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COMMENTARY

The Smart Classroom Grows Ever Smarter amid Technological Advances

Longjun Zhou

Division of Education and Economy, China Center, International Education Communication Agency, the BASE, USA

"All children start their school careers with sparkling imaginations, fertile minds, and a willingness to take risks with what they think."
–Ken Robinson

THE CLASSROOM is the most vital component of any educational setting, providing the venue for teaching and learning. Amid the rapid development of information technology, the evolution of its functioning is also being expedited.

The notion of the smart planet was advanced in IBM's "*A smarter planet: The next leadership agenda*" in 2008, which laid out a vision that our planet would become smaller, flatter, more open, and more importantly, smarter as we infuse intelligence into the systems and processes that provide goods and services (Palmisano, 2008). As predicted, the physical and digital infrastructures of our planet have converged, and technology has been continuously embedded into the vast majority of objects we use, giving rise to concepts such as the smart city, smart healthcare, smart transportation, and smart energy grid, among others. As a result of the increase in digital awareness and application in the education world, the smart classroom emerged.

In their discussion of the role of education for a smarter planet, Rudd et al. (2009) summarized the benefits of the smart classroom as being able to provide a learning environment that improves student achievement by increasing their access to resources and tools for collaboration; a student data environment that supplies real-time information, insights, and strategies to teachers and faculty; open source applications, content, and standards to enhance cost-effectiveness and interoperability; devices that deliver high functionality while reducing acquisition, support, and operational costs by centralizing services; and cloud-based services and infrastructures that create a dynamic, green, and flexible desktop as well as IT environments that are built on world-class technologies. With advantages like these, the smart classroom outperforms the traditional classroom by removing the barriers of time and space in student learning, increasing teacher-student and inter-student in-class interactions, making teaching more efficient, and facilitating multi-dimensional student evaluation (Gao & Peng, 2023).

The development of the smart classroom in China has been ongoing in recent decades. It can be traced back to 2000, when the multimedia classroom featured by the application of "computer plus projector" was introduced to schools at all levels. The "Three Links and Two Platforms Program" (namely, the school link to broadband-based network, class link to excellent teaching content, individual link to the online learning space; the national public educational resource and educational administration platforms), launched by the Ministry of Education in 2012, catalyzed a new wave of smart classroom construction in China. Since then, digital learning resources and technologies, such as mobile devices, smart whiteboards, and all sorts of educational app, have been widely applied to classroom teaching, generating various smart classroom models including the interactive whiteboard classroom, 1:1 laptop classroom, and mobile tablet classroom (Wang & Li, 2019). 2015's "Internet plus" initiative marked the establishment of the digital transformation as a national strategy in China. The digital transformation in education gives new impetus to the building of smarter learning environments that facilitate more in-depth integration of instruction and intelligent technologies (Xie, 2016). The new-generation smart classroom is distinguished by its application of cutting-edge technologies, such as cloud computing, big data, and artificial intelligence, and deployment of mobile intelligent terminals, allowing enhanced teaching and learning experience.

Smart *classroom research shows a growing* trend in recent years. The *Construction and Application of Smart Classrooms in China*: *A Literature Review Based on 93 Studies* in this issue examines the status quo of the construction and application of the smart classroom in China by reviewing the published research findings and pinpointed issues arising in the said processes, as well as proposing targeted suggestions (Ren, 2024). It is hoped that this article can spark more discussions on the development of smart learning environments in the context of digital transformation of education.

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COMMENTARY

Peer Instruction: Assisting Active Learning in Science Education

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> *"Education is not the filling of a pail, but the lighting of a fire."*
> *–William Butler Yeats*

PEER INSTRUCTION is an interactive teaching method advanced by Harvard University professor Eric Mazur. It is a form of active learning meant to increase students' engagement and collaboration in the classroom, using conceptual tests (or ConcepTests) and teaching aids like the clicker (Zhu & Dong, 2018). Research demonstrates that it assists with students' grasp and application of disciplinary knowledge (Zheng et al, 2020).

With peer instruction, the teacher divides a lesson into several sections with each of them covering a number of concepts. The students are assigned pre-class preparation tasks, and in the class, the teacher administers to them a test for each section and gathers answers from each individual student using the clicker or flashcard. When more than 70% of the students give correct answers, the teacher will only provide brief instruction on the section tested and quickly move on to the next section. If 30-70% students answer the questions correctly, the teacher will require students to discuss relevant concepts in groups and administer the same test again after their discussion. The necessity of more group conversations depends on students' performance in the repeated test (Mazur, 1997). This practice is an innovation in classroom instruction, creating an active, cooperative teaching environment that encourages inter-student and teacher-student interaction (Zhang & Mazur, 2010).

Peer instruction, as an active learning strategy, has garnered wide attention in the education community. Michinov et al. (2015) argued that social constructivism theoretically underpins peer instruction, in which social interactions, taking the forms of in-class discussions and cooperation, play crucial roles in student knowledge construction. Research found that peer instruction, from the perspective of cognitive development, helps improve the conceptual understanding, problem solving performance, critical thinking, decision-making procedure, and scientific reasoning ability of the students while also increasing teacher-student interactions and enhancing students' concentration (Crouch & Mazur, 2001; Gok & Gok, 2017). It also contributes to bolstering student satisfaction with courses and attendance by enhancing their in-class emotional experience (Gok & Gok, 2017). Nevertheless, the peer instruction method is not without its limitations. According to Smith et al. (2011), not all students benefit from the peer instruction method; high-achieving students tend to gain more from it than those low-performing ones. A portion of students do not like peer instruction simply because of the fear of being embarrassed when making mistakes in peer interactions. Also, the teacher may encounter serious challenges in organizing in-class interactions and evaluating students' involvement when the class size is bigger than 50, or there is a lack of technological assistance (Gok & Gok, 2017).

Despite the potential difficulties with the application of peer instruction, the efforts to integrate it into classroom teaching are ongoing. Peer instruction was initially applied to college physics teaching and subsequently introduced to other disciplines such as medicine, nursing, biology, mathematics, and English, and to all education levels. In addition, researchers have also tried to combine peer instruction with other teaching models, such as the flipped classroom (Rowley & Green, 2015), to further optimize student academic gains. So far, however, peer instruction has been most heavily used in science education such as physics education (Henderson et al., 2012; Zheng et al., 2020), which indicates that this teaching method has extraordinary advantages in increasing instructional outcomes of science subjects.

Chemistry, a branch of natural science, involves many complex and abstract concepts (Coll, 2006) and is often rated as a challenging subject by students. Peer instruction has the potential to be productive in a chemistry classroom as it is an instructional strategy intended to facilitate students' grasp of scientific concepts. *Implementation of Peer Instruction Method on Teaching of Acids and Bases to 12th-Grade Students: An Action Research* in this issue is an investigation of the applicability and effectiveness of peer instruction in senior secondary chemistry education using both qualitative and quantitative data. Its research findings show that peer instruction improved the students' conceptual learning and was also efficacious in eliminating their misconceptions, and that student participants perceived it as a useful, effective learning method and developed more positive attitudes towards chemistry and in-class discussion after their implementation of this method (Ozcan et al., 2024). Given the limited research duration and small sample size of the study, it may not be appropriate to generalize its conclusions to other teaching settings. Yet, it could still serve as a valuable resource for teachers and education researchers who are exploring the effects of peer instruction as an active learning strategy.

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ORIGINAL ARTICLE

Implementation of Peer Instruction Method on Teaching of Acids and Bases to 12th Grade Students: An Action Research¶

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***Abstract**: This study aims to investigate the applicability and effectiveness of the peer instruction method on teaching the subject of acids and bases at the 12th-grade level. In addition, it aims to determine the effect of peer instruction on students' attitudes towards chemistry and in-class discussion, and to examine students' opinions regarding peer instruction post-implementation. The sample of the study consisted of 21 students studying in their 12th grade at a private high school. During the research process, the unit of acids and bases was covered by the researcher using the peer instruction method and the implementation was completed over a 5-week period. The study was designed as an action research, with both qualitative and quantitative data collected and examined. The study's quantitative data were collected through the Acids-Bases Concept Test (ABCT), Chemistry Attitude Scale (CAS), Argumentativeness Scale (AS), and concept questions, while the qualitative data were collected through the Method Opinion Scale (MOS), semi-structured interview, and observation. The analysis of the data was carried out using quantitative and qualitative methods. The results showed that there was a notable increase in the academic achievement of the students after the implementation. Furthermore, the results obtained from ABCT and semi-structured interviews indicated that peer instruction improved the students' conceptual learning, and was also effective in eliminating their misconceptions. Although the pretest-posttest scores of the CAS and AS did not demonstrate a considerable statistical difference, the observation and semi-structured interview data highlighted that the students' attitudes towards chemistry and in-class discussion increased positively. At the end of the implementation, it was observed that the stu-*

dents' attitudes towards the peer instruction method were positive and that the students considered it to be very useful and effective.

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***Keywords**: Peer Instruction, Acids-Bases, Conceptual Learning, In-Class Discussion, Attitude*

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Introduction

CHEMISTRY is taught as a core subject since it is one of the basic sciences and is encountered in many aspects of life. However, due to its abstract concepts and symbols, many students perceive chemistry as the most difficult science to learn (Coll, 2006). The subject of acids and bases, which has an important place in high school chemistry courses, is perceived as challenging by students due to its abstract nature that requires them to exhibit strong analytical skills, thus misconceptions can often occur (Nakhleh, 1992). Some of the misconceptions identified in the literature regarding acids and bases are as follows (Cartrette & Mayo, 2010; Kind, 2004; Muchtar, 2012; Ross & Munby, 1991):

- Acidic solutions do not contain OH- ions.
- Concentration is a measure of the strength of acidity of basicity.
- The equivalence point and the turning point are the same thing.
- For a substance to be acidic, it must contain H in its structure.
- In titrations, neutralization is not complete if either acid or base is weak.
- Misunderstanding the definition of amphoteric concept.
- Misconceptions about the arrangement of ions or molecules at the molecular level in acid-base solutions.
- Acidity strength depends on the number of hydrogen in the substance, and the strength of basicity depends on the number of hydroxides in the substance.
- The K_W value is always equal to 1.0×10^{-14}.
- The expression $K_W = [H]^+ \times [OH]^-$ is only valid for pure water.
- All solutions have the same pH value at the equivalence point.
- All acid-base titrations produce neutral solutions at the end point.

Formation of these misconceptions and the difficulties experienced by students in understanding these chemistry topics reveal inadequacy in their analysis and synthesis skills and that they try to understand the concepts based only on the words of their teacher under traditional lesson teaching methods (Birk & Kurtz, 1999). In addition, students frequently encountering acid-base terms in their daily lives (for example, pH values are clearly written on many cleaning, cosmetic, and beverage products) cause some of these misconceptions to be reinforced and unscientific inferences made. For these reasons, it is necessity to study teaching methods in which students examine acid-base topics in greater depth in order to internalize the concepts (Halakova & Proksa, 2007). It has been reported in the literature that students achieve more effective, permanent, and in-depth learning with active learning methods based on the constructivist approach, which encourages their participation and to take responsibility in lessons, directs them to think and make inferences, and includes the sharing of ideas (Dancy et al., 2016; Hake, 1998; Modell, 1996; Prince, 2004).

Active learning is described as cognitively engaging students through learning materials instead of them receiving knowledge passively (Bonwell & Eison, 1991). In an active learning environment, students are active participants and implement teaching activities planned and prepared by their teacher (Duch et al., 2001). In active learning, students test their hypotheses, share, have discussions within a framework determined by their teacher, are able to develop new products and ideas by working in groups, and are given the opportunity to make inferences by questioning; hence, it is suggested that such methods should be integrated more into teaching processes (Bonwell & Eison, 1991). Chi and Wylie (2014) referred to learning materials or activities (e.g., pre-reading, summarizing) selected for students to undertake during instructional activities. They identified three practical issues faced by teachers when developing active learning in lessons: 1) How to engage students meaningfully and cognitively; 2) Very few criteria exist for the design and implementation of active learning; and 3) Teachers possess no guidelines on how to modify current assignments for active learning. Chi and Wylie (2014) then proposed the ICAP framework, which empirically supports increasing active learning through four modes; interactive (I), constructive (C), active (A), and passive (P), based on the highest level of learning being from interactive to passive (I > C > A > P). Constructive modes can involve individual learners, whereas interactive modes may include collaborative or peer-to-peer discussion conditions. It has been reported in the literature that peer cooperation is an important supporter for the cognitive development of individuals (Cassidy et al., 2019). This taxonomy is deemed as effective and supportive in classifying cognitive engagement activities during active learning methods such as peer instruction. In addition to constructivism, peer instruction also supports the ICAP framework as its theoretical underpinning.

Peer instruction, which is a method used in active learning, aims to increase students' conceptual learning levels by partially changing and reorganizing traditional lessons (Mazur, 1997). Through this method, immediate feedback can be obtained to reveal and eliminate learners' misconceptions, and is aimed to motivate an entire class rather than just those eager to learn. In learning environments where peer instruction is applied, students are asked questions that challenge their minds to help them understand the concepts being taught to a greater depth. Moreover, students who are unable to sufficiently understand a subject from the teacher's perspective or style of expression and experience difficulties in answering questions are offered the opportunity to review and reevaluate the concepts through discussion with their peers (Crouch & Mazur, 2001; Watkins & Mazur, 2010). When the literature is examined, it can be seen that while there many studies approach chemistry subjects through different teaching methods at the high school level, published research examining the effects of peer instruction on the teaching of chemistry subjects has been very limited (Golde et al., 2006; Koretsky & Brooks, 2011). According to the literature reviewed for the current study, peer instruction can increase students' academic success (Porter et al., 2011), as well as their rate of attendance (Porter et al., 2013), improves their conceptual learning (Smith et al., 2011), develops a positive perception in students who are more motivated towards lessons (Gök, 2012), provides for a more effective discussion environment (Nielsen et al., 2016), and improves students' confidence in answering questions (Lasry et al., 2013) as well as their problem-solving skills (Cortright et al., 2005).

The aim of the current study was to investigate the effectiveness and applicability of peer instruction as a method to teach the acids and bases topic at the 12th-grade level. Peer instruction has been frequently used in physics teaching (Kudo et al., 2017) and has been shown to produce successful results. It is therefore considered that peer instruction, which encourages students to think, question, and discuss throughout the lesson, will also be an effective method to help students comprehend difficult chemistry subjects at the desired level (Brooks & Koretesky, 2011; Ergin et al., 2019; Lasry et al., 2008).

Research Questions

Can peer instruction be used as an effective method in teaching acids and bases?

