a single means of teaching, students in the process of learning is easy to produce an aversion to learning, learning interest will slowly disappear. The popularization and use of intelligent technology has completely changed this situation, and the large information capacity and outstanding features are the important characteristics of the intelligent classroom. Wooten, J. J. showed that classroom media clips help to increase student attention and enhance their classroom engagement, and that editing long videos into small clips as instructional materials simultaneously addresses both the lack of depth of short videos and the tedium of long videos, as well as promotes talk about interactions between classes [21]. Khamparia, A. and Pandey, B. discussed the impact of multimedia technology on the teaching and learning process in on-line education, on the one hand the technology provides students with adaptive course learning resources, on the other hand it enhances the frequency of teacher-student interactions, which positively affects the learning outcomes of students [22]. Hao, Y. W. et al. studied the interactive teaching mode based on intelligent devices, which is conducive to improving the relevance and effectiveness of instructional design by utilizing the intelligent blackboard to carry out functions such as multimedia presentations and interactions, which in turn stimulate the students' interest in learning [23]. Yu, H. et al. analyzed the differences in teacher-student interaction behaviors and student engagement in smart and traditional classrooms, and synthesized pedagogical, spatial, and technological aspects to propose a classroom interaction model applicable to smart classrooms to promote classroom interaction [24]. Dai, Z. et al. enhanced the level of classroom interaction by implementing a project-based teaching methodology in a smart classroom and emphasized that this smart learning environment will dramatically improve students' thinking skills and interest in learning [25]. Shamim, M. R. H. et al. proposed a TPACK (Technology, Pedagogy, and Content Knowledge) model for measuring classroom interactions and attempted to provide recommendations for creating instructional designs that include TPACK components in teaching and learning activities [26]. Gan, C. L. and Balakrishnan, V. address the poor quality of interaction in teacher-centered face-to-face teaching and propose the use of communication technologies to simplify the process of interaction between teachers and students and thus enhance the effectiveness of interaction [27]. Edwards, B. I. examined the role of smart technologies in enhancing the level of classroom interaction and the learning experience, emerging technologies represented by artificial intelligence and virtual reality have significantly transformed the learning space, thus positively affecting interactions and manipulations in the space [28]. Ali, Q. A. and Sahab, N. M. explored an interaction design approach for virtual classroom platforms, which as an immersive teaching and learning method gradually replacing face-to-face teaching and online learning, will bring a teaching and learning experience that meets the expectations of teachers and students [29]. It can be seen that the significant advantages of intelligent teaching technology create good conditions for students' initiative and motivation. The above study provides inspiration for the realization of classroom interaction in business English teaching. Teachers should follow the trend of the times, make full use of the increasingly common use of intelligent teaching technology, produce colorful, interesting and focused courseware, let students see more intuitive business English communication occasions, stimulate students' strong interest in English learning, and learn to transform textbook knowledge into practical business exercises, mastering communication The course will also help students learn to transform textbook knowledge into practical business exercises, master communication skills, and better participate in classroom interactions.

The article incorporates the advantages of Zigbee protocol in terms of high time, large capacity, low power consumption, anti-interference, etc., and designs a classroom interactive teaching system. The receiver, transponder and remote control are used as hardware components. On the software side, a balanced address allocation mechanism for teaching interaction is established based on ZigBee technology, and the address-location correspondence of classroom interactive data is analyzed so as to optimize the interactive performance of the teaching system. The performance of the constructed system is tested in terms of functional framework and interactive address allocation. With the help of the classroom interactive behavior coding system in the smart classroom environment, the classroom interactive behavior is coded, and the differences between the traditional classroom and the classroom interactive based on the system in this paper are compared from the aspects of classroom structure, teacher's speech, student's speech, and technological application, so as to test the realization effect of the system.

II. Design of ZigBee-based Smart Classroom Interactive Teaching System

II. A.Analysis of ZigBee operating frequency and data transmission

ZigBee technology can support a variety of network structures, which include star, tree, and mesh topologies [30]. The different topologies are shown in Figure 1. In this paper, tree network topology is used for the convenience of teachers to control the student nodes.