Research Sub-Questions

- Considering the Acids-Bases Concept Test pretest–posttest mean scores, does a statistically significant difference exist between the academic achievement levels of students?
- How does teaching acids and bases with peer instruction affect students' conceptual learning levels?
- What effect do peer discussions during lessons have on students' understanding of a subject?
- Is there a statistically significant difference between students' attitudes towards chemistry lessons in terms of the Chemistry Attitude Scale pretest and posttest average scores?
- Is there a statistically significant difference between students' attitudes towards discussion in terms of their pretest–posttest Argumentativeness Scale average scores?
- What are the students' attitudes and views towards the peer instruction method?

Peer Instruction Method

Peer instruction, which is described as an active learning method, is seen to increase students' individual participation in lessons, enabling them to learn by directing them towards discussion with their peers, and to take greater responsibility for their own learning (Zhu, 2007). Peer instruction was first developed by Eric Mazur in the 1990s (Mazur, 1997). In the implementation phase of the method, the teacher first divides learning units into small sections which include certain concepts so that these concepts can each be covered in small time periods. At the beginning of the lesson, students' reading assignments are checked by way of administering a quiz or by evaluating small assignments they completed prior to the lesson. The aim being to make students more familiar with concepts related to the subject being taught, and for teachers to shape their lesson preparations having seen their students' current knowledge level of a particular topic ahead of the lesson. During the lesson itself, the teacher sets a conceptual question which the students then attempt to answer through the use of appropriate flash (answer) cards. If approximately 90% or more of the class are able to answer correctly, the teacher moves on to the next small section. However, if only 30% of the students or less were able to answer correctly, the teacher reworks the topic in detail. Where the correct answer rate falls between these two ratios, the teacher tasks the students to discuss the question with their peers and then to update their answers accordingly. At the end of this process, the students' answers are reevaluated by the teacher and the next step is decided upon in accordance with the updated correct answer ratio of the class.

Methodology

In this study, the action research method was employed to determine the effect of peer instruction on the students' level of learning the concepts of acids and bases, as well as their attitudes towards the chemistry lessons. In action research studies, researchers take part as practitioners with the aim being to understand the dynamics of the process and its effect, to find solutions, and to generate new ideas (Johnson, 2014). In this classroom-based study, the first author designed a research based on their own classroom teaching as a high school chemistry teacher employed at a private high school, where the high performance of students is a significant focus. The school expects its teaching staff to employ student-centered methods and active teaching methodologies in order to promote student activity during the teaching-learning process. The researcher-teacher's aim was for students to effectively participate and learns in their chemistry lessons; however, based on prior experiences in the teaching of acids and bases at the 12th-grade level, students do

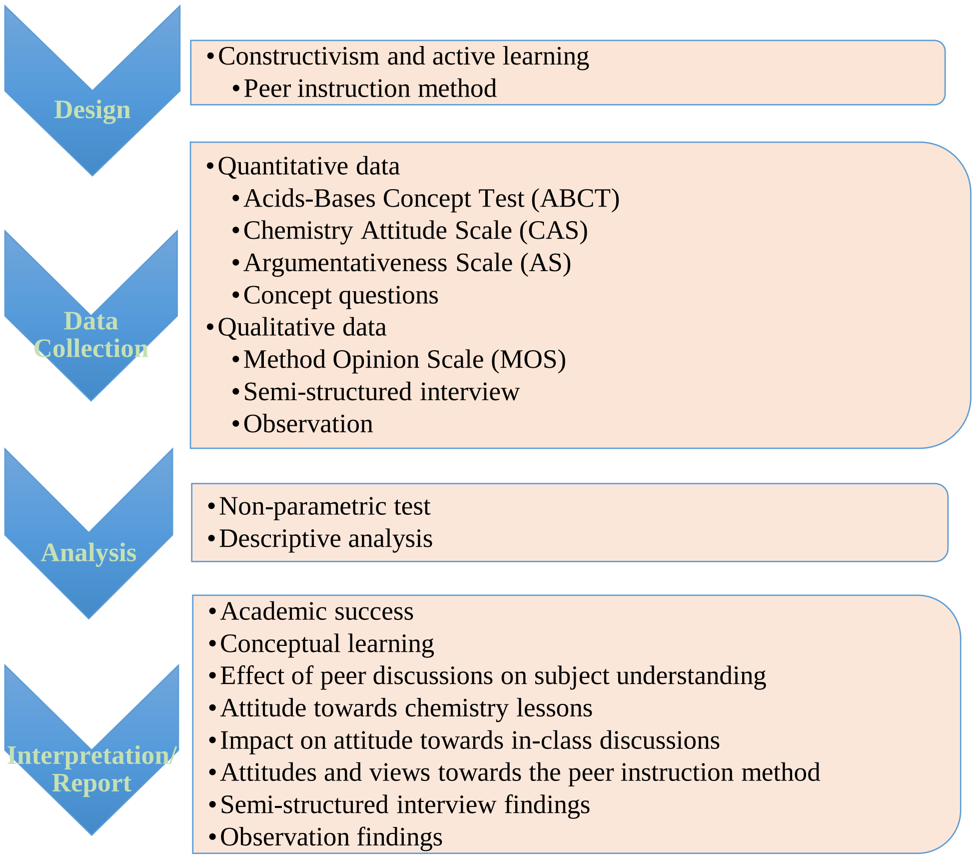

Figure 1. Action Research Process.

not actively participate during classes and held certain misconceptions about the concepts involved.

Not wanting their students simply to study with an exam-oriented focus, especially in the 12th grade with university entrance exams held at the end of their school year, the researcher-teacher wanted to break this general trend. After having interviewed other teaching colleagues, it was noted that they too experienced the same problems, and confirmed that active learning methods were never applied in 12th-grade classes at the school. The researcher-teacher held a doctoral degree and was familiar with active teaching strategies from their postgraduate education, and was therefore quite enthusiastic to use peer instruction as an active learning method. With the intention of trying to improve 12th-grade students' understanding of acids and bases content through a change of teaching style, the researcher-teacher reviewed the related literature and developed a plan to conduct the research. The research process and action plan was then shared with other researchers who joined the study. The processes of designing the study, collecting, analyzing, and interpreting the data, and then reporting the results (Glanz, 2014) (see the action research process illustrated in **Figure 1**) were predominantly under the responsibility of the researcher-teacher as first author of the current study.

Participants

The study group consisted of 21 students studying in their 12th grade at a private high school. Since the first author worked as a teacher at this institution, this action research study was conducted in their own 12th-grade chemistry class, utilizing convenience sampling as an appropriate means to access the target community. Both science and mathematics courses were taught in the English language at the school, and the academic level of the students, who are required to pass a special exam to attend the school, were very close to each other. The 12th-grade students who participated in the study had previously taken chemistry courses at the ninth, 10th, and 11th grade, and had therefore received basic level tuition on the topic of acids and bases in their 10th grade.

Data Collection Tools

Acids and Bases Concept Test

The Acids and Bases Concept Test (ABCT) was developed for use both as a pretest to measure the students' knowledge about acids and bases prior to being taught with the peer instruction method, and again as a posttest to measure their conceptual learning after the subject had been taught. The test was created by the researchers based on the current chemistry textbooks used at the school, past exam questions, and conceptual acid-base questions taken from the literature (Demerouti et al., 2004; Pınarbaşı & Canpolat, 2011; Ross & Munby, 1991). The ABCT consists of 30 multiple-choice questions, each with four options. Students were allowed 40 minutes to complete the test. The test is scored as 1 point for each correct answer and 0 points for any incorrect answers, with a maximum test score of 30 points.

In order to check whether or not the test questions sufficiently overlapped with the objectives to be measured (content validity), the expert opinion of the other researchers of the study and three chemistry teachers were sought. In addition, the ABCT was first developed as a pilot exercise, with 40 questions applied to 75 students at two different high schools. As a result of the post-pilot analysis, 10 questions that were deemed not to have any distinguishing features were subsequently removed from the finalized version of the test. The Cronbach's alpha reliability coefficient for the ABCT was found to be 0.71.

Method Opinion Scale

The Method Opinion Scale (MOS) was prepared by the researchers in order to evaluate the opinions and thoughts of the participant students regarding the effectiveness and efficiency of the peer instruction method after the subject had been taught. The MOS consists of seven open-ended questions. In their preparation, the questions were presented to two faculty members who were experts in their respective fields. In order to ensure that the questions were sufficiently short in length yet fully understandable, and also that they covered all aspects of the peer instruction method, and the researchers paid utmost attention to the experts' suggestions. During implementation of the MOS, the participant students were requested not to write their names on the answer sheet in order that they could respond without feeling undue pressure and to eliminate any thoughts of receiving negative feedback from their teacher if they gave any negative responses. The students were given 40 minutes to respond to the scale.

Chemistry Attitude Scale

The Chemistry Attitude Scale (CAS) was developed by Geban et al. (1994) and applied in the current study to measure the effect of the peer instruction method on students' approaches towards chemistry lessons. The CAS was first applied in the study prior to acids and bases being taught with the peer instruction method, and then reapplied again after the instruction. The scale, which is a 5-point, Likert-type instrument with anchors of 5 = *strongly agree*, 4 = *agree*, 3 = *undecided*, 2 = *disagree,* and 1 = *strongly disagree,* consists of 15 items in total. Responses to the CAS are scored from 5 to 1 for the items affirming the students' positive attitudes towards the lessons, and from 1 to 5 for the items dealing with negative attitudes, and the results then converted into numerical data. The Cronbach's reliability coefficient for the CAS was found to be 0.93.

Argumentativeness Scale

Infante and Rancer (1982) developed the Argumentativeness Scale (AS) to measure whether or not students' attitudes towards discussion change during lessons. The scale is presented as a 5-point, Likert-type instrument (5 = *always*, 4 = *often*, 3 = *I am indecisive*, 2 = *sometimes*, and 1 = *never*) and consists of 20 items in total. The AS was applied in the current study both before and after the acids and bases topic was taught using the peer instruction method. The Cronbach's internal consistency coefficient of the original scale was .91, and the scale's Turkish adaptation by Kaya and Kılıç (2008) presented a Cronbach's alpha reliability coefficient of 0.73.

Responses to the AS are scored from 5 to 1 for items that affirmed the students' positive attitudes towards discussion, and from 1 to 5 for items based on their negative attitudes, and the results were then converted into numerical data.

Semi-Structured Interview

According to the data obtained from the ABCT having been applied as a posttest, semi-structured interviews were conducted in order to gather more detailed information from which to examine the conceptual learning levels of the participant students and their views on the peer instruction method after the acids and bases topic had been taught using the peer instruction method. The interview questions were prepared by considering the answers given by the students to the ABCT and the events that emerged during the course of the lessons. The interviews were conducted with six students, with two volunteers chosen from among those who scored above average, average, and below average in the ABCT posttest.

The interview questions were applied in two parts. First, seven questions were asked that aimed to elicit the participant students' in-depth opinions about the peer instruction method. Second, the concepts that students often have misconceptions about regarding acids and bases were determined, and 10 open-ended concept questions were designed in order to examine their understanding of these topics and to reveal the reasons behind any misconceptions. Each semi-structured interview lasted for approximately 40 minutes and was audio recorded.

Observation

Detailed observation notes were taken by the researcher at the end of each lesson taught using the peer instruction method. The aim was to reach more reliable results by supporting the qualitative data obtained from the MOS and the semi-structured interviews with observations from the lessons. The students' motivation during the lessons taught with the peer instruction method were carefully observed and noted, as well as their readiness, their communication with their peers during the discussions, and the overall effect that the method had on their participation during each lesson.

Table 1. Concepts Related to Acids-Bases.

Concept		Planned Time
1.	Conjugated acid Conjugated base Amphoteric	80 minutes
2.	Neutralization Titration	80 minutes
3.	pH Autoionization of water	80 minutes
4.	Strong acids Strong bases Weak acids Weak bases	80 minutes
5.	Lewis acid Lewis base Nucleophile Electrophile	40 minutes
6.	Ionization of weak acids Ionization of weak bases	80 minutes
7.	Buffer solutions	40 minutes
8.	Hydrolysis	40 minutes
9.	pH curves End point Equivalence point	120 minutes
10.	Indicators	40 minutes

Concept Questions

Multiple-choice questions covering each concept in the acids and bases unit were first prepared. Students' misconceptions about acids and bases most frequently mentioned in the literature were taken into consideration during the preparation of the questions. The questions were then examined by two faculty members for content validity and any necessary improvements were applied in line with their opinions.

The participant students then answered the questions individually using an answer sheet. In cases where the percentage of correct answers in the class was between 30% and 90%, the students reviewed their answers by discussing them with their peers and then marked their new individual answers on their answer sheet. In this way, the responses to these questions also presented data regarding the peer instruction method application, as well as an opportunity to examine the contribution of the students' discussions to their conceptual learning levels.

Implementation

The peer instruction method application was completed over a 5-week duration, with five 40-minute lessons per week. Prior to commencing the lessons, detailed lesson plans were prepared by dividing the teaching unit into 10 compatible subtitles. Based on the nature of peer instruction, these subtitles were then subdivided into ten 12-minute time periods in which one or more of the concepts they contain (see **Table 1**) would be studied. It should be noted that the time allowed for answering and discussing the concept questions is excluded from these time periods.

As the subject of acids and bases was being taught using the peer instruction method, the subtitles to be covered in each upcoming lesson were given as textbook reading assignments in order for the students to arrive at the lesson having prepared in advance. In addition to these assignments, the students were tasked with answering reading quiz questions at home in order to gain familiarity with the required basic concepts and terminology. These assignments were collected from the students before the start of each lesson, quickly examined, and general preliminary information about the relevant section provided. This approach was employed to help the students gain familiarity with the concepts to be covered in the lesson, identify any points with which they experienced difficulties in understanding, and to then focus more on those areas during the upcoming lesson.

The lesson process started with the teacher explaining the objectives of the subject to be covered and the content of the lesson. Then, as an introductory activity, a thought-provoking question was asked to the students about the textbook chapter they would discuss, and their answers noted. Next, the subject was discussed based on a detailed explanation provided about the question. For example, considering acid-base theories, as a thought-provoking question, the students were asked, “What do the terms acid and base mean to you?” After a reflection period of about 2 minutes, some of the students volunteered their answers. Afterwards, the meaning of the terms was briefly explained and then the Arrhenius acid-base theory was discussed, followed by an examination of the historical development process of acids and bases.

According to Arrhenius, acids are substances that increase the H^+ ion concentration in their aqueous solutions, while alkalis, as soluble bases, are substances that increase the OH^- ion concentration in their aqueous solutions. These expressions were explained by showing the equations of acids and bases in their aqueous solutions with examples on the classroom whiteboard. Afterwards, the limitations of this theory were emphasized, along with how it helps in forming the foundations for new theories. Thus, the content was attempted to be associated with the nature of science. For example, Equation 1 was presented on the whiteboard, emphasizing that the reaction between a weak base, ammonia, and hydrogen chloride gas cannot be explained by this theory since ammonia does not contain OH- ions.

$$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s) \quad (1)$$

Figure 2. Students Holding Up Flashcards during Application.