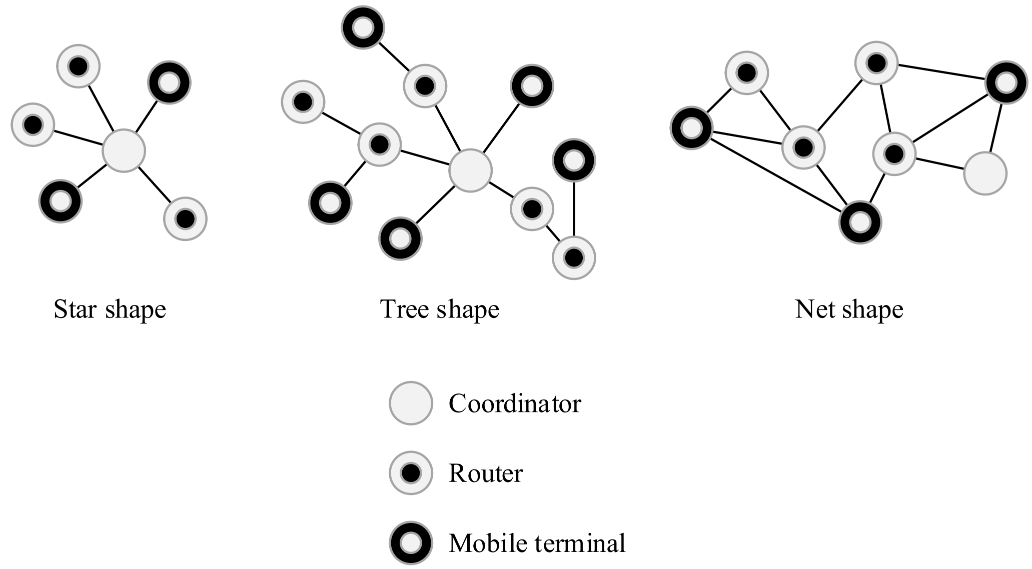

Figure 1: Topological structure

In the tree network topology, two physical layer standards, 2.4GH and 868/915 MHz, are defined using the IEEE 802.15.4 standard, so that three operating frequencies are present in the system. Both physical layers use a uniform data format based on DSSS. Different operating frequencies will be used in different regions with different modulation means and transmission speeds. The frequency interval of each band is shown in Table 1.

Table 1: ZigBee's working frequency

Physical layer/MHz	Working frequency/MHz	Region	Modulation method	Transmission parameter	
				Transmission speed/kb/s	Data coincidence
868	868~868.6	Euramerican	BPSK	25	Binary
915	902~928	North America	BPSK	45	Binary
2450	2400~2483	World	O-QPSK	255	Orthogonal

The 4GHz band is a globally harmonized band, and the use of this band for this system can reduce the production cost and avoid mutual interference with other wireless communication devices. The physical layer contains a total of 27 channels and the channel composition is shown in Table 2.

Table 2 ZigBee channel composition

Channel coding	Central frequency/MHz	Channel interval/MHz	Frequency limit/MHz	Frequency limit/MHz
k=0	868.3	0	868.6	868
k=1,2,…10	906+2(k-1)	2	928	902
k=11,12…26	2401+5(k-11)	5	2483	2400

II. B.Address Allocation Mechanism

There are two address allocation mechanisms in ZigBee network topology, distributed and high level address allocation methods. The distributed allocation mechanism is used in this study. In the network, there exists an associated depth for any device that indicates the minimum number of hops required for the device to reach the coordinator. Assuming that the coordinator depth is 0, the depth of its first level child nodes is denoted as 1. The nodes are able to be represented using the maximum cluster tree depth L_m, the maximum number of child nodes C_m with the maximum number of routing nodes per node R_m. The formula for determining the address size $Cskip(d)$ of all routing child nodes of depth d is as follows:

$$Cskip(d)=\begin{cases} 1+Cm\times(Lm-d-1) & Rm=1 \\ \dfrac{1+Cm-Rm-Cm\times Rm^{Lm-d-1}}{1-Rm} & Rm\neq 1 \end{cases} \tag{1}$$

In Equation (1), $Cskip(d)$ indicates the degree of address offset between the parent nodes in layer $d+1$.

If $Cskip(d)$ of the device is equal to 0, then this device belongs to the terminal node in the network and cannot continue to add child nodes. For the terminal node, the address allocation method depends on the order of the human network, then the formula for calculating the network address of the child node is as follows:

$$An=\begin{cases} Cskip(d)\times(n-1)+1, 1\le n\le Rm & Router \\ Cskip(d)\times Rm+n, 1\le n\le (Cm-Rm) & EndDevice \end{cases} \tag{2}$$

In equation (2), n denotes the number of terminal nodes.

II. C.Overall framework design of the system

With the development of modern informatization teaching, classroom interactive teaching is no longer a single question and answer and solving puzzles, and is not limited to a specific time and space, teachers and students are in a large network structure, the teacher implements teaching activities such as teaching, assessment and evaluation through remote control terminals, and the students learn and evaluate feedback online based on cell phones, computers and other smart terminals [31]. The business English classroom interactive teaching system to be designed in this study should cover the functions of online teaching, answering, attendance, evaluation and feedback, and consists of two modules: Zigbee wireless communication network and classroom interactive software. Among them, the Zigbee wireless communication network consists of handheld transponders, remote controls, transceivers, etc., and each component has a four-layer structure of application layer, network layer, media access control (MAC) layer, and physical layer, and each layer of the structure is authorized to implement the protocol standard of Zigbee wireless communication network. The student terminal can realize online Q&A and teaching activities based on the Zigbee wireless communication network by using the handheld transponder and the teacher terminal by using the remote control, while the transceiver can initialize and construct the Zigbee wireless communication network to accept the network request from the teacher and student terminals for interactive teaching in the classroom. The overall framework of the system is shown in Fig. 2.

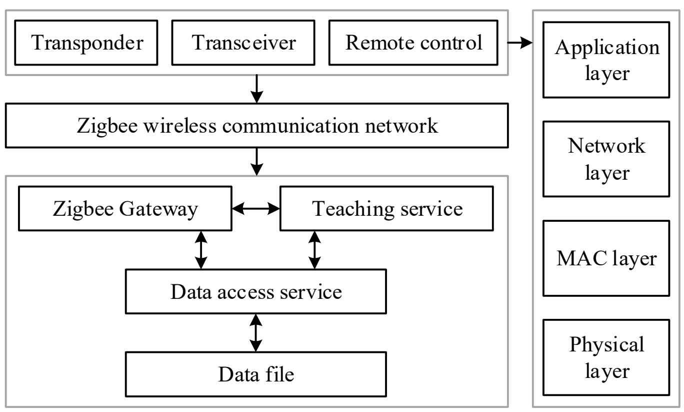

Figure 2: The overall framework of the system

II. D.Hardware selection and design of the system

From the above framework design, it can be seen that the classroom interactive teaching system based on Zigbee wireless communication consists of hardware such as Zigbee chips, receivers, transponders and transceivers, and is analyzed as follows with the focus on the selection and design of these hardware.

II. D. 1) Zigbee Chip

TI's CC2430 model Zigbee chip is a true system-on-chip CMOS solution, which uses 0.18μm CMOS manufacturing process, current loss is extremely low, in the network signal transceiver mode, current loss are below 25mA, sleep and active mode can be switched independently, for classroom interaction in the classroom interactive teaching in the ultra-long battery energy support needs, and has a 2.4GHz ISM band integrated radio frequency (RF) radio transceiver in line with the IEEE802.15.4 standard, configured with lightweight, low-power 8051 microcontroller core, wireless reception sensitivity and anti-jamming performance is better, suitable for different classroom interactive teaching environment of the wireless network communication needs. At the same time, in the classroom interactive system, a Coordinator needs to be selected as the core node of the Zigbee wireless communication network, which is used to upload and send interactive information, and the transceiver is selected to realize this function here. After the transceiver is turned on, the Zigbee wireless communication network will be initialized and formed on a suitable channel. Moreover, the energy-saving design of the system should be realized, so that the remote control and transponder held by teachers and students can play the function of EndDevice of the Zigbee wireless communication network, and go into a dormant state when there is no interactive teaching activity, and run when there is a demand. Since the current of the EndDevice of CC2430Zigbee chip is controlled within 3A in the dormant state, it can support the long-term and low-power operation of the remote control and transponder.

II. D. 2) Hand-held terminal equipment

Teachers and students hold remote controls, transponders, transceivers, and other terminal devices, which are the effective support for online attendance and question-and-answer teaching interactions. Among them, the student transponder is the hardware support for students to take attendance and submit questions, which is embedded in the Zigbee network in the framework design, so that students can transmit the response information to the transceiver based on the wireless communication network, and can run for a long time by using ordinary batteries because it is operated by buttons. The remote control is a teacher's terminal device with key functions embedded in the Zigbee wireless communication network, which can assist the teacher in accomplishing teaching activities such as classroom teaching, online Q&A, teaching interaction, attendance assessment, etc., and get rid of the time and space limitations of classroom interactive teaching bounded by the keyboard or mouse. Based on Zigbee wireless communication technology, teachers can interact with each other anywhere in the classroom, which is convenient for real-time tracking and checking students' learning feedback. The transceiver is the core device for classroom interaction on each teaching computer, which is equipped with a built-in Zigbee module and connected to the teaching computer through a hardware interface, so that it can receive real-time and accurate responses and remote control information from teachers and students, and transmit them to the host computer. Usually, the hardware interface exists universal serial bus (USB) interface, serial port two categories, but CC2430Zigbee chip is not configured with a USB interface, therefore, the need to add a USB driver part of the system, and the selection of the serial port as the transceiver and the teaching computer's hardware interface can be eliminated USB driver design, and the CC2430 chip comes with two general-purpose asynchronous transceiver (UART) and the driver code, so that the serial port connection design. The CC2430 chip comes with two general-purpose asynchronous transceiver ports (UART) and driver code, which makes the serial port connection design simpler.

II. E. Software function realization

The touch control integrator in the software design belongs to the communication bridge between the various parts of the system, not only to realize the communication with the mobile terminal, but also combined with the teacher's client set up by the student split-screen information to map the touch signal on different screens, so the system software design is the most important thing is to formulate the communication protocols of the various parts of the system.

(1) Communication with the mobile terminal The format of the mobile terminal sent to the touch controller is shown in Table 3. In the table, Computer Name and User Name represent the device name and user name respectively, which identify the sender of the information, and Action1~Action4 represent the touch action of 4 points, including two types of pressing and popping up, and Point1~Point4 are the coordinates of 4 points.

Table 3: Touch data format

Data type	Field name
String	Computer Name
String	User Name
Action	Action1
Action	Action2
Action	Action3
Action	Action4
Point	Point1
Point	Point2
Point	Point3
Point	Point4
int	Point C

(2) Communication with the Teacher Client

The purpose of communication between the integrator and the teacher's terminal includes informing the IP address of the teacher's terminal and receiving the split-screen information set by the client. For example, if a teacher assigns a task for two students to answer at the same time, at this time, the students can give their answers directly on their mobile terminals and display them on the big screen. One student's answer is in the left half of the area, and the other student's answer is mapped to the right half of the area, without interfering with each other. The process of realizing this function is as follows:

Step 1: Unify the coordinates. The resolution and coordinate range of different terminals are not consistent, so they need to be normalized. In this paper, according to the touch screen touch range 1920 * 1080 will all mobile terminal touch coordinates mapped to the interval, the formula is as follows. Where $ScreenX$, $ScreenY$ indicates the maximum value of horizontal and vertical coordinates, $Input.x$ and $Input.y$ are the initial touch coordinates:

$$x1 = Input.x * 1920 / ScreenX \tag{3}$$

$$y1 = Input.y * 1080 / ScreenY \tag{4}$$

Step 2: User number:

$$Loc = hash(UserName) \tag{5}$$

The data sent from the mobile terminal to the integrator contains the user name, which is unique and can be used to accurately determine the coordinate mapping region number in the touch data by using a hash vote.