Second, the Brønsted–Lowry acid–base theory was discussed. According to this theory, Equations 2-4 can be used to explain that acids are proton donors and bases are proton acceptors. It was also stated that in aqueous solutions, a proton can be represented as H^+ or as a hydronium ion H_3O^+.

$$HCl(aq) + H_2O\,(l) \rightarrow H_3O^+(aq) + Cl^-(aq) \quad (2)$$
$$CH_3COOH(l) + H_2O\,(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq) \quad (3)$$
$$NH_3\,(aq) + H_2O\,(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq) \quad (4)$$

In order to draw the students' attention to the misconception that "water cannot act as an acid or a base, it is just a solvent," which is frequently encountered in the literature, the question "Can pure water with a pH of 7 at 25°C act as an acid or a base?" was asked. The students were then given about 2 minutes to think before their answers were taken. Afterwards, the teacher gave a detailed explanation of the problem. From Equations 2-4, it can be stated that water behaves as a base by accepting a proton when it reacts with acids, and acts as an acid when it reacts with bases by donating protons. Therefore, substances that can act as both Brønsted–Lowry acid and Brønsted–Lowry base are classified as amphoteric substances.

After the explanation, the first multiple-choice conceptual question was asked to the students, who were then given 2 minutes to answer the question individually. When the time was up, the students were asked to show their answers using flashcards (cards with options A, B, C, and D; see **Figure 2**) that had previously been left on their desks by the teacher.

The teacher tallied up the students' answers and determined the class percentage of correct answers before moving to the next phase of the peer instruction process based on this percentage.

Following this, the concept of conjugate acid-base pair and amphoteric substances were studied for a period of 10-12 minutes. It was emphasized that there is only one hydrogen atom difference between a conjugate acid-base pair, and it was stated that amphoteric substances can act as either a Brønsted–Lowry acid or a Brønsted–Lowry base, depending on their reaction. These concepts were then explained on the whiteboard using Equations 5-7.

$$H_2PO_4^{-}(aq) + OH^{-}(aq) \rightarrow HPO_4^{2-}(aq) + H_2O(l) \quad (5)$$
$$H_2CO_3(aq) + OH^{-}(aq) \rightarrow HCO_3^{-}(aq) + H_2O(l) \quad (6)$$
$$HCO_3^{-}(aq) + S^{2-}(aq) \rightleftharpoons HS^{-}(aq) + CO_3^{2-}(aq) \quad (7)$$

The multiple-choice concept questions prepared for this section were directed to the students and the same steps of the peer instruction method were then repeated.

The misconceptions most frequently encountered in the literature were associated with the relevant sections and asked to the students in the form of questions throughout the course of the lesson in order to draw their attention to these misconceptions. These questions were also embedded in the lesson plans. In order to eliminate these potential student-held misconceptions, the teacher gave detailed explanations and examples once the students' answers had been received. The remaining sections were then treated in the same manner as explained here for the first section.

Data Analysis and Ethical Considerations

For the analysis of the quantitative data obtained from the research, non-parametric tests were performed using IBM's SPSS program. Data from the ABCT's pretest and posttest applications were analyzed by applying the Wilcoxon signed-sum test, which is the non-parametric equivalent of the dependent (paired) group t-test and is recommended for use in cases where the number of participants is less than 25 (Gravetter & Wallnau, 2015). In the analysis quantitative data generated from the CAS and AS applications, Wilcoxon signed-sum test was used in order to determine whether or not a statistically significant difference existed from before and after the application. Results from the concept questions, as another form of quantitative data collection, were presented separately for each subtitle by calculating the individual correct answer percentages of the students before and after the discussion.

The qualitative data obtained from the MOS, researcher observations, and semi-structured interviews were reviewed according to descriptive analysis techniques and coded using appropriate categories. Direct quotations from the study's semi-structured interviews were frequently selected to support interpretations and inferences and to facilitate the reader's interpretation of the results. In addition, the researcher-teacher analyzed the data by consulting with another researcher in the study, who was an expert in the area of peer instruction, for the purposes of consensus. Both qualitative and quantitative approaches were used together in the current research, which was designed within the framework of an action research study. It has been stated in the literature that inferences obtained based on the use of qualitative and quantitative methods together can be more explanatory and enlightening (McMillan & Schumacher, 1997). The data obtained from the quiz questions and researcher observation notes were evaluated as supportive and complementary to the data obtained with other data collection tools. Thus, data triangulation was attempted to be provided.

All students participating in the study were administered the same peer instruction practices under the same conditions and by the same teacher. The researcher-teacher made the application and observations without prejudice, to the best of their knowledge. The participating students had not previously been taught with the peer instruction method. Six volunteer students were selected for the semi-structured interviews, and attention was paid to the interviews being conducted during the week following the end of the application in order to ensure the students' retention of information about the application and its process. The collected data were evaluated according to both positive and negative results in terms of dependability. The findings obtained from the theoretical framework were compared with the findings of similar studies from the current literature. The current research study was conducted according to the permission received from the researchers' university ethics committee. In addition, the students' parents were duly informed about the nature of the study, and parental permission and student participation forms were collected prior to commencement of the application. While presenting the data, in place of the participants' real names being used, pseudonym participant codes of S1, S2… were used instead.

Findings

Effect of Peer Instruction on Academic Achievement

According to the results of the ABCT's application, a statistically significant difference was found to exist between the students' pretest and posttest scores ($z = -4.020$, $p < 0.05$). It was determined that the students' pretest

Table 2. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-posttest scores	Negative Ranks	0a	-4.020	0.000
	Positive Ranks	21b		
	Ties	0c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

Table 3. Misconception Analysis Results.

Misconception*		Pretest %	Posttest %
1	For a substance to be acidic, it must contain H in its structure.	85.7	52.4
2	Misrecognition of the definition of the concept of amphoterism.	81.0	38.1
3	Misconception about the arrangement of ions or molecules at the molecular level in acid-base solutions.	57.1	42.8
4	In titrations, if either acid or base is weak, neutralization does not occur completely.	71.4	28.6
5	KW value is always equal to 1.0 x 10-14	28.6	0.0
6	The expression KW = $[H]^+$ x $[OH]^-$ is valid only for pure water.	76.2	28.6
7	Acidic solutions do not contain OH^- ions.	19.0	0.0
8	Acidity strength depends on the number of hydrogens in the substance, and the basicity strength depends on the number of hydroxides in the substance.	90.5	90.5
9	Concentration is a measure of acidity or basicity strength.	14.3	4.8
10	Equivalence point and turning point are the same thing.	90.5	38.1
11	All solutions have the same pH value at the equivalence point.	76.2	4.8
12	All acid-base titrations form neutral solutions at the end point.	57.1	23.8

*Includes misconceptions with a prevalence of more than 10%.

score average was 10.10 out of a possible 30 points, and that the posttest score average was 19.52. The Wilcoxon test results are presented in **Table 2**.

From the Wilcoxon signed-sum test, the difference between the mean scores was revealed as being statistically significant, with the difference in favor of the posttest. In other words, the academic achievement levels of the students had increased significantly by the end of the implementation.

Effect of Peer Instruction on Conceptual Learning

Table 3 presents the students' misconceptions based on data analyzed from the ABCT application, which was prepared considering well-known misconceptions on the subject, and applied both as a pretest and a posttest.

According to **Table 3**, there was a significant improvement seen in eliminating misconceptions that the students held prior to the application, except for one (misconception 8). The following question tests this misconception:

Which of the following is a weak acid?

- H_2SO_4
- H_3PO_4
- HNO_3
- $HClO_4$

Considering the answers given by the students to this question, it was determined that 15 of the students chose option D in both their pretest and posttest, and that a high percentage (90.5%) of the students held this misconception in both test applications. It was concluded that the students continued to associate the acidic strength in direct proportion to the number of hydrogens in the substance at the end of the implementation. Since both H_2SO_4 and HNO_3 are acids that are frequently given as examples in both the students' resources and lectures, it is notable that of the students who selected option B or D, option B (H_3PO_4) was preferred as the strong acid, which has a high hydrogen number.

Table 3 shows that there was significant elimination of eight misconceptions based on comparing the students' posttest scores to their pretest (misconceptions 1, 2, 4, 6, 9, 10, 11, and 12) and that some were completely eliminated (misconceptions 7 and 5). However, despite this change, it can be seen that some of the students' misconceptions persisted even after the study application (misconceptions 3 and 8) and that these were quite resistant to change. Based on the answer given to the question in which misconceptions 1 and 7 were tested, it was understood that the students did not consider Lewis acids when considering acids. Teaching a large part of the acid-base unit on the basis of the Brønsted-Lowry theory and usually giving the examples of known acids and bases may have been affective in the formation of these misconceptions.

Specific to misconception 2, it was determined that there were seven students who thought that a substance could not act as both a Bronsted-Lowry acid and a Bronsted-Lowry base in both their pretest and posttest responses. In the question regarding misconception 4, the students are required to know in which forms ethanol and hydrogen chloride exist in aqueous solutions; however, the findings revealed that the students were unable to sufficiently visualize the dissolution of ethanol and hydrogen chloride in water at the molecular level. There was a significant improvement seen for misconception 4, but following the application, six students still thought that a strong acid could not be completely neutralized with a weak base. The results for misconception 5 revealed that the majority of the students understood that the value of K_W changes at different temperatures and thus the pH values of pure water can also change. For misconception 6, following the application, most of the students understood that the expression $K_W = [H]^+$.

Table 4. Findings of Concept Questions.

Topic	Concept Question	Pre-Discussion Answers (%)		Post-Discussion Answers (%)	
		True	False	True	False
Acid-Base Theories	1.	85.7	14.3	100.0	0.0
	2.	71.4	28.6	85.7	14.3
	3.	95.2	4.8	-	-
	4.	95.2	4.8	-	-
	5.	90.5	9.5	-	-
	6.	90.5	9.5	-	-
	7.	81.0	19.0	90.5	9.5
	8.	90.5	9.5	-	-
Properties of Acid-Bases and pH Scale	1.	85.7	14.3	100.0	0.0
	2.	71.4	28.6	81.0	19.0
	3.	23.8	76.2	57.7	42.3
	4.	71.4	28.6	95.2	4.8
	5.	95.2	4.8	-	-
	6.	66.7	33.3	90.5	9.5
Strong/Weak Acids and Bases	1.	66.7	33.3	90.5	9.5
	2.	85.7	14.3	100.0	0.0
	3.	76.2	23.8	85.7	14.3
	4.	81.0	19.0	100.0	0.0
	5.	76.2	23.8	95.2	4.8
	6.	52.4	47.6	66.7	33.3
Acid-Base Calculations	1.	33.3	66.7	61.9	38.1
	2.	81.0	19.0	95.2	4.8
	3.	76.2	23.8	100.0	0.0
Ka, Kb Values for Conjugated Acid-Base Pairs, Relationship of Kw Value with Temp., pKa, pKb	1.	66.7	33.3	95.2	4.8
	2.	81.0	19.0	100.0	0.0
	3.	23.8	76.2	90.5	9.5
	4.	76.2	23.8	100.0	0.0
	5.	95.2	4.8	-	-
	6.	85.7	14.3	95.2	4.8
Buffer Solutions	1.	42.9	57.1	95.2	4.8
	2.	61.9	38.1	71.4	28.6
	3.	90.5	9.5	-	-
	4.	33.3	66.7	90.5	9.5
Salt Hydrolysis	1.	52.4	47.6	100.0	0.0
	2.	14.3	85.7	71.4	28.6
	3.	76.2	23.8	95.2	4.8
pH Curves	1.	57.2	42.8	95.2	4.8
	2.	38.1	61.9	61.9	38.1
	3.	57.2	43.8	100.0	0.0
	4.	61.9	38.1	100.0	0.0
Indicators	1.	57.2	42.8	71.4	28.6
	2.	61.9	38.1	81.0	19.0
	3.	66.7	33.3	100.0	0.0
	4.	85.7	14.3	100.0	0.0
	5.	76.2	23.8	95.2	4.8
	6.	66.7	33.3	95.2	4.8

$[OH]^-$ was valid not only for pure water but for all aqueous solutions. Regarding misconception 9, it appears that the students ignored the need to understand the solution concentrations whilst comparing acidic strengths using the solution pH values. In addition, an unlisted (additional) misconception was also identified, that "acids in solutions with lower pH, are stronger."

A significant improvement was seen regarding misconception 10, although eight of the students still held this same misconception even after having received the instruction. Both the pretest and posttest results for misconception 11 showed that the students understood that the pH values at the equivalence point can change according to the strengths of neutralized acids and bases. Finally, although there was a noticeable improvement between the pretest and posttest scores regarding misconception 12, five of the students who selected incorrect options following the application failed to understand that the pH value at the equivalence point should be less than 7 at the end of a weak base-strong acid titration.

Effect of Peer Discussions on Understanding the Subject

Table 4 presents the percentages of the students' correct and incorrect answers for the concept questions for each subtitle, with both their first individual answers (pre-discussion) and the again after the peer discussion activity. In questions where the students' individual answers were correct by 90% or more, no discussion was held, hence no post-discussion percentages are shown.

According to **Table 4**, when the percentages of incorrect first individual answers are compared with the incorrect answers determined after the discussion, it can be seen that a significant improvement exists for those questions that were discussed. In some cases, although there was a notable improvement in the students' individual answers to the concept questions after the discussion, where this improvement still failed to meet the desired level, new tests were conducted with different concept questions after having been explained in detail. When the answers given to these concept questions asked based on new tests were examined after the discussion, it can be seen that the percentage of incorrect answers was 10% or below.

Effect of Peer Instruction on Attitudes towards Chemistry

Since the scores obtained from the Chemistry Attitude Scale did not show normal distribution, the Wilcoxon signed-sum test was employed. The analysis results showed that there was no statistically significant difference be-

Table 5. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-Posttest test scores	Negative Ranks	7a	-1.008	0.313
	Positive Ranks	13b		
	Ties	1c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

Table 6. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-Posttest scores	Negative Ranks	4a	-1.874	0.061
	Positive Ranks	14b		
	Ties	3c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

tween the students' pretest and posttest mean scores ($z = -1.008$, $p < 0.313$). According to the descriptive results, the students' pretest mean score was 54.19 out of a possible 75, whilst the posttest mean score was 57.48. The Wilcoxon test results are presented in **Table 5**.

According to **Table 5**, the difference between the mean scores was not found to be statistically significant according to the results of the Wilcoxon signed-sum test. However, as can be seen, the posttest means score was higher than that of the pretest.

Effect of Peer Instruction on Attitudes towards Argument

It was determined that the Argumentativeness Scale data did not show a normal distribution, and therefore the Wilcoxon signed-sum test was applied. The analysis results revealed that there was no statistically significant difference found between the students' pretest and posttest scores ($z = -1.874$, $p < 0.061$). According to the descriptive results, the students' pretest mean score was 70.3 out of a possible 100, whilst the posttest mean score was 76.0. The Wilcoxon test results are presented in **Table 6**.