Step 3: Coordinate mapping. If the split screen is not set up on the teacher's end, multiple students will share the same touch area. After the completion of the split-screen settings, the student's touch area can be mapped on the PC touch screen in a block, at this time more than one student at the same time touch will not interfere, the formula is as follows:

$$LocX = Loc \% Wid \tag{6}$$

$$LocY = Loc / Wid \tag{7}$$

$$Result.x = 1920 * LocX / Wid + x1 / Wid \tag{8}$$

$$Result.y = 1080 * LocY / Hei + y1 / Hei \tag{9}$$

In the above formula, Loc represents the serial number of the screen, Wid and Hei represent the number of columns and rows of the divided area, $LocX, LocY$ represents the number of rows and columns of the student's touch area, $x1$ and $y1$ represent the horizontal and vertical coordinates after the normalization process, and $Result.x$ and $Result.y$ represent the touch coordinates calculated in the end.

After completing the above steps, the system software module design is completed, thus realizing the interactive teaching between teachers and students.

III. Smart Classroom Interaction Analysis and Coding System

In this study, a coding system for analyzing classroom interaction in a smart classroom environment was used for data collection. The collected data were combined to verify whether the above-designed system could be realized in a business English classroom. The ratio of each behavior was calculated according to its data processing rules. The interaction analysis system analyzes the three dimensions of “speech”, “technology” and “silence”.

(1) The dimension of "speech" is divided into two aspects: "teacher's speech behavior" and "student's speech behavior". "Teachers' speech behaviors" are divided into: lectures, verbal evaluation, organizational instructions, open-ended questions, and closed-ended questions. "Students' speech behavior" is divided into: active questioning, discussion and communication, verbal evaluation, passive response, and active response.

(2) The dimension of "technology" is divided into two aspects: "teacher-technology" and "student-technology". "Teacher-Technology" is divided into: operation demonstration content, display of student achievements, teacher evaluation, and technical guidance. "Student-Technology" is divided into: self-directed learning, cooperative practice, sharing and presentation, and student evaluation.

(3) The dimension of "silence" is divided into two aspects: "silence that contributes to teaching" and "pause or chaos that does not contribute to teaching".

III. A. Coding rules

Based on the above dimensions, the classroom behaviors were sampled every 3 seconds, assigned a coding symbol and recorded, and a total of 800-1000 coding symbols were formed in one class. Due to the complexity of classroom teaching activities, the richness of teaching content, and the diversity of interactive forms, it is difficult to judge certain teaching behaviors and some interactive behaviors are lost due to camera switching in the coding process [32], therefore, in order to reduce the impact of the above situations on the data, the following coding rules are agreed upon in this study:

(1) When there are multiple interactive behaviors within a unit of time, the main interactive behavior is selected to be recorded according to the context.

(2) When two interactive behaviors alternate within a unit of time, the behavior that accounts for a larger portion of the unit of time is selected for recording.

(3) When student group communication, cooperative inquiry, and discussion activities are taking place, and the teacher's classroom visits are not guided or organized, they are recorded only as student inquiry and discussion.

(4) If the teacher provided individual group instruction for a discussion that was not supported by technology, it was coded as “5.”

(5) Teachers' invitations to students to answer questions were coded as “5.”

(6) When students complete exercises with the help of traditional learning tools such as books, exercise books, pens, etc., they are coded as “i”.

(7) Classroom silence that occurs when the teacher writes about the topic or subject matter is coded as “i”.

(8) When a classroom lull occurs during instruction due to technology or other reasons, it is coded as “j”.

(9) If multiple interactive behaviors occurred in consecutive units of time, they were recorded separately, e.g., if a student evaluated another person's response and then added his or her own response, they were coded as “10” and “7”, respectively.

III. B. Analyzing ratios

According to the coding data can further calculate the ratio of classroom interaction behavior, so as to further analyze the classroom teaching structure, classroom interaction behavior, teacher and student speech situation, technology use and other situations in the smart classroom. The calculation formula is designed by combining the coding rules for analyzing classroom interaction in the smart classroom environment.

Teacher speech ratio:

$$\sum_{k=1}^{5} Row(k) / \sum_{k=1}^{j} Row(k) \tag{10}$$

Ratio of questions in teachers' speech:

$$\sum_{k=2}^{3} Row(k) / \sum_{k=1}^{5} Row(k) \tag{11}$$

Ratio of open-ended questions in teacher questioning:

$$Row(2) / \sum_{k=2}^{3} Row(k) \tag{12}$$

Ratio of closed questions in teacher questioning:

$$Row(3) / \sum_{k=2}^{3} Row(k) \tag{13}$$

Student speech ratios:

$$\sum_{k=6}^{10} Row(k) / \sum_{k=1}^{j} Row(k) \tag{14}$$

Ratio of active speech in student speech:

$$\sum_{k=7}^{8} Row(k) / \sum_{k=6}^{10} Row(k) \tag{15}$$

Student Active Response Ratio:

$$Row(7) / \sum_{k=6}^{10} Row(k) \tag{16}$$

Ratio of student-initiated questions:

$$Row(8) \sum_{k=6}^{10} Row(k) \tag{17}$$

Percentage of active responses in student-initiated speech:

$$Row(7)\sum_{k=7}^{8}Row(k) \tag{18}$$

Percentage of active questions in student-initiated speech:

$$Row(8)\sum_{k=7}^{8}Row(k) \tag{19}$$

Technology utilization ratio:

$$\sum_{k=a}^{h}Row(k)/\sum_{k=1}^{j}Row(k) \tag{20}$$

Rate of teacher manipulation in technology use:

$$\sum_{k=a}^{d}Row(k)/\sum_{k=a}^{h}Row(k) \tag{21}$$

Rate of student manipulation in technology use:

$$\sum_{k=e}^{h}Row(k)/\sum_{k=a}^{h}Row(k) \tag{22}$$

Classroom Instructional Silence Ratio:

$$\sum_{k=i}^{j}Row(k)/\sum_{k=1}^{j}Row(k) \tag{23}$$

Beneficial pedagogical silence ratios:

$$Row(i)/\sum_{k=1}^{j}Row(k) \tag{24}$$

IV. Empirical analysis

IV. A. System testing

IV. A. 1) Testing process

This test configures the management function module in the running SQLServer database, and the IP address of the Windows Server 2008 server operating system is pre-set, and the campus network support is enabled to ensure that the whole test environment is consistent with the interactive teaching environment in the classroom. After the preparatory work is completed, the DDR3SDRAM chip and the touch integrator and other hardware are installed in accordance with the instructions, and the DDR3SDRAM chip is in operation, and the power supply voltage of each line of the hardware is tested, and the maximum value is 1.95V, and the minimum value is 1.65V, which can satisfy the system's voltage operation requirements. Touch integrator in the operating state, the touch test in the system Web page, can be based on the touch user information, the use of touch integrator on the student terminal data parsing.

After parsing the data, it determines whether the interactive communication between the student terminal and the teacher terminal is normal. Under the condition of normal communication, the hardware and software are connected to each other. After entering the correct user name and password in the interactive function interface of the system, click on the login button to display the functions of pre-study before class, classroom interactive function, after-class practice function and background management function. Click on the classroom interactive function to enter the classroom interactive program. After the teacher selects the corresponding course on the PC and sends the teaching materials, the students can download them to the mobile terminal for pre-course study. Teachers' questions and students' answers are completed in the classroom interactive part, and students and teachers interact with each other through the text chat function. This shows that the system is currently running normally. The performance test of the system at this time is conducted to analyze the operating effect of the system.

IV. A. 2) Test results

Under the above test conditions, this paper randomly selects the client performance such as dedicated working set occupied memory, working set occupied memory, CPU occupancy, system startup time, the time taken to open the course window, the time taken to open the interactive window, etc., and the network performance such as the network bandwidth of the server, the time taken to upload/download the file operation, etc., to conduct a comprehensive test. With all other conditions being consistent, the system in this paper is compared with the design of the interactive analysis system in Flanders based on event logging (System 1) and the design of the interactive teaching system in classroom based on 5G wireless communication (System 2), and the test results are shown in Table 4. 1000 and 5000 are the number of concurrent users of the system. a~h denote the memory occupied by the dedicated working set, the working set occupied memory, CPU occupancy during system operation, system startup time, time to open the course window, time to open the interactive window, network bandwidth of the server, and time to upload/download file operations, respectively. During the operation of the interactive teaching system, the higher the number of concurrent users, the higher the memory occupied by the interactive data of the system, and the longer it takes to open various types of courses, which affects the effective operation of the system.

After using System 1, the dedicated working set occupies more memory, and the working set occupies the same amount of memory, and the CPU occupancy rate of the system is still high under the premise that no other programs are opened, and the time for students to open the course window is extended, which is not conducive to the operation of the interactive system. After using System 2, the dedicated working set and working set occupied memory are reduced, and there exists a certain degree of improvement over System 1. However, the network bandwidth of the server of this method is large, and the operation time of uploading/downloading files is relatively long, and the network performance of students' classroom interaction is poor, which needs to be further optimized. And after using the system designed in this paper, the performance of systems A, B, C, D, E, F, G, and H are all substantially reduced. Among them, the working set occupies memory floating around 20~30M, the CPU occupancy is below 16%, and the time of uploading/downloading files is within 3000ms. It can be seen that the bandwidth and latency for students to send interactive text messages to the system are small, and the concurrency performance of the system server is good. And the client's course window opening time and student window opening time have decreased dramatically, even lower than 4s, which effectively improves the interactive learning effect of students in the classroom, and conforms to the research purpose of this paper.

Table 4: Systematic test results

Systematic energy	System 1		System 2		Ours	
	1000	5000	1000	5000	1000	5000
A/M	31.26	44.61	21.34	34.16	16.47	20.63
B/M	65.41	79.64	41.63	55.64	24.31	30.14
C/%	42.61	63.41	32.14	50.75	14.93	15.74
D/s	1.36	2.06	0.91	1.33	0.35	0.44
E/s	63.14	71.36	45.36	60.98	1.28	3.56
F/s	76.39	85.02	61.96	71.63	8.41	10.96
G/Mbps	1.36	3.49	1.54	4.22	0.84	1.93
H/ms	7500	2400	8600	3300	3000	1100

IV. B. System testing

IV. B. 1) Subjects and Periodicity

The study selected two classes in the freshman year of a university in C city as the research objects, which were recorded as the control class and the experimental class respectively. Taking the business English course as an example, the experimental class designs and conducts a total of eight lessons based on ZigBee's Smart Classroom Interactive Teaching System. The control class used the traditional teaching design program to conduct classroom teaching.