Table 7. Attitudes and Opinions of Students Towards Peer Instruction.

Question	Excerpts from the students' responses	f	%
How did the peer instruction teaching method used for acids and bases affect your interest in the course?	"My interest in the lesson increased." "It helped reinforce the subject, increased my motivation, and helped me see my mistakes.", "It made the lesson more efficient."	21	100.0
How would you compare the way in which the acids and bases topic was handled in this course with the way that other topics were handled in terms of your understanding of the subject?	"It was more effective than the way other subjects are handled in terms of understanding the subject." "I understood the subject better this way." "It saves time."	17	81.0
	"There was no perceived difference between the methods."	4	19.0
How did the way the acids and bases topic was handled affect your participation in the course?	"It positively affected my participation in the course."	19	90.4
	"It did not affect my participation."	1	4.8
	"It reduced my participation."	1	4.8
Did the classroom peer discussions have any impact on your understanding of the acids and bases topic?	"The discussions helped me understand the topic better, added a different dimension and perspective to the way I learned the topic, and increased the permanence of my learning."	19	90.4
	"It didn't have any effect on my understanding of the subject."	2	9.6
Were the reading quizzes considered as helpful?	"It was helpful."	14	66.7
	"Its contribution was limited."	4	19.0
	"It didn't help."	3	14.3
Did the way the acids and bases topic was handled make you enjoy classroom discussions?	"The discussions held during the course were effective and productive, and for this reason, I participated in the discussions with pleasure, realized any mistakes I had made through discussing with my peers, and had the opportunity to see different perspectives from these discussions."	17	81.0
	"No, it did not make me like [the subject]."	4	19.0
Did you find that the reading assignments for the acids and bases topic useful to your learning of the subject?	"I found the reading assignments to be useful since when we arrived at the lesson, we already had an idea about the subject, which increased our participation in the lesson."	15	71.4
	"It partially helped my learning."	4	19.0
	"I don't think it helped."	2	9.6

According to **Table 6**, it was determined that the difference between the students' Argumentativeness Scale pretest and posttest scores was not statistically significant. However, the posttest means score of the students was found to be higher than the pretest mean score.

Students' Attitudes and Opinions towards Peer Instruction

Table 7 presents the seven questions about the attitudes and opinions of the students towards the peer instruction method together with excerpts from their answers. According to the results, the students considered that peer instruction helped to increase their motivation. Those students who answered that there was no difference between the traditional and peer instruction methods considered that they had the opportunity to reinforce what they had learned, and that although this helped in their success, it did not change their level of understanding of the subject. Except for one student, all of the participants stated that the teaching of the acids and bases subject using peer instruction had positively affected their participation in the lessons. One student who responded negatively determined that their motivation sometimes decreased whilst waiting for the questions to be asked. It was observed that students responded positively when questioned about the effect of peer discussions being held in the classroom regarding their understanding of acids and bases. Two of the students stated that the discussions had no effect on their understanding of the subject, and mentioned that they preferred not to change their answers post-discussion where they were still unsure about their answers.

A small number of the participants indicated that the contribution of the reading quizzes was limited or none, and that, in addition, these tests created unnecessary stress for the students. Those students who found the tests to be of no benefit also stated that it was difficult to solve questions in situations that required them to provide detailed information. These results show that reading quizzes positively impacted the majority of the participating students as a pre-lesson preparation tool.

Most of the students stated that the discussions held as part of their course were effective and productive. On the other hand, those who negatively responded did so with simple, short answers such as “no, it [the discussion] didn’t make them like it [presumably, the subject]” without elaborating with any further explanation. The majority of the students found the reading assignments they were given to complete before the lessons were prepared in a way that was useful to the learning of the subject. A few of the students considered the reading assignments to be of limited benefit, and stated that they were seen as useful in terms of attending lessons already prepared, but that they were insufficient in terms of fully understanding the main concepts of the subject. Those participants who did not find the reading assignments to be useful did not consider that the subject could be understood through reading unless a teacher then also explained the subject.

Semi-Structured Interview Findings

Opinions about the Peer Instruction Method

It was determined that the answers given by the students to the seven semi-structured interview questions about the peer instruction method coincided with their explanations given in the Method Opinion Scale, and that they were mostly positive.

From the analysis of the answers given to the question about the advantages of teaching with peer instruction, the students said that they felt they understood the subject better, participated more in the lessons, were able to appreciate different ideas and perspectives, take note of and correct their own mistakes during the discussions, arrive at the lesson more prepared, and that it reinforced their understanding of the topic.

With regards to any disadvantages of teaching with the peer instruction method, the students did not express much in the way of negativity, although they did identify certain disadvantages; that peer discussions can sometimes get tough, the application takes longer, concept test questions can be difficult, leading to the thought that some students would not be able to learn the topic.

The interviewed students responded positively when asked, “How did the peer instruction teaching method used for acids and bases affect your interest in the course?” They mentioned that their interest level increased, that they were more motivated during the lessons, and that the discussions were enjoyable.

The concept test questions projected on to the whiteboard were considered by the students to be useful in terms of learning the subject. These questions were found to be effective in terms of understanding the subject, and that they were thought-provoking and positive in terms of increasing the permanence of the topic being taught.

It was indicated that discussing the concept test questions with their peers had a positive effect on the students’ learning. The students’ responses of the relevant semi-structured interview question revealed that they were able to comprehend the topic better through seeing different perspectives, that they were able to express themselves better, that their answers were attempted to be attributed to a reason, and that the discussions led the students to think more deeply and increased the permanence of the subject in their minds.

All but one of the interviewed students stated that the application of peer instruction for other chemistry topics could also be effective and beneficial. They also mentioned that the method provided them with the opportunity to participate in the lesson more actively and to correct their mistakes promptly. On the other hand, one student stated that the effectiveness of the method may differ from one topic to another.

The last of the seven questions posed during the first part of the semi-structured interview examined the effect of reading quizzes on the students’ learning of the topic. All of the students stated that the quizzes had a positive effect on their learning, that they had understood the basic points of the topic, which points they needed to study more carefully, and that they came to the lesson with a better idea about the topic and thereby felt more prepared.

Misconceptions about Acids and Bases

The 10 questions that formed the second part of the semi-structured interviews attempted to determine the students' level of understanding of the concepts related to the acids and bases topic that was being taught.

When the students were asked "How do you define acids and bases?" it was seen that five students defined acids and bases according to the Bronsted-Lowry theory, which was a correct means of definition. Two of the students stated that it could be defined according to three theories, with one student correctly remembering the Arrhenius theory. All of the students made definitions according to Lewis's theory, and that only one student remembered this theory incorrectly. An example of one student's answer is as follows:

We defined acids and bases according to three theories. Let's start with Arrhenius first; acids give hydrogen ions when dissolved in water, while bases give hydroxide ions. According to Bronsted-Lowry, acids donate protons and bases accept protons. According to Lewis, acids are electron pair acceptors and bases are electron pair donors. [S4]

The students were then asked, "What can be said about the acidity-basicity of water?" When their answers were examined, it was seen that the students first answered that water was neutral. Five of the students correctly mentioned the amphoteric property of water, stating that it can act as an acid or a base against different substances. One of the students said that, "Since the acid concentration in lakes can increase due to acid rain, these waters are called acidic" (S2), which was incorrect. On the other hand, concerning the question about the acidity-basicity of $Al(OH)_3$, all of the students responded that the material would also exhibit amphoteric properties since Al metal is amphoteric. An example of a student's answer to this question, together with their interaction with the teacher, is as follows:

The Kw value of the water is 10^{-14}. This indicates that the water is neutral because its pH and pOH values are 7. [S1]

Can't water act as an acid or a base? [Teacher]

We can decide this according to the substance with which water reacts. For example, if we compare it with HCl, water becomes a base, if we compare it with NaOH, water becomes an acid. It is amphoteric. [S1]

What can you say about the acidity-basicity of $Al(OH)_3$? [Teacher]

It is also an amphoteric substance; it can show both acidic and basic properties. Al(OH)3 may appear as a base but it can behave as an acid in reaction with NaOH. [S1]

With regards to the question, "What do you understand by the strength of acidity-basicity?" four of the students answered correctly. One student attempted to explain the question with Ka-Kb, pKa-pKb values, and the researcher asked a second question to further probe the student's understanding, and although the students offered a correct explanation the expected answer was not obtained. Another student first tried to answer the question using the concept of pH, but gave the wrong answer to the researcher's second question. However, the correct answer was given when the researcher asked for a new explanation using a third question that included a clue (as follows):

We can explain it by the concentration of H^+ or OH^- ions that an acid or base contains. As the H^+ ion increases, the pH value decreases and we consider this as a stronger acid. The opposite is true for bases. [S2]

How would you explain the concept of strong acid vs. weak acid? [Teacher]

By neutralization reactions. For example, if we can neutralize a strong base only with a strong acid, it is called a strong acid. If the base is weak, the neutralized acid is called a weak acid. [S2]

Can we explain it according to their dissociation in water? [Teacher]

If it is completely ionized in water, it is considered as a strong acid or base, while if it is partially ionized, it is called a weak acid-base. So we look at the degree of ionization in the water. [S2]

The students were then asked "Can you compare the pH values of pure water at 25°C with pure water at 100°C?" All of the students responded that the pH values of pure water would differ at the two temperatures. Two of the students incorrectly answered, having stated that the pH value of pure water at 100 ℃ would be greater than 7 and would show basic properties. Other students correctly answered, saying that the H^+ and OH^- concentrations would be equal in pure water at different temperatures, that the pH value would decrease at high temperatures, but pure water would be neutral at all temperatures. An example of one of the student's response is as follows:

We can say that they are both neutral, but we cannot say that the pH values of both are the same. This is because, as the temperature increases, *the H^+ and OH^- concentrations also increase. While these values are 10-7 at 25°C, and let's say 10-6 at 100 ℃, then the pH value of the water will be 6. [S3]*

What can be said about the acidity-basicity of water at these temperatures? [Teacher]

Water is neutral at both temperatures, but the pH values will differ. [S3]

From the question, "How can the change in the pH value at the equivalence point be explained according to the acid-base strength used in the titration? (give examples)," two of the students stated that since strong acids are fully ionized and weak bases are partially ionized, the pH is less than 7 at the equivalence point of their titration. Another student stated that since the initial pH of strong and weak acids differs, titrations with the same base will result in a different pH at the equivalence point. The researcher then asked, "Can you explain that in another way?" to which four students stated that there would be salt hydrolysis, but only one student gave the correct explanation. An example dialogue is as follows:

When weak acids or weak bases are titrated with a strong acid–strong base, the pH value will be different from 7 at the equivalence point. The salt formed is either acidic or basic. [S6]

How would you explain that? [Teacher]

For example, in acidic salt, conjugate acid of the weak base is present. In its reaction with water, H^+ is formed. Salt hydrolysis occurs. [S6]

The students were then asked, "Can you draw the NaOH–CH_3COOH titration graph?" and it was determined that six students drew the correct graph in response. Their graphs showed the approximately correct pH values at the start, end, and equivalence points, and were accepted as correct. The students showed that the initial pH of acetic acid was 3-5 since it is a weak acid, with a pH at the end of the titration of 12-13 since NaOH is a strong base, and the pH at the equivalence point was greater than 7. In addition, the students were asked to choose an indicator for this titration, and it was observed that all of the students chose the correct indicator in the appropriate pH range.

Next, the students were asked, "Can you show the variation of hydroxide and hydrogen ions in a solution with respect to each other on a graph?" Four of the students drew a correct graph, showing that the amounts of H^+ and OH^- ions changed inversely proportional to each other, but that the concentration of either could not be 0, while two of the students failed to provide the correct response.

The students were also asked, “What can be said about the acidity–basicity of sodium acetate and ammonium chloride salt?” It was seen that five of the students classified the two salts correctly, whilst one student failed to make the correct classification. The students were additionally required to explain their answers using reaction equations, with three students providing the correct equations. However, three other students wrote down the ionization of these salts in water, but could not remember the hydrolysis reaction of the ions from a weak acid–weak base with water. An example answer is as follows:

The solution of sodium acetate salt becomes basic. This is because the salt is formed from the reaction of a weak acid such as acetic acid and a strong base such as sodium hydroxide. When dissolved in water, it decomposes into acetate and sodium ions. OH^- ions are formed from the reaction of acetate ion with water, which makes the solution basic. Ammonium chloride is an acidic salt. H^+ ions are formed from the reaction of the ammonium ion with water, making the solution acidic. [S4]

Next, there followed a question, “How do you prepare a solution that can resist pH change?” All of the students knew that a buffer solution should be prepared in order for a solution to be resistant to pH change and they also correctly stated the components of a buffer solution. The teacher then asked, “How does it resist pH change when we add a small amount of strong acid to a buffer solution?” It was determined that five of the students answered the question correctly, whilst one could not provide the correct explanation. The following is an example response:

Buffer solutions can show resistance to pH changes, and these can be prepared by mixing a weak acid and its salt or a weak base and its salt. [S6]

How does the buffer resist the pH change when we add a small amount of strong acid to the solution? [Teacher]

There is a weak acid and its conjugate base in the solution. This conjugate base neutralizes it by reacting with the added acid. [S6]

Finally, the students were asked, “Can you explain using equations how an acid-base indicator gets different colors at different pH values?” Five of the students gave the correct answer, whilst one student was unable to provide an answer to the question. It was observed that the students who answered correctly also wrote the desired reaction equation as $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$, and added that the weak acid indicators and their conjugate bases gave different colors. An example of the students' answers is as follows:

Colors change according to the change in the concentrations of a weak acid indicator and its conjugate base in a solution. Since the HIn concentration will increase when acid is added, the color it gives becomes more dominant and this is the color that we see. [S5]

Observation Findings

From the researcher's observations, it was noted that the teacher did not talk all the time during the lessons and that the students were afforded the opportunity to discuss topics among themselves which contributed considerably to their active participation in the lessons. It was also noted that those students who willingly participated in the peer discussions when solving the concept questions tried to persuade each other by giving different examples. The students participated in the discussions from the beginning to the end of the lessons, and appeared to easily ask questions that they may have otherwise been afraid to ask their teacher directly. However, it was also observed that some of the students, albeit limited in number, avoided taking part in any classroom peer discussion, particularly during the initial weeks of the application.

It was observed that some of the students completed their reading assignment homework by preparing a summary, whist others only read the relevant section. It was also noted that those students who prepared a summary were able to grasp the subject more quickly and that they participated in the lessons more willingly. The teacher walked among the students during the peer discussions, and noted that those students who understood the concepts well seemed openly willing to explain their opinions to their peers.

It was notably only very rarely observed that students whose first individual answer was correct changed their answers following a peer discussion. The case of students holding on to an incorrect answer and not changing it following a peer discussion was also not observed very frequently. It was observed, however, that the students thought longer about and made reasoning for those concept questions that were asked in the form of "…which or which ones are true?"

Conclusion and Discussion

In order to measure the effect of the peer instruction method on the academic achievement levels of the participant students, the Acids-Bases Concept Test was developed and used as both a pretest and posttest. When the ABCT results were analyzed, it was determined that the students' academic success had increased significantly. These findings are also consistent with similar studies from the literature, e.g., Crouch and Mazur (2001), James (2006), Lasry et al. (2008, 2016), Perez et al. (2010), Schell and Butler (2018), and Zingaro and Porter (2014). It can be said that the students' active participation in the lesson by solving the concept test questions, discussing them with their peers, and having the opportunity to reevaluate any elements of the concepts that they did not understand based on their peers' ideas was seen to positively affect their academic achievement levels. The researcher-teacher observed that the concept questions seemed quite challenging for the students to answer, leading them to think more deeply. However, the peer discussions regarding these questions were seen to positively affect the permanence of the knowledge they gained. These results also are consistent with data obtained from the students' semi-structured interviews. In addition, it was considered that the students arrived at their classes having already become familiarized with the topic that would be studied due to their reading assignments and follow-up reading quizzes, which made it easier for the students to understand the topic of study.

During the in-class peer discussions, the teacher participated by walking around the class, helping the students to think more deeply and discuss the appropriate concepts, to move discussions in the right direction by asking crucial questions where they had become stalled, and to provide the students with clues that effectively drew demotivated groups back into the discussion. It may be said that these factors also positively affected the academic achievement level of the participant students. Turpen and Finkelstein (2009) obtained similar results from research undertaken at the University of Colorado, in which they observed the practices of six physics instructors who taught using the peer instruction method within the same department. The authors stated that in classes where the student-teacher interaction was high, the students participated in their lessons more willingly, and not only answered the questions correctly but also expressed their reasoning more clearly.

It has been frequently stated in the literature that conceptual learning directly affects academic success (Petres, 2008). In terms of the current study, a significant increase was observed in the conceptual learning levels of the participant students, with visible improvement noted in the resolving of misconceptions in parallel with their increased academic achievement. However, it has also been frequently stated that special teaching methods are required to reduce or eradicate learners' misconceptions, and that traditional teaching methods are deemed insufficient to achieve this outcome (Kaya, 2011; Schmidt, 1997). Connected to this, in research by both Lasry et al. (2013) and Zhang et al. (2017), it was reported that peer instruction practices help improve students' conceptual learning levels.

As can be seen in **Table 4**, upon comparing the percentages of individual correct answers given by the participant students to the concept questions before and after the discussions, a significant increase was observed after the peer discussion had taken place. The researcher-teacher also observed that the students made greater efforts to understand the concepts by extending their mental activities across a larger part of each lesson, along with working on the solution of concept questions and peer discussions during the lessons. Additionally, the answers given by the students to the semi-structured interview questions notably coincided with these same observations. As stated in the literature, scientific discussion undertaken during lessons can positively affect students' conceptual learning (Erduran et al., 2004; Naylor et al., 2007). As an example that supports this finding, the percentages of correct answers given by the students in the current study to the second concept question in the seventh subtitle (see as follows) before and after the peer discussions are presented:

Which salts will dissolve in water to give solutions with a pH above 7?

I. Na_2CO_3
II. CH_3COONa
III. Na_2SO_4

A. *I and II only*
B. *I and III only*
C. *II and III only*
D. *I, II and III*

It was determined that the majority of the participant students answered this question incorrectly prior to their peer discussions (three answered correctly, 18 were incorrect). However, after the discussions, there was a remarkable improvement noted with 15 of the students choosing the correct option (D), and the number of students who answered incorrectly correspondingly decreased from 18 down to six. At this point, it can be seen from their individual answers prior to the discussion that the students thought that SO_4^{2-} ion does not result in a hydrolysis reaction with water since it comes from a strong acid. In fact, although it is accepted that this ion does not undergo hydrolysis with water, by making rough assumptions as seen in many classroom textbooks, students may think sensitively and in greater detail during peer discussions and come to realize that SO_4^{2-} ion has a Kb value and conjugate base of HSO_4^- ion, and therefore may undergo hydrolysis with water. This demonstrates how the students' discussions significantly affected their understanding of the subject, and that this interaction should be considered an important factor in the structuring of student knowledge (Tullis, 2018). It was observed by the researcher-teacher that the students appeared to easily ask questions to their peers during these discussions which they would perhaps otherwise have been reticent to ask their teachers or would not have felt the need to ask. The written answers provided by the students to the questions in the Method Opinion Scale also coincided with these observations. In addition, the students received instant feedback from their peers or teachers during the discussions. Self-evaluations made in this way are deemed important since students gain the opportunity to review any points that they may have previously misunderstood (Kirschner et al., 2015).

According to Piaget, an individual's effective learning is possible with a dynamic balance that should take place between the dimensions of assimilation and regulation (Fosnot & Perry, 2005). The emergence and sustainability of this balance seems more possible with the creation of learning environments that increase the individual's intrinsic motivation and where they can be actively involved (McKeachie, 2002). The observations made by the teacher during the practice in the current study show that the learning environments in which the peer instruction method was applied conformed to this definition.

Students' attitudes towards a course are one factor that can affect their academic success (Schibeci, 1984). It is thought that students who have a positive attitude towards a course will have higher intrinsic motivation, and that this may affect their academic success. When the effect of peer instruction on students' attitudes towards chemistry was examined in the current study, it was seen that no statistically significant difference existed between the pretest and posttest mean scores of the Chemistry Attitude Scale, although the posttest mean score was shown to be higher. In addition, when this finding was evaluated together with the results of the Method Opinion Scale, an improvement was noted in the students' attitudes. The findings revealed that all 21 of the participant students stated that the application conducted with peer instruction increased their interest in the lesson, helped to reinforce their learning, was a source of motivation, helped them see their own mistakes, kept their interest fresh, and made the lesson more productive. The observations made by the teacher during the lessons also supported this noted improvement in the students' attitudes towards their lessons. It may therefore be said that a clear relationship exists between positive developments in student attitude towards their lessons and the peer instruction method (Zhang et al., 2017). The first two questions of the semi-structured interviews also examined the participant students' opinions towards peer instruction. When the students' responses to these questions were examined, it was seen that they were mostly positive and considered the method to be useful in their learning. In addition, the teacher observed that some of the students who were initially hesitant when the application started, increasingly adopted the method as the course progressed, and more willingly participated in the lessons.

Discussion has been described as an opportunity for teachers to observe students' misconceptions and their communication skills, and to then provide appropriate feedback (Arends, 2007). Discussion within the classroom environment can be used to develop students' thinking and problem-solving skills by creating a learning environment in which they can actively participate together through discussion, which is a known means of effective communication (Erduran & Jiménez-Aleixandre, 2008). Teaching methods that help students to enjoy discussion as a learning aid provide learners with importance opportunities to acquire a culture of discussion. In the current study, it was observed that the differences between the pretest and posttest scores of the Argumentativeness Scale were not statistically significant, although the mean posttest score was notably higher. In addition, considering the results obtained from the Method Opinion Scale, the majority of the participant students responded that their in-class discussions based on the peer instruction method were considered to be effective and productive, and therefore the students happily participated, came to realize their own mistakes during discussions with their peers, and had the opportunity to see different perspectives in problem solving. The teacher also observed that the students participated more willingly in discussions during lessons taught with peer instruction.

The study also determined that some students, albeit small in number, stated that the peer instruction method had not helped them in liking the concept of in-class discussion. The teacher observed that some students particularly avoided discussion in the lessons. Upon further examination, the teacher established that these same students also did not participate in discussions within other lessons either, preferring instead to remain silent, maintaining only limited social interaction with their peers, and were generally unwilling to talk in the classroom.

Limitations, Implications and Suggestions

The current study applied the peer instruction method over duration of 5 weeks. There are some opinions in the literature that this timeframe would be insufficient for behavioral changes to be observed in variables such as attitude since they require deep investigation, and that considerably more time than 5 weeks would be needed (Fernández, 2017). For this reason, it should be considered that more extensive results could be obtained with a longer-term study in order to observe clear changes in students' attitudes towards their course of study. It is therefore suggested that future studies in which changes in students' attitudes towards chemistry are to be observed should be conducted with peer instruction applications over an extended period of time.

The current study's application was limited to 21 participant 12th-grade students at a private high school in Turkey, where the first author was employed as a teacher. Whilst action research is predominantly conducted using small study groups, and considering that the researcher was also a practitioner, the current study was not aimed at generalizing results applicable to other group sizes or types (Johnson, 2014). Among the suggestions put forward by the current study is the use of experimental-control group research as an approach that can handle greater participant numbers, where the effectiveness of the method itself is scientifically measured, and where generalizable results can be obtained.

The current study is one of the first of its kind in Turkey to apply peer instruction as a teaching and learning method in high school chemistry lessons. The study showed that peer instruction was an applicable method, suitable as a personal teaching style, and that it may be used with other subjects and different teaching methods. This finding is also noted in the literature, with peer instruction considered a flexible method of teaching (Dancy et al., 2016). Based on the teacher's experience in the practical process itself during the current study, instruction could be given to students on how to answer reading quiz questions used to measure their level of reading assignment fulfillment. In addition, writing summaries or web-based assignments could be used in place of reading quizzes. In terms of the peer instruction method, careful preparation and planning should be undertaken prior to classroom lessons, and due attention paid to the preparation of lesson plans and concept questions that cover the whole teaching unit before the application takes place. During peer discussion, the teacher should circulate among the students in order to check that their discussions are being conducted in accordance with the intended purpose. Through the development of activities to introduce peer instruction as a method that can be used by teachers, it should be ensured that they gain the requisite knowledge and skills regarding the application of this method. As such, similar studies could be conducted in the future that examine the effectiveness of peer instruction in the teaching of other chemistry topics.

It may be said that the current study will act as a useful resource for teachers wanting to learn about peer instruction as a method of teaching and its application for chemistry subjects in particular. It is considered that peer instruction is a teaching method that can provide teachers with opportunities to improve their classroom practices due to its effectiveness in terms of applicability without any additional cost being incurred or need for additional physical equipment.

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ORIGINAL ARTICLE

Development of an Achievement Test for the 6th Grade Sound and its Properties Unit¶

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***Abstract**: In this study, it was aimed to develop an achievement test taking into account the subject acquisitions of the sound and properties unit in the sixth-grade science course. In the test development phase, firstly, literature review for the study was conducted. Then, 30 multiple choice questions in align with the subject acquisition in the 2018 science curriculum. This 30-question test was presented to opinion of three academicians and a science teacher for the validity of the test. Necessary adjustments were made in line with the opinions of the experts. Subsequently, the draft test, modified according to the experts' feedback, was applied to a total of 300 seventh-grade students. After the analysis, the number of questions in the test was reduced to 27. As a result of item analysis, mean difficulty index value of the test was 0.41, and item discrimination indexwas 0.49. The reliability analysis for the developed test was found 0.92 by calculating the KR-20 reliability coefficient value. By considering, the validity and reliability analysis results, it was concluded that the final version of the developed test, grounded in Bloom's Taxonomy, is a valid and reliable test with different difficulty levels.*

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Introduction

SCIENCE is a significant natural science that enable us to inquire how the universe and nature go through a process and what their functions are. From past to present, many researchers have investigated the concepts in students' minds about various phenomena. Some of them prove that student concepts and scientific knowledge are inconsistent, while some of them think otherwise (Celeon & Subramaniam, 2010). It is seen that the concepts in science are not directly associated with events, principles and tangible concrete objects or experiences time to time. This situation especially causes primary school children who have not yet passed to the abstract stage to be unable to construct the concepts in science subjects in a meaningful way. Therefore, this situation indicates that most of the subject concepts in science are cognitive and theoretical concepts. Also, when looked at the subject-concepts in the sound and its properties unit, it is seen that it has an abstract property (Aksoy & Özcan, 2020). It is also known that most of the science subjects are related to daily life. Although the unit of sound and its properties is a subject from daily life, how sound is formed, the void environment, the materialized environment, how sound does not propagate in a void environment, the speed of sound or microscopic scale explanations remain abstract for students. Therefore, there are serious difficulties in structuring the knowledge in this unit. In the study conducted by Demirci and Efe (2007) students confuse the formation of sound with the propagation of sound and think that sound propagates in an immaterialized environment. They think that sound stops as a result of encountering an obstacle. For this reason, this situation has attracted the attention of many researchers and various researches have been deemed appropriate by the researchers. Yanar et al. (2019) developed a test related to the light and sound unit in their study. The study was applied to 200 students in a secondary school in Kayseri. As a result of the statistical analysis, one question was removed and a test consisting of 19 items in total was prepared. Consequently, a test that can be used in scientific studies and teachers' evaluation processes was prepared. According to the study conducted by Küçük et al., (2021) the opinions of science teachers as to the teaching of the 6th grade sound and its properties unit were taken. In this study, a case study, which is one of the qualitative research designs, was used. The opinions of 39 science teachers were taken in total. As a result of the analysis, although the teachers interpreted the sound topics as easy to understand and the unit was oversimplified, it was concluded from the teachers' statements that the students had difficulty in understanding and structuring the subject concepts. In the study conducted by Akson et al. (2023) it was investigated how design-based activities affect the knowledge and attitude levels of the sound and its properties unit. According to the results of the study, it was determined that design-based activities positively affected students' achievement in the sound and its properties unit. There are also some studies on misconceptions related to sound and properties unit (Dinçer & Özcan, 2016; Kistak, 2014; Wild, et al., 2013). Additionally et al. (2019) conducted research on how sound and its properties are represented. Studies have also been conducted on how sound is modeled in students' minds (Yüzbaşoğlu, 2018).

When some of the studies conducted above are investigated, the most important issue in learning is to reveal the meaningful learning status. The main goal is to increase the achievement of students by providing meaningful learning. Therefore, the teacher, who has an important place in the system, has a crucial duty and responsibility. The teacher need to observe the achievement of the student, notice the change in his/her achievement, analyze the change in order to observe it better, and provide the required conditions for meaningful learning (Özcan, et al., 2019).