IV. B. 2) Comparison and Analysis of Classroom Interaction Feedback Data

The role of different classroom interactive feedback modes is analyzed in terms of the ratio of teacher-student interactive feedback behaviors, students' classroom participation, and learning initiative. The statistics of teacher-student classroom interactive feedback in the experimental and control classes are shown in Table 5.

Table 5: Students and students interact feedback

Coding	Classroom behavior coding		Cross-reference class		Laboratory class	
			Frequency	Proportion	Frequency	Proportion
1	Teachers accept emotions		2	0.12%	6	0.35%
2	Teachers praise or encourage		13	0.77%	22	1.27%
3	Receive or adopt opinions	3.1 Accept or adopt	64	3.77%	53	3.06%
		3.2 Technology-based guidance	42	2.47%	73	4.21%
4	Question	4.1 Open question	81	4.77%	126	7.27%
		4.2 Closed problem	71	4.18%	81	4.67%
5	Teacher teaching	5.1 Traditional explanation	279	16.43%	141	8.13%
		5.2 Based on the students' answer to the results	422	24.85%	406	23.41%
		5.3 Technology presents multimedia content	83	4.89%	55	3.17%
6	Teacher instruction		6	0.35%	6	0.35%
7	Criticize or maintain authority		2	0.12%	1	0.06%
8	Student passive response	8.1 Verbal passive response	155	9.13%	143	8.25%
		8.2 The student completes the written reply	77	4.53%	62	3.58%
9	Student response	9.1 Student response	11	0.65%	79	4.56%
		9.2 Students ask questions	0	0.00%	12	0.69%
		9.3 Students and peer discussions	66	3.89%	121	6.98%
10	Silence	10.1 It's not helping the confusion of the teaching	8	0.47%	6	0.35%
		10.2 The silence of teaching	4	0.24%	16	0.92%
11	Teacher control technology		71	4.18%	66	3.81%
12	Student manipulation		241	14.19%	259	14.94%
Total			1698	100%	1734	100%

(1) The classroom behaviors in Table 5 were processed according to the categories in the coding system to form the statistics of classroom behaviors in four dimensions such as teacher speech, student speech, silence and technology as shown in Figure 3. Comparative analysis on the proportion of teacher and student speech in the classroom showed that the proportion of teacher speech in the experimental class decreased compared to the control class and was 6.77% lower than the control class. The proportion of student speech increased and was 5.86% higher than the control class. With the addition of technology to classroom teaching, the students' subject position in the classroom was further promoted, which side by side shows that the rational use of technology by teachers can help to enhance students' participation in the classroom. In terms of the degree of technology use, the proportion of technology in the classroom teaching of ZigBee-based smart classroom interactive teaching system has risen slightly compared to traditional classroom teaching, while classroom silence maintains the original proportion unchanged, but the reason for silence is different from that in the traditional classroom, and is more due to technological reasons triggering the students' observation of responding to the information.

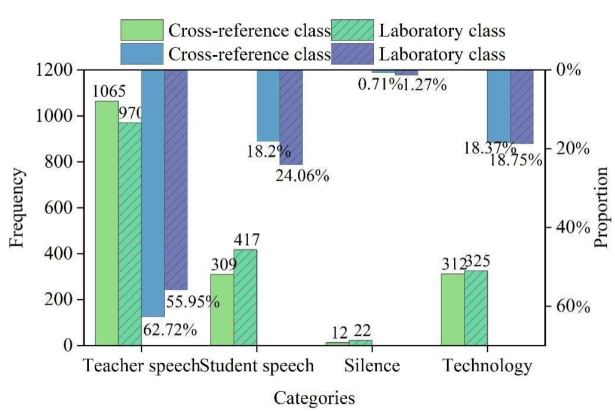

Figure 3: Different categories of behavior statistics

In terms of specific coding behaviors, it can be seen that the percentage of classroom lecturing behaviors by teachers has decreased, while in contrast, the participation of students in responding has improved, reflecting more frequent participation in the classroom. Analyzing the different categories of classroom behaviors, the teacher's speech and the student's speech also show the same trend of decreasing proportion of the former and increasing proportion of the latter. Therefore, the ZigBee-based smart classroom interactive teaching system can help to promote students' participation in teaching activities and further realize student-oriented classroom teaching.

(2) The classroom behaviors of students' responses were classified, with students' oral passive responses and written responses constituting the category of passive participation, and students' active responses, active questioning and peer discussion constituting the category of active participation, and their frequencies and total percentages were summarized to form the statistics of students' classroom participation as shown in Figure 4. In terms of the passive participation category, the passive participation rate of students in the control class and the experimental class was 13.66% and 11.83%, respectively, and the experimental class decreased compared with the control class. At the active participation level, the proportion of active participation of students in the control class is only 4.54%, while the proportion of active participation of students in the experimental class is 12.23%, which is a significant increase compared with the control class. This reflects that the ZigBee-based smart classroom interactive teaching system helps to improve students' motivation and initiative in classroom learning.