For all these, the measurement and assessment system manage to determine what extent the students have learnt the acquisitions and concepts. Still, the students' incorrect and incomplete knowledge is revealed thanks to measurement and evaluation (Metin, 2013). In addition, teachers, in the measurement and assessment process, serve with the purposes of providing feedback to students, increasing students' motivation, evaluating the effectiveness of programs when necessary, and improving teaching processes (Sabancı & Yazıcı, 2017). In this respect, it is ensured that students make healthy decisions about their professional future (Akarsu, 2018). Therefore, it is important for teachers to know how and in what way to make reliable-valid assessment for an effective measurement and assessment (Newfields, 2016; Korkmaz & Kaptan, 2005; Sabancı & Yazıcı, 2017). Nowadays, tests consisting of multiple-choice items are especially preferred in making decisions in teaching in measurement and assessment (Kartz & Slomka, 1999). The reasons of this preference are that there is no time and space restriction during the application of multiple-choice items so that many participants can be tested in a short time. Moreover, the questions can be asked from cognitive levels from knowledge to analysis level by increasing the number of items and options. This also increases the content validity, and most significantly, scoring can be done easily and in a short time (Öksüz & Güven-Demir, 2019). When national-international studies in the literature are investigated, it is seen that achievement tests that are suitable for the acquisitions in various units related to science have been developed (Yalınkılıç & Gül, 2023; Kargın & Gül, 2021). After these studies are examined, it is also seen that tests, suitable for the target acquisitions in the sound and its properties unit, were developed (Aksoy & Özcan, 2020).On the examination of the literature, it is seen that the sound and its properties unit was given together with the light unit in the science subjects of the sixth grade in the past curricula (Yanar, et al., 2019). The reason of this is that the studies which were carried out before the 2018 science curriculum. In the 2013 science curriculum, for the sixth grade, light and sound subjects were included in the same unit and there are three learning acquisition for the subject of sound. However, in the 2018 curriculum, just one unit is allocated to the subject of sound and it is stated that nine target learning acquisitions need to be comprehended under four subtopics. Therefore, when the studies conducted before 2018 are examined, it is seen that since the unit of sound and its properties is within the scope of the unit of light and sound according to the 2013 program, the tests developed were prepared in accordance with the outcomes of these two subjects (Yazıcıoğlu, 2017; Aydın & Kömürkaraoğlu, 2016; Şener-Çoruhlu, et al., 2016; Bakırcı, et al., 2015; Evrekli, et al., 2012). One of the studies on sound and its properties based on the science curriculum after 2018 was developed by Aksoy et al. (2023).

Purpose of the Research

On account of limited number of achievement tests related to the unit of sound and its properties after the 2018 science curriculum was published, it was aimed to prepare a valid reliable achievement test for the sixth grade. Thus, it is aimed to objectively measure the acquisitions-concepts in the unit of sound and its properties. For this purpose, answers to the following questions were sought.

Is the achievement test (SPAT), developed for determining the sixth grade students' achievement levels, valid? Is the achievement test (SPAT), developed for determining the sixth grade students' achievement levels, reliable?

Methodology

Procedures

In this study, an achievement test was prepared to determine the level of academic achievement of sixth grade secondary school students within the scope of sound and its properties unit. The validity and reliability of the study were tested and analyses were performed. In line with the acquisitions of the 2018 science curriculum (Ministry of National Education [MoNE], 2018), the test items were created inspired by the question banks (test books) of various publications. The relevant questions banks were prepared within the framework of sample questions developed by the Ministry of National Education [MoNE]. At first, expert opinion was taken for the questions determined for the test, and then a pilot study was conducted with 300 students. After that, validity-reliability and item analyses of the test were conducted. Ethical approval for this research was obtained from Harran University Eth-

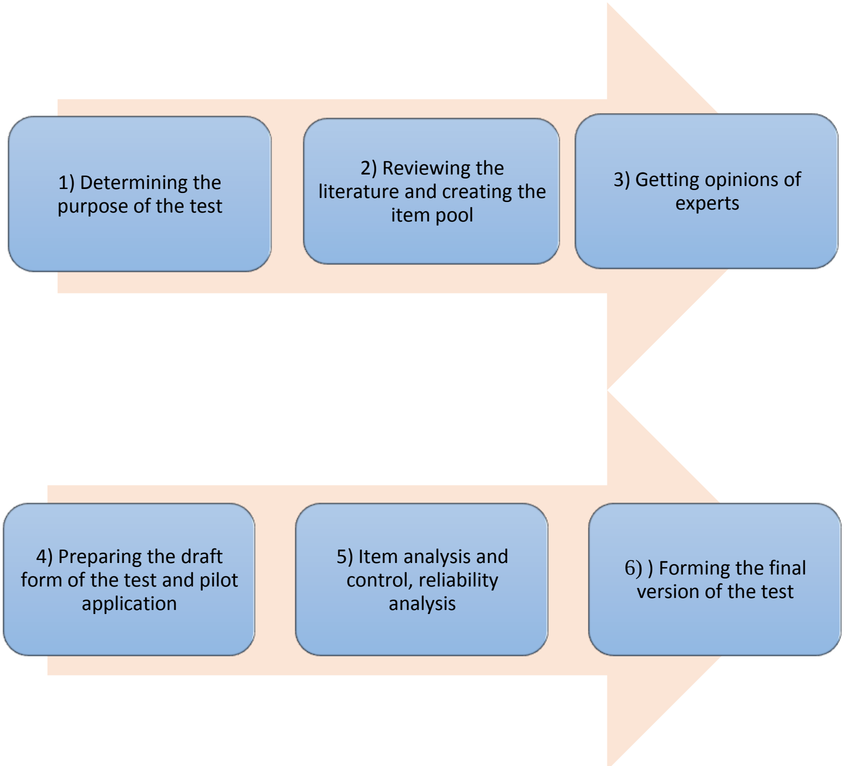

Figure 1. Development Stages of SPAT.

ics Commission dated 16.06.2023 and numbered 2023/88. Kızkapan and Bektaş (2018) argue that the processes to be followed in the development process of a test should be as given in **Figure 1**. SPAT was also developed by following this process.

Research Model

This study was conducted with the survey method based on the quantitative research paradigm. According to McMillan and Schumacher (2010) survey method is considered appropriate for obtaining information about individuals' attitudes, demographic characteristics, ideas, behaviors, beliefs, values, habits, etc. Therefore, in this study, the survey method was used to develop an academic test that determines students' achievement levels.

Participants

While determining the participants of the study, the convenience sampling method, which is a type of the purposive sampling method, was selected. The convenience sampling method should be selected in accordance with the research (Kadıoğlu, 2019). Some of the most important purposes of choosing the convenience sampling method are that it facilitates researchers in terms of time, labour, cost and application (Fraenkel, et al., 2012). The participants of this research is a total of 300 students studying in a public school in Haliliye district of Şanlıurfa province, which is in the South East Anatolia Region, during the 2023-2024 academic year. However, a total of 270 students were taken into consideration for item analysis.

Research Instruments

The Development of the Achievement Test

In the study, SPAT was developed in order to determine the level of students' academic achievement on the subject of sound and its properties. Sound and its properties unit consists of four subtopics as sound propagation, different hearing of sound in different environments, speed of sound and finally interaction of sound with matter. During the preparation phase of the SPAT, the test items were developed and selected by considering the questions inspired by the test books which were developed by taking into account the sample unit acquisition and comprehension questions that published by MoNE. Immediately after the questions were determined, it was asked to a science teacher working in MoNE and three experts in the field of science to prepare the table of specification. In this way, their opinions were taken in terms of content validity. It was also considered that the experts in the field of science had more than one year of professional experience and had studies in the field of science education. While the opinions of the experts were taken for the SPAT, the question related to the acquisition was asked and they were asked to indicate whether this acquisition represented the question or not. In addition to this, their opinions on the cognitive level of the question and grammar of the question were also taken.

Within the light of the feedback from the experts and teacher, the questions that did not match the acquisitions in the sixth grade sound and its properties unit were regulated. In addition, grammatical structure and the cognitive levels of the questions were asked to the experts and the required optimizations were made by considering the suggestions of the experts. The question 12, which was regulated as an example by taking into account the opinions of the experts regarding the acquisitions, the cognitive level and grammatical structure of the determined questions, is given in **Table 1**.

According to the experts' opinions, as the root of the question 12, which is an example of the adjusted questions as given in **Table 1**, has a

Table 1. An Example of Questions Adjusted in Line with Expert Opinion.

Initial form of the question	Final form of the question
(see below)	(see below)

Initial form of the question

Experiment	Environments where sound propagates	Environments where sound does not propagates
1	Outer space	Air
2	Bottle filled with water	Vacuum-sealed glass bowl
3	Wall	Outer space
4	Vacuum-sealed glass bowl	Wall

According to the table, the environments in which some sound propagates and does not propagate are given. Accordingly, in which of the numbers are the environments mismatched?

A) 1 and 4
B) Only-3
C) 1 and 2
D) Only-4

Final form of the question

Experiment	Environments where sound propagates	Environments where sound does not propagates
1	Outer space	Air
2	Bottle filled with water	Vacuum-sealed glass bowl
3	Wall	Outer space
4	Vacuum-sealed glass bowl	Wall

According to the table, some environments in which sound propagates and does not propagate are given. Accordingly, in which of the numbers are the environments mismatched?

A) 1 and 4
B) Only-3
C) 1 and 2
D) Only-4

Table 2. Acquisitions and Related Questions in the Sound and Its Properties Unit of the 2018 Science Curriculum.

Acquisition No	Acquisition	Question #
1	S.6.5.1.1. Students will be able to predict the environment in which sound can propagate and test their predictions.	9, 10, 12, 13, Removed-25*, 26
2	S.6.5.2.1. Students will be able to discover by experimenting that sounds are heard differently when the sound source changes.	2, 8
3	S.6.5.2.2. Students will be able to discover by experimenting that sound is heard differently with the change of the environment in which it propagates. The concept of frequency will not be mentioned.	21, Removed-27*
4	S.6.5.3.1. Students will be able to compare the speed of sound in different environments.	1, 3, 4, 5, 11, 14, 15, 16, 17, 22, Removed-24*, 29
5	S.6.5.4.1. Students will be able to give examples of reflection and absorption of sound	6, 18, 28, 30
6	S.6.5.4.2. Students will be able to make predictions to prevent the spread of sound and tests their predictions	23
7	S.6.5.4.3. Students will be able to explain the importance of sound insulation. Technological and architectural applications developed for sound insulation will be mentioned.	20
8	S.6.5.4.4. Students will be able to give examples of acoustic applications. Applications in modern and cultural architecture will be emphasized. For example, the acoustics architecture of the Süleymaniye Mosque will be referred.	7
9	S.6.5.4.5. Students will be able to design an environment that will serve as an example of sound insulation or acoustic applications	19

**Represents the items removed from the test as a result of the analysis carried out on the process of the test development.*

grammatical error in expression, the necessary corrections were made and the question was given its final form. In line with the opinions of experts, warnings regarding other questions were taken into consideration and necessary evaluations were made in forming the final version of the test.

Table 2 shows the acquisitions and related questions in the sound and its properties unit of the 2018 science curriculum. The questions 24, 25 and 27 were marked with "R" (removed). These questions were removed from the test because the values of these questions were calculated insufficient in the item analysis.

As proved in **Table 2**, all of the items in the item pool that was created during the test phase have been optimized into a level that can be applied to students, by ensuring the face validity of the test. According to the revised Bloom taxonomy stated by Andersen et al. (2001), the question 24 of the test is at the factual knowledge-remember level. The questions of 1-6-7-8-9-10-22-25-26-28-30 are at the conceptual knowledge understood level. The questions of 3-4-5-11-14-16-18-20-21-27-29 are at the conceptual knowledge-apply level. The questions of 2-12-15-17-19-23 are at the conceptual knowledge- analyze level and the question 13 is in the conceptual knowledge evaluate level. The developed test was conducted with the total of 300 seventh grade students. For the pilot application, the test was carried out in 40-minute period during a lesson. Before, carrying out the pilot application, students were informed that it was not intended to give any grades and that data was only collected for a research. As a result of the pilot application, the data gathered from 270 students were included in the analysis. Then, all necessary analysis for validity, reliability and item analyzes were carried out. **Table 3** shows the acquisitions in the unit of sound and its properties in the science curriculum and the cognitive level of the questions including these acquisitions.

When **Table 3** is examined in detail, in the developed for the first learning acquisition within the scope of the sound and its properties unit, there are questions 9, (R) 25, 26, which are at the level of conceptual knowledge for acquisition and at the level of understand for the question; the question 10 is at the level of conceptual knowledge- apply; the question 12 is at the level of conceptual knowledge- analyze; the question 13 is at the level of conceptual knowledge and evaluate. For the second acquisition, the question 8 is at the level of conceptual knowledge- understand and question 2 at the level of conceptual knowledge-analyze. Considering the third acquisition, the questions 21 and (R) 27 are at the conceptual knowledge- apply level. For the fourth acquisition, while the question (R) 24 is at factual knowledge-remember level; question 1 is at conceptual knowledge-remember level; the question 22 is at the conceptual knowledge- understand level; the questions 3, 4, 5, 11, 14, 16, 29 are in the conceptual knowledge- apply level and the question 15 is at the conceptual knowledge-analyze level. For the fifth acqui-

Table 3. Table of Indicators According to the Renewed Bloom Taxonomy.

Cognitive Process Dimension	Remembering				Understanding				Apply				Analyze				Evaluate				Create			
	FK	CK	PK	MK	FK	CK	PK	MK	FK	CK	PK	MK	FK	CK	PK	MK	FK	CK	PK	MK	FK	CK	PK	MK
S.6.5.1.1. Students will be able to predict the environment in which sound can propagate and test their predictions.	-	-	-	-	-	9, 25, 26	-	-	-	10	-	-	-	12	-	-	-	13	-	-	-	-	-	-
S.6.5.2.1. Students will be able to discover by experimenting that sounds are heard differently when the sound source changes.	-	-	-	-	-	8	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
S.6.5.2.2. Students will be able to discover by experimenting that sound is heard differently with the change of the environment in which it propagates.	-	-	-	-	-	-	-	-	-	21, 27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.6.5.3.1. Students will be able to compare the speed of sound in different environments.	24	1	-	-	-	22	-	-	-	3, 4, 5, 11, 14, 16, 29	-	-	-	15	-	-	-	-	-	-	-	-	-	-
S.6.5.4.1. Students will be able to give examples of reflection and absorption of sound	-	-	-	-	-	6, 8	-	-	-	18	-	-	-	23	-	-	-	-	-	-	-	-	-	-
S.6.5.4.2. Students will be able to make predictions to prevent the spread of sound and tests their predictions	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.6.5.4.3. Students will be able to explain the importance of sound insulation.	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.6.5.4.4. Students will be able to give examples of acoustic applications	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.6.5.4.5. Students will be able to design an environment that will serve as an example of sound insulation or acoustic applications	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-

FK: Factual Knowledge, CK: Conceptual Knowledge, TK: Transactional Knowledge, MK: Metacognitive Knowledge.

sition, the questions 6 and 28 are at conceptual knowledge- understand level; the question 18 is at the conceptual knowledge-apply level, and the question 23 is at the conceptual knowledge analyze level. For the sixth acquisition, there is just the question 30 at the conceptual knowledge- understand level. For the seventh acquisition, there is question 20 in the conceptual knowledge- apply level. For the eighth acquisition, there is question 7 in the conceptual knowledge-understand level and for the ninth acquisition, there is question 19 in the conceptual knowledge-analyze level.