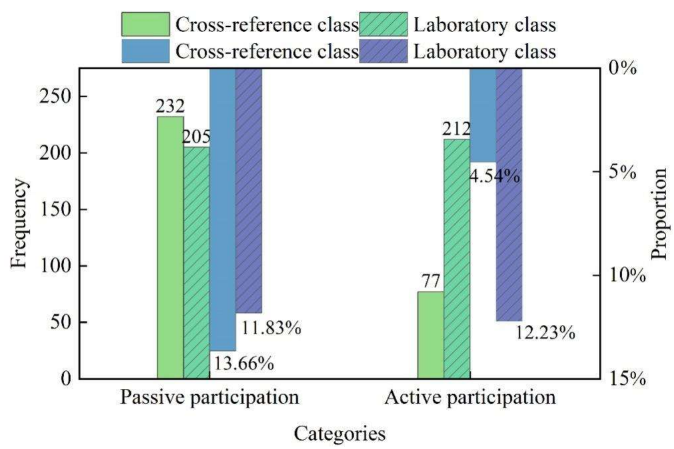

Figure 4: Student classroom response behavior statistics

(3) After the end of the lesson, the teacher set up a summative evaluation quiz about what had been learned in the lesson, and the average posttest scores of the control class and the experimental class were compared and analyzed. The mean and standard deviation of the scores of the two classes were obtained through the software, and the statistics of the posttest scores are shown in Figure 5. The average quiz scores of the control class and the experimental class are 73.65 and 83.09 respectively, and the average score of the experimental class is higher than that of the control class.

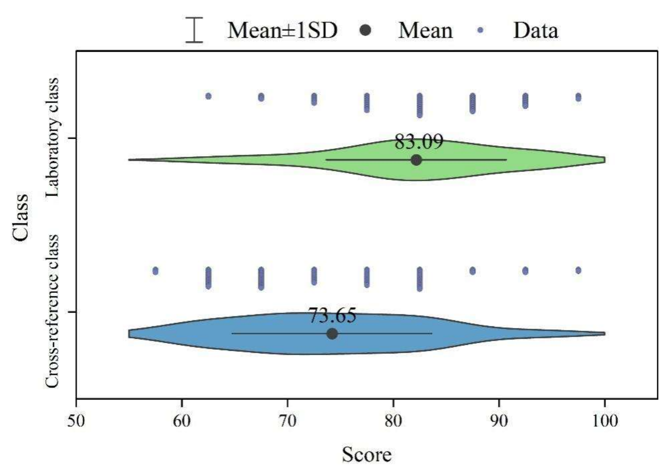

Figure 5: Achievement statistics

An independent samples t-test was done on the performance of the two classes as shown in Table 6. The p-value of independent samples t-test for the control class and the experimental class is $0.023<0.05$, which indicates that the difference in achievement between the control class and the experimental class is statistically significant. Therefore, the results of the post-test scores show that the teaching effect of the two experimental classes is better than that of the control class. It indicates that the ZigBee-based smart classroom interactive teaching system for classroom teaching helps to improve the teaching effect.

Table 6: Independent sample T test

	Levin variance equivalence test		Average equivalent T test						
	F	Sig.	T	Freedom	Sig.(2-tail)	MD	SED	The difference is 95% confidence interval	
								Upper limit	Lower limit
Assumed equal variance	0.063	0.723	-2.065	88	0.023	-9.44	2.2105	-8.5632	-0.1452
Unassuming equal variance	-	-	-2.066	88	0.023	-9.44	2.1365	-8.5634	-0.14365

In summary, with the help of the data collected by the classroom teaching interaction analysis coding system, this paper verifies that the classroom interactive teaching system designed based on communication technology can effectively promote interactive feedback between teachers and students in the business English classroom.

V. Conclusion

In this paper, ZigBee technology is utilized to design a smart classroom interactive teaching system, which performs better in the process of running the interactive teaching system. Combined with the business English classroom performance data counted by the Smart Classroom Interactive Analysis Coding System, the realization of the ZigBee-based Smart Classroom Interactive Teaching System is examined.

Compared with the control class using the traditional instructional design scheme, the proportion of teacher speech and the proportion of passive participation in the teaching experiment based on the system of this paper are 6.77% and 1.83% lower than the control class, and the proportion of student speech and the proportion of active participation are 5.86% and 7.69% higher than the control class. The average test score of the experimental class was finally higher than that of the control class by 9.44. It shows that the ZigBee-based Smart Classroom Interactive Teaching System can effectively promote students' active learning, enhance students' classroom participation, stimulate students' interest in learning as well as improve students' learning outcomes in Business English courses.

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References

[1] Roshid, M. M., & Kankaanranta, A. (2025). English communication skills in international business: Industry expectations versus university preparation. Business and Professional Communication Quarterly, 88(1), 100-125.

[2] Motseke, M., & Maja, M. M. (2019). Classroom Interaction: A Problem in the Teaching of English to Non-Native English Speakers. The International Journal of Literacies, 26(1), 49.

[3] Larasati, F. (2018). Student centered learning: an approach to develop speaking skill in EFL classroom. English Community Journal, 2(1), 153-157.

[4] Kustyarini, K., Utami, S., & Koesmijati, E. (2020). The importance of interactive learning media in a new civilization era. European Journal of Open Education and E-Learning Studies, 5(2).

[5] Livingston, J. (2017). Online resources as an extension of digital media instruction and classroom interaction. In EDULEARN17 Proceedings (pp. 5787-5790). IATED.

[6] Halim, A. (2024). OPTIMIZATION OF INTERACTIVE LEARNING MEDIA USAGE IN MADRASAH. Indonesian Journal of Education (INJOE), 4(1), 114-127.

[7] Wannapiroon, P., Nilsook, P., Kaewrattanapat, N., & Wannapiroon, N. (2021). Augmented Reality Interactive Learning Model, using the Imagineering Process for the SMART Classroom. Tem Journal, 10(3).

[8] Xu, D., & Tsai, S. B. (2021). A Study on the Application of Interactive English-Teaching Mode under Complex Data Analysis. Wireless Communications and Mobile Computing, 2021(1), 2675786.

[9] Rohmah, T. (2017). Classroom interaction in English language class for students of economics education. Arab World English Journal (AWEJ), 8(2).

[10] Septiani, A. N. N. S. I., & Rejekiningsih, T. (2020). Development of Interactive Multimedia Learning Courseware to Strengthen Students' Character. European Journal of Educational Research, 9(3), 1267-1280.

[11] Sari, M. N., Ningsih, P. E. A., & Novita, A. (2023). An Analysis of English Classroom Interaction Pattern at Eleventh Grade of SMKN 4 Kerinci Based On El Hanafi Theory. Jurnal Sosial Humaniora Sigli, 6(1), 105-115.

[12] Jiang, M. Y. C., Jong, M. S. Y., Lau, W. W. F., Chai, C. S., Liu, K. S. X., & Park, M. (2022). A scoping review on flipped classroom approach in language education: Challenges, implications and an interaction model. Computer Assisted Language Learning, 35(5-6), 1218-1249.

[13] Erkan, A. (2019). Impact of Using Technology on Teacher-Student Communication/Interaction: Improve Students Learning. World Journal of Education, 9(4), 30-40.

[14] Meng, J. (2024, December). Impact of Deep Generative Models on College English Classroom Interaction. In 2024 IEEE 4th International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA) (Vol. 4, pp. 626-631). IEEE.

[15] Xu, T. (2022). Immersion teaching method of business English based on virtual reality technology. Journal of Information & Knowledge Management, 21(Supp02), 2240015.

[16] Shi, H. (2024). Empowering the Construction of English Ecological Classrooms with Smartphones. Advances in Economic Development and Management Research, 1(2), 73-82.

[17] Tipmontree, S., & Tasanameelarp, A. (2018). The effects of role-playing simulation activities on the improvement of efl students' business English oral communication. Journal of Asia TEFL, 15(3), 735.

[18] Moorhouse, B. L., Li, Y., & Walsh, S. (2023). E-classroom interactional competencies: Mediating and assisting language learning during synchronous online lessons. Relc Journal, 54(1), 114-128.

[19] Sun, J. C. Y., & Hsieh, P. H. (2018). Application of a gamified interactive response system to enhance the intrinsic and extrinsic motivation, student engagement, and attention of English learners. Journal of Educational Technology & Society, 21(3), 104-116.

[20] Lv, X. (2025). Innovation in classroom interaction mode of business English teaching driven by biomechanics and data analysis. Molecular & Cellular Biomechanics, 22(4), 1626-1626.

[21] Wooten, J. J. (2020). Integrating discussion and digital media to increase classroom interaction. International Review of Economics Education, 33, 100174.

[22] Khamparia, A., & Pandey, B. (2018). Impact of interactive multimedia in E-learning technologies: Role of multimedia in E-learning. In Digital multimedia: concepts, methodologies, tools, and applications (pp. 1087-1110). IGI Global Scientific Publishing.

[23] Hao, Y. W., Jun, H., & Ali, N. (2024). Construction of Classroom Interaction Mode Based on Smart Blackboard. Canadian Journal of Educational and Social Studies, 4(4), 1-14.

[24] Yu, H., Shi, G., Li, J., & Yang, J. (2022). Analyzing the differences of interaction and engagement in a smart classroom and a traditional classroom. Sustainability, 14(13), 8184.

[25] Dai, Z., Sun, C., Zhao, L., & Zhu, X. (2023). The effect of smart classrooms on project-based learning: A study based on video interaction analysis. Journal of Science Education and Technology, 32(6), 858-871.

[26] Shamim, M. R. H., Jeng, A. M., & Raihan, M. A. (2024). University teachers' perceptions of ICT-based teaching to construct knowledge for effective classroom interaction in the context of TPACK model. Heliyon, 10(8).

[27] Gan, C. L., & Balakrishnan, V. (2017). Enhancing classroom interaction via IMMAP–an interactive mobile messaging app. Telematics and Informatics, 34(1), 230-243.

[28] Edwards, B. I. (2021). Emerging trends in education: envisioning future learning spaces and classroom interaction. Emerging technologies for next generation learning spaces, 7-18.

[29] Ali, Q. A., & Sahab, N. M. (2023). Interactive Design of a Virtual Classroom Simulation Model Based on Multimedia Applications to Improve the Teaching and Learning Process in the Tikrit University Environment. Fusion: Practice & Applications, 12(2).

[30] Haorun Lv,Lina Liu,Juanjuan Li,Yi Xu & Yan Sheng. (2024). Design of Hybrid Topology Wireless Sensor Network Nodes Based on ZigBee Protocol. Electronics,14(1),115-115.

[31] Gao Meirong. (2022). Smart campus teaching system based on ZigBee wireless sensor network. Alexandria Engineering Journal,61(4),2625-2635.

[32] David Johannes Hauck,Andreas Steffen & Insa Melle. (2024). Analyzing first-semester chemistry students' transactive talk and problem-solving activities in an intervention study through a quantitative coding manual. Frontiers in Education,9,1423330-1423330.