Results

In this study, the difficulty index (Pj) and item discrimination index (rjx) values of each item were calculated to ensure the validity of the test (**Table 4**). In the literature, the discrimination index takes value between -1 and +1. When this value approaches zero, it means that there is a problem in distinguishing the upper and lower groups of the item. The value closes to +1 means that the discrimination is high. On the other hand, when the item discrimination index takes the value (-), it is interpreted that the lower group is more than the upper group in the number of respondents and this situation does not serve the desired purpose (Kubiszyn & Borich, 2003). The item difficulty index shows the correct answer rate for each item in the test and takes values between 0 and 1. As a result of the analysis, if the value is close to 0, the item is quite difficult, and if it is close to 1, the item is interpreted as quite easy (İlhan & Hoşgören, 2017).

According to Çalık and Ayas (2003) items with item difficulty index (Pj) $\leq$ 0.29 are very difficult, items with 0.30-0.49 are moderately difficult, items with 0.50-0.69 are easy, and items with 0.70-1.00 are very easy. Besides, items with item discrimination index (rjx) $\geq$ 0.40 are very good and do not need to be edited, items with a rjx of 0.30-0.40 indicate that the item is very good and does not need to be edited, items with a rjx of 0.20-0.30 indicate that the item can be used when necessary or advised to be changed, items with a rjx of $\leq$ 0.20 indicate that the item can be edited or advised to be used, and finally, items with a rjx of zero or negative values indicate that the item is not recommended to be included in the test. With regard to criteria that mentioned above, the items with a discrimination index below 0.30 (24, 25, 27) were removed from the test in this study. Moreover, when the difficulty index was analyzed, the values below 0.29 for the items (24, 25 and 27) were excluded from the test because of being in the “very difficult” group. The remaining 27 items were included in the test as they were in good, medium, very good values in terms of discrimination and difficulty

As a result of the item analysis, it is seen that this 27-item test covers all the acquisitions related to the subject in the science curriculum. The mean difficulty index of the overall SPAT was calculated as 0.41 and the mean

Table 4. Item Difficulty and Item Discrimination Index Values in the Development Process of the SPAT.

Q	G	A	B	C	D	Empty	Full	(Pj)	(rjx)
1	Upper	2	10	5	55*	0	30	0,47	0,56
	Lower	5	30	23	14	0	30		
2	Upper	2	2	48*	20	0	30	0,42	0,48
	Lower	7	17	13	35	0	30		
3	Upper	44*	10	13	5	0	30	0,36	0,48
	Lower	9	21	26	16	0	30		
4	Upper	2	5	18	47*	0	30	0,39	0,51
	Lower	6	22	34	10	0	30		
5	Upper	4	10	12	46*	0	30	0,38	0,5
	Lower	19	16	27	10	0	30		
6	Upper	4	6	12	50*	0	30	0,41	0,55
	Lower	15	25	22	10	0	30		
7	Upper	5	48*	7	12	0	30	0,4	0,51
	Lower	24	11	33	4	0	30		
8	Upper	18	5	2	47*	0	30	0,4	0,5
	Lower	23	24	14	11	0	30		
9	Upper	1	2	4	47*	0	30	0,4	0,5
	Lower	30	10	21	11	0	30		
10	Upper	4	49*	12	7	0	30	0,42	0,51
	Lower	17	12	22	21	0	30		
11	Upper	6	8	8	50*	0	30	0,45	0,47
	Lower	21	19	16	16	0	30		
12	Upper	44*	7	14	7	0	30	0,37	0,47
	Lower	10	23	16	23	0	30		
13	Upper	6	7	8	51*	0	30	0,45	0,5
	Lower	14	22	24	15	0	30		
14	Upper	6	53*	7	6	0	30	0,49	0,48
	Lower	6	18	21	27	0	30		
15	Upper	6	42*	16	8	0	30	0,35	0,45
	Lower	19	9	28	16	0	30		
16	Upper	6	41*	17	8	0	30	0,34	0,45
	Lower	18	8	25	21	0	30		
17	Upper	0	2	17	53*	0	30	0,48	0,5
	Lower	14	19	22	17	0	30		
18	Upper	49*	12	6	5	0	30	0,43	0,5
	Lower	13	25	17	17	0	30		
19	Upper	0	8	20	44*	0	30	0,37	0,47
	Lower	18	18	26	10	0	30		
20	Upper	5	7	13	47*	0	30	0,4	0,5
	Lower	17	19	25	11	0	30		
21	Upper	13	6	4	49*	0	30	0,42	0,5
	Lower	29	18	13	12	0	30		
22	Upper	11	45*	9	7	0	30	0,38	0,47
	Lower	26	11	28	7	0	30		

23	Upper	2	49*	16	5	0	30	0,42	0,51
	Lower	26	12	25	9	0	30		
24	Upper	41	12	9	10*	0	30	0,23	0,04
	Lower	38	22	5	7	0	30		
25	Upper	15	13*	32	12	0	30	0,27	0,08
	Lower	19	7	25*	21	0	30		
26	Upper	54*	8	7	3	0	30	0,47	0,54
	Lower	15	20	18	19	0	30		
27	Upper	24	26	12*	10	0	30	0,26	0,06
	Lower	23	17	7	25	0	30		
28	Upper	15	44*	7	6	0	30	0,38	0,45
	Lower	23	11	18	20	0	30		
29	Upper	51*	13	6	2	0	30	0,47	0,47
	Lower	17	26	17	12	0	30		
30	Upper	12	0	54*	6	0	30	0,48	0,52
	Lower	21	19	16	16	0	30		

** Refers to the correct answer of the item, (Pj) item difficulty index, (rjx) item discrimination index According to the analysis items written in bold (24. 25. ve 27) were removed from the test.*

discrimination index value was calculated as 0.49. For the reliability analysis of the final version of the test, a total of 300 students were implemented, however the data of 270 students were included in the analysis. As a result of the analysis to calculate the difficulty index and discrimination index of the items, the items of 24, 25 and 27 were not at a sufficient value and were removed from the test. As a consequence of this application, the KR-20 reliability coefficient was found to be 0.92. According to Can (2014) since the KR-20 value in this test is greater than 0.60, it means that it is quite reliable in determining students' achievement levels.

Discussion

Wherefore the limited number of achievement tests related to the sound and its properties unit after the publication of the 2018 curriculum, it was aimed to develop a valid and reliable achievement test that measures the acquisitions-concepts in the sound and its properties unit in sixth grades. The final version of the developed test consists of 27 questions in total by passing through preparation phases. According to Andersen et al. (2001) the question 24 in this test is in the factual knowledge-remember level; the questions 1-6-7-8-9-10-22-25-26-28-30 are in the conceptual knowledge understand level; the questions 3-4-5-11-14-16-18-20-21-27-29 are in the conceptual knowledge apply level; the questions 2-12-15-17-19-23 are in the conceptual knowledge- analyze level; the question 13 is in the conceptual knowledge-evaluate level.

Most of the questions in this developed test are at the conceptual knowledge level. As the questions include target behaviors such as interpreting information, drawing conclusions, determining causes and relationships, reordering in line with existing knowledge, comparing, finding similarities, comparing results, rearranging and calculating, they are of the conceptual knowledge-understand level (e.g., the questions 3-4-5- 11-14-16-18-20-21-27-29). Moreover, target behaviors such as directly remembering the knowledge, defining, selecting, sorting, naming, listing indicate that the question is in the factual knowledge-remember level (e.g., the questions of 1-6-7-8-9-10-22-25-26-28-30). Target behaviors such as asking for a cause-effect relationship, sorting by examining, establishing relationships, dividing knowledge, making inferences, and distinguishing indicate that it is in the conceptual knowledge-analyze level (e.g. questions 2-12-15-17-19-23).

The question 13, which is in the conceptual knowledge evaluate level, includes target behaviors such as combining data according to a certain relationship, creating and combining various possibilities, and determining knowledge (Cangüven, et al., 2017). As a result of the item analysis carried out in the development process of the achievement test, the difficulty index and discrimination index of each item in the test were calculated. While the difficulty index of the items varied between 0.34 and 0.49, the mean item difficulty value of the test was calculated as 0.41. When the item difficulty index approaches 1, it means that the test is weak, and when it approaches 0, it means that the test is more powerful (Turgut & Baykul, 2012).

The mean difficulty index of a test is expected to be around 0.50 (Gömleksiz & Erkan, 2010). Accordingly, it can be stated that the test in this study is close to mean difficulty. In addition, as a result of the analysis, the discrimination index of each item in the test was calculated and although these values were between 0.45-0.56, the mean item discrimination of the test was found to be 0.49. The discrimination index takes values between +1 and -1. This value is used to show whether it distinguishes between students with higher levels of achievement in the test and students with lower levels of achievements. A value approaching +1 indicates a higher level of discrimination, while a value approaching 0 indicates a lower level of discrimination (Bayrakçeken, 2012).

Accordingly, looking at questions 24, 25 and 27, question 24, which had an item difficulty index of 0.23 and a discrimination index of 0.04, was removed from the test because it was both difficult and indiscriminate as a result of the item analysis. Similarly, question 25 was removed from the test because its item difficulty index was 0.27 and its item discrimination index was 0.08. Finally, question 27, which was a difficult item with a difficulty index of 0.26 and an item discrimination index of 0.06, was removed from the test. As a result, we can say that this test shows that it distinguishes students with high achievement level from students with low achievement level.

The KR20 reliability coefficient value of the developed PSCT was found to be 0.927. According to Altunışık et al. (2007) this value shows that the test has a reliable structure.

With refer to this, when looked at the questions 24, 25 and 27, the question 24 which had an item difficulty index of 0.23 and a discrimination index of 0.04, was removed from the test because it was both difficult and indiscriminate as a result of the item analysis. Similarly, the question 25 was removed from the test because its item difficulty index was 0.27 and its item discrimination index was 0.08. Finally, the question 27, which was a difficult item with a difficulty index of 0.26 and an item discrimination index of 0.06, was removed from the test. As a result, it can be stated that this test distinguishes students with higher achievement level from students with lower achievement level. The KR20 reliability coefficient value of the developed SPAT was found to be 0.927. According to Altunışık et al. (2007) this value shows that the test has a reliable structure.

The test developed in this study was finalized using statistical analyses such as reliability analysis and item analysis. When the literature is reviewed, it is mentioned that information about the construct validity of the test should be obtained through tetrachoric factor analysis, which is recommended to be used in recently developed tests (Nacaroğlu, et al., 2020; Keçeci, et al., 2019). As it is known, in the scoring of an achievement test, those who answer incorrectly are coded as 0 (zero) and those who answer correctly are coded as 1 (one). Therefore, typical factor analyses are performed with the SPSS program for statistical analysis in the coding from 1 to 5, which is frequently preferred in surveys. However, unlike the SPSS program, the construct validity of a test can be determined with the help of programs such as Mplus and FACTOR for scores coded as 0-1. 1,0 is used to determine the degree of relationship between two artificial and discontinuous variables with two categories (DokumacıSütçü & Oral, 2019).

Conclusion and Suggestions

- In this study, tetrachoric factor analysis was not preferred because it was not in the researcher's area of expertise. For this reason, it is recommended that a tetrachoric factor analysis be conducted to examine the construct validity in future test development studies on this subject.
- In this study, although the required number of participants in the literature was reached with the convenience sampling method, it is recommended that studies with as large a sample size as possible be conducted in order to increase the reliability of the test and make more precise measurements.

- For the generalizability of the results, schools with different achievement levels should be selected and a parallel test should be developed to address large masses.
- For future research, open-ended questions that will develop higher level skills recommended to be asked in the tests to be developed for the same subject. Since multiple-choice questions were selected in this study, Bloom's Taxonomy is not sufficient to reveal higher level skills. Therefore, it is recommended to develop new tests that can measure both questions balanced with learning acquisitions and various skills.
- It is recommended to be conducted more than one pilot application of this test to determine the difficulty of the test in determining students' achievement in the subject of sound and its properties.
- It is also recommended to prepare questions with stronger distracters to determine students' misconceptions about this subject in future studies to be carried out in the development of the SPAT.
- As a result, it is suggested that this test can be applied as a readiness test for higher level students, as an end-of-unit assessment and as a test for reinforcement of unit topics. In addition, as a result of the statistical analysis for each item in the test, it is also recommended to develop new tests that will determine the level of students' misconceptions and conceptual understanding by looking at the strong distracters.

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APPENDIX I.

Development of an Achievement Test for the 6th Grade Sound and its Properties Unit

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Ortaokul Altıncı Sınıf Ses ve Özellikleri Başarı Testi

Sevgili öğrenciler;

Bu testin amacı, sizin fen bilimleri dersi ses ve özellikleri ünitesindeki konu-kazanımlar ile ilgili akademik başarılarınızın ne düzeyde olduğunu tespit etmektir**.** Cevaplarınız Fen Bilimleri dersi notlarınızı etkilemeyecek olup, bilimsel amaçlı olarak kullanılacaktır. Bu çalışmaya katıldığınız için ayrıca teşekkür ederim.

Adı:
Soyadı:
Sınıf:

1. Büşra, çalar saati çalıştırıp cam bir fanusun içine koymuştur. Daha sonra fanusun içinde havayı (hava boşaltma tulumbası) yardımıyla tamamen boşalmıştır. Sonrasında çalar saatten çıkan sesi tekrar dinlemek istemiştir.

(Havası boşaltılmış cam fanus)
İlk durum

(İçinde hava olan cam fanus)
Son durum

Büşra ilk durumda sesi duymazken son durumda çalar saatten çıkan sesi duyabilmiştir. **Buna göre bu durumu aşağıdakilerden hangisi açıklar?**

A) Cam fanus sesi iletmez.
B) Ses fanusta yansımıştır.
C) Çalar saatin sesi yeterince yüksek değildir.
D) Maddesel olmayan ortamda ses yayılmaz.

2. Bir öğrenci eline aldığı demir kaşığı, önce tahta masaya sonra sandalyenin metal ayağına sonrasında cam şişeye yavaşça vuruyor. Her seferinde aynı şiddetle vurmasına rağmen farklı sesler işitiyor. **Buna göre bu durumun nedeni aşağıdakilerden hangisinde doğru verilmiştir?**

A) Sesin maddesel olan ortamda yayılması
B) Gaz maddelerin sesi katılardan daha iyi iletmesi

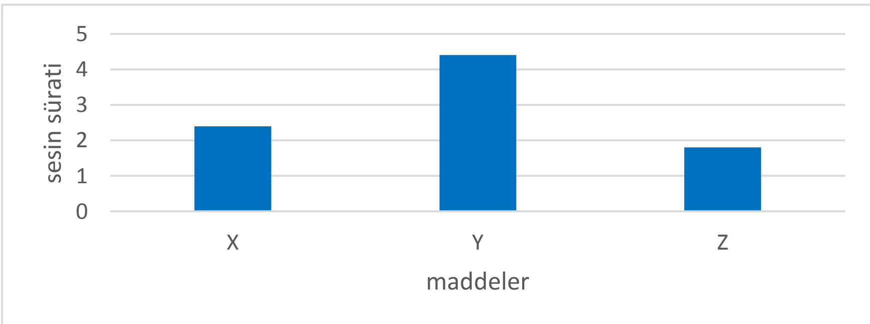
C) Farklı maddelerden üretilen seslerin farklı duyulması
D) Sesin süratinin değişmesi

3.

1. 2. Madde	Sıcaklık(℃)	Sesin sürati (m/s)
3. **Hava**	20	344
4. **Demir**	20	5130
5. **Su**	20	1440

Yukarıdaki tabloda aynı sıcaklıktaki farklı maddelere ait sesin süratleri karşılaştırılmıştır.
Buna göre; aşağıdakilerden hangisi söylenemez?
A) Sesin sürati en iyi gaz maddelerdedir.
B) Sesin sürati en iyi katı maddelerdedir.
C) Sesin sudaki sürati havadakinden fazladır.
D) Sesin katı ortamındaki sürati sıvı ortamından fazladır.

4.



Yukarıda eşit sıcaklıklardaki x, y, z maddelerinde sesin yayılma süratleri verilmektedir.
Buna göre maddenin yoğunlukları arasındaki ilişki nasıldır?
A) X> Y >Z
B) X> Z> Y
C) Z> X> Y
D) Y> X> Z

5. Fen bilimleri öğretmeni olan Ömür, sesin bir enerji olduğunu gösteren günlük hayattaki olaylarla ilgili öğrencilerden bir poster hazırlamalarını istiyor. Buna göre;
I. Alçaktan uçan bir uçağın bir okulun camlarını titretmesi
II. Ses bombasının patlaması sırasında camların kırılması
III. Ameliyatta böbrek taşlarının ses dalgaları ile kırılması
Öğrenciler verilen bu örneklerden hangilerini posterlerinde kullanabilirler?
A) I ve III
B) Yalnız II
C) II ve III
D) I, II ve III

6.

-Basketbol salonlarının parke zemin ile kaplı olması ve yankı olması

-Bir kaloriferin sıcak su borusunun çatlak olup olmadığının tespit edilmesi

Yukarıda verilen bu iki olayla ilgili sesin hangi özelliği anlatılmak istenmiştir?

A) Sesin sürati
B) Sesin soğurulması
C) Sesin bir enerji türü olduğu
D) Sesin yansıması

7. **“**Akustik, sesin özelliklerini farklı ortamlardaki yayılımını, bulundukları ortamla etkileşimini inceler. Bilim insanları, fizik mühendisleri, inşaat mühendisleri binaları tasarlamadan önce akustik ile ilgili araştırmalarda bulunur.” **Akustikle ilgili yukarıda verilen bilgiye göre aşağıda verilen mekânlardan hangisinde akustik biliminden yararlanılır?**

A) Otopark
B) Sinema Salonu
C) Alışveriş merkezi
D) Hastane

8. Fen bilimleri öğretmeni Esra, öğrencisi Eda'ya ses ile ilgili bildiklerini söylemesini istiyor. **Buna göre Eda hangisini <u>yanlış</u> söylemiştir?**

A) Sesin yayıldığı ortam değişirse sesi farklı işitiriz
B) Ses boşlukta yayılmaz.
C) Ses en iyi katı maddelerde yayılır.
D) Farklı ses kaynaklarından aynı ses duyulur.

9. Şanlıurfa Ortaokulunda okuyan bir grup öğrenci teneffüs vaktinde top oynarken bir müddet sonra ders zilinin çaldığını duyarlar. Bir önceki ders ses ve özellikleri ünitesinde ses ile ilgili bilgileri öğrenen Zeliha arkadaşlarına bir soru yöneltir. “Sizce biz ders zilini nasıl duyabiliyoruz?”

Tuncay: Hoparlörden çıkan ses doğrusal olarak yayıldığı için duyabiliyoruz.
Sıdıka: Bence ses havada (gaz maddelerde) yayıldığı için duyabiliyoruz.
İlya: Sesin dalgalar halinde titreşim hareketi yaparak yayılması ve maddesel ortam olan hava ortamında yayılmasıyla duyarız.

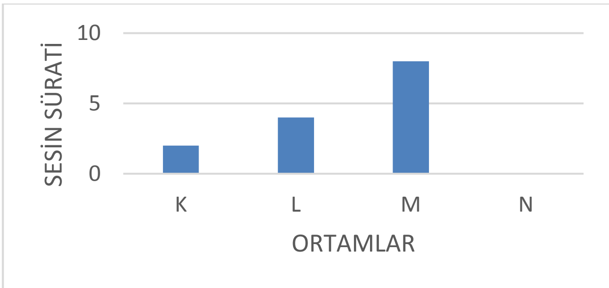
Zeliha'nın yönelttiği soruya hangisi veya hangileri doğru cevaplamıştır?

A) Yalnız Sıdıka
B) Sıdıka ve İlya
C) Tuncay ve İlya
D) Yalnız İlya

10. Sessizlik gerektiren bir ortamda (kütüphanede) olan Berat, sokaktaki iş makinelerin oluşturduğu sesin kulağına ulaşıncaya kadar sırasıyla iletildiği ortamlar hangisinde doğru verilmiştir?

A) Katı-Gaz-Sıva
B) Gaz-Katı-Gaz
C) Katı-Katı-Gaz
D) Gaz-Gaz-Katı

11.



Yukarıdaki grafikte sesin ortamlara göre sürat karşılaştırması verilmiştir. Buna göre bu ortamlardan hangisi maddesel olmayan (boşluk) ortam olabilir?
A) K
B) L
C) M
D) N

Deney	Sesin yayıldığı ortamlar	Sesin yayılmadığı ortamlar
1	Uzay boşluğu	Hava
2	İçi su dolu şişe	Havası alınmış cam fanus
3	Duvar	Uzay boşluğu
4	Havası alınmış cam fanus	Duvar

12.
Yukarıdaki tabloya bakıldığında sesin yayıldığı ve yayılmadığı bazı ortamlar verilmiştir. Buna göre numaralardan hangisi veya hangilerinde ortamlar <u>yanlış</u> eşleştirilmiştir?
A) 1 ve 4
B) Yalnız-3
C) 1 ve 2
D) Yalnız-4

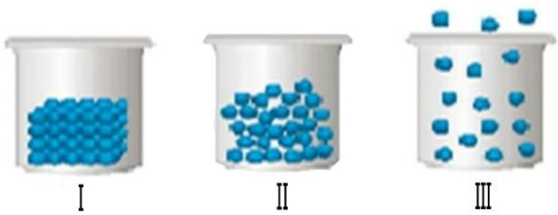
13.

Ses kaynakları değiştikçe duyulan sesin farklılaşması enstrümanın titreşen kısmının büyüklüğüne, yapıldığı maddenin cinsine, uzunluğuna, kalınlığına, gerginliğine vb. değişkenlere bağlıdır.

Yukarıdaki bilgiye göre ses ile ilgili aşağıdaki yorumlardan hangisi <u>yapılamaz</u>?

A) Enstrümanlardaki titreşen kısmın büyüklüğü sesin farklı duyulmasına neden olur.
B) Farklı sesler farklı kaynaklardan çıkar.
C) Farklı cinsteki maddeler farklı sesler çıkartır.
D) Farklı enstrümanlar havası alınmış bir ortamda farklı duyulur.

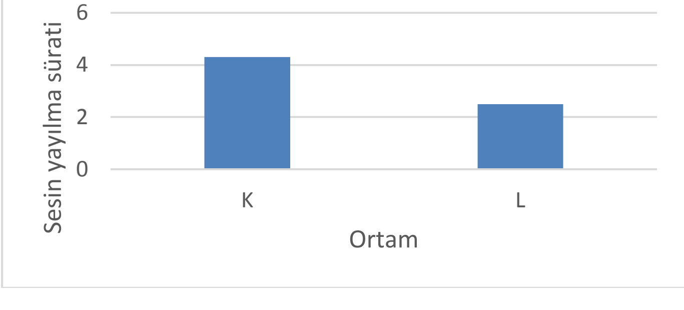
14.



Aynı ortamlarda (sıcaklıkta) olan maddelerde sesin sürat karşılaştırması nasıl olur?

A) II > I > III
B) I > II >III
C) I > III > II
D) II > III > I

15. Aşağıda sesin bazı ortamlardaki sürati ile ilgili bir grafik verilmiştir. Grafik incelendiğinde,



I. Ortam sıcaklıkları eşitken K ortamını oluşturan tanecikler arasındaki mesafe, L ortamından azdır.
II. Ortamın sıcaklıkları eşitken K ortamının yoğunluğu, L ortamından daha yoğundur.
III. Ortam sıcaklıkları eşitken K ortamındaki titreşim hareketi, L ortamından fazladır.

Yukarıdaki çıkarımlardan hangileri yapılabilir?
A) Yalnız I
B) I ve II
C) II ve III
D) I, II ve III

16. Verilen görselde Özge, karşı komşuları olan Ayşe'ye sabah ve öğle vaktinde oyun oynamak için aynı şekilde seslenmektedir.

Vakit	Sesin ulaşma süresi
Sabah	1,8 s
Öğle	1.4 s

Özge'nin sesinin Ayşe'ye ulaşma süreleri tablodaki gibi olduğuna göre aşağıdaki yorumlardan hangisi yapılamaz?
A) Özge'nin sesi öğle vakti sabah vaktine göre Ayşe'ye daha önce ulaşmıştır.
B) Ses sabah vakti daha süratlidir.
C) Hava öğle vaktinde daha sıcak olabilir.
D) Havanın öğle vaktinde yoğunluğu daha fazla olabilir.

17. Serpil, gece vakti odasının penceresinden dışarıyı seyrederken şimşek çaktıktan bir süre sonra gök gürültüsünü duyabilmiştir.

Bu olayın nedeni aşağıdakilerden hangisi olabilir?
A) Işık boşlukta yayılır.
B) Sesin yayılma sürati ışıktan fazladır.
C) Ses boşlukta yayılmaz.
D) Işığın yayılma sürati sesten fazladır.

18. Nuriye okuldaki koro gösterisi için eline aldığı mikrofonla seslendireceği şarkıyı önce **banyoda** daha sonra **boş bir odada** sonrasında da **eşyalı bir odada** söylemiştir**. Şarkı söylerken her üç ortamda da sesini ses kayıt cihazına kaydetmiştir. Buna göre Nuriye'nin şarkı söylerken ki sesinin bu üç ortamda yayılması arasındaki ilişki nasıl olabilir?**

Banyo
(I)

Boş Oda
(II)

Eşyalı Oda
(III)

A) I>II>III
B) I>III>II
C) II>III>I
D) III>I>II

19.

Pamuk

Sünger

Strafor

Yukarıda ses yalıtımını önlemek için kullanılan bazı malzemeler verilmiştir. **Ses yalıtımını önlemek için kullanılan bu malzemelerin en önemli sebebi ne olabilir?**

A) Uzun ömürlü olması
B) Sesi çok iyi iletmeleri
C) Sesi iyi soğuramamaları
D) Yumuşak ve gözenekli olmaları

20. Akustik, seslerin özelliklerini inceleyen bir bilim dalıdır.

- Gürültünün azaltılması
- Sesin dengeli dağılımı
- Sesin kulağa hoş gelecek (estetik) şekilde yayılması
- Ses yalıtımı

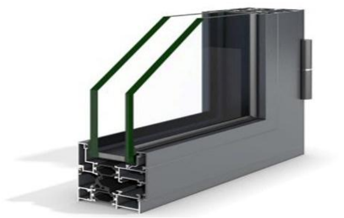
Gibi konulara akustik düzenlemeler ile çözüm bulunmaktadır. **Aşağıda verilen örneklerden hangisi akustik düzenleme <u>gerektirmez?</u>**

A) Cami
B) Konferans salonu
C) Sinema salonu
D) Banyo

21. Mustafa elindeki ses kayıt cihazıyla sokakta ve evde şarkı söyleyip daha sonra dinlemek için kaydediyor. **Buna göre Mustafa'nın sesleri kaydetmesinin amacı aşağıdakilerden hangisi ile açıklanır?**

A) Sesin soğurulmadığını ispatlamak
B) Sesin boşlukta yayılmadığını ispatlamak
C) Aynı ortamlardaki farklı kaynaklardan farklı ses çıktığını ispatlamak
D) Aynı ses kaynağından çıkan sesin farklı ortamlarda farklı duyulduğunu ispatlamak

22. "Çift cam teknolojisi: İki camın kenarlarına fitil koyup birbirine yapıştırılmasıyla elde edilen hem ısı hem ses iletimini oldukça azaltan bir teknolojidir."



Camlar birbirine yapıştırılırken camlar arasına Argon (Ar) gazı doldurularak işlem yapılır.

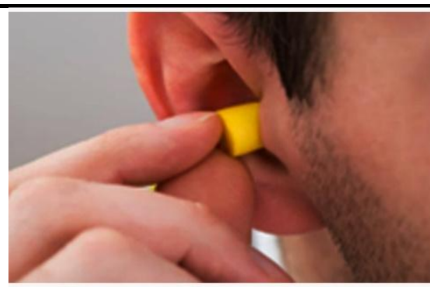
Buna göre camların arasına Argon gazı doldurulmasının sebebi aşağıdakilerden hangisi ile açıklanabilir?

A) Gazların hem sesi hem ısıyı daha iyi iletmesi
B) Gazların ses iletimini katı ve sıvılara göre daha az iletilmesi
C) Sıvıların ses iletiminin gazlardan daha iyi olması
D) Gazların sesi sıvılara göre daha fazla yansıtması

23.

Çalıştığı iş yerinde yüksek ses şiddetine maruz kalan Mehmet Bey yüksek sesin baş ağrısı yapması sebebiyle görseldeki gibi kulak tıkaçları takmıştır. Buna göre Mehmet Bey'in kullandığı kulak tıkacı ile ilgili;

I. Sesi yansıtmalıdır
II. Sesi soğurmalıdır
III. Dış ortamlardaki sesleri daha iyi kulağına aktarmalıdır
IV. Yumuşak ve gözenekli yapıda olmalıdır



Yorumlarından hangileri yapılabilir?

A) Yalnız I
B) II ve IV
C) I, II ve III
D) I ve III

24. Aşağıdaki ortamların hangisinde sesin yayılma hızı en yavaştır?

A) Hava **B)** Zeytinyağı **C)** Bakır **D)** Tahta

25. Ses dalgasının çarptığı ortamda enerjisini kaybetmesine ve bunun sonucunda yayılamamasına soğurulma denir. Yumuşak ve gözenekli malzemeler, sert ve pürüzsüz malzemelere göre sesi daha iyi soğurur. **Buna göre sesi soğurma amaçlı,**

I. Sünger
II. Tahta
III. Demir

Malzemelerinden hangileri kullanılabilir?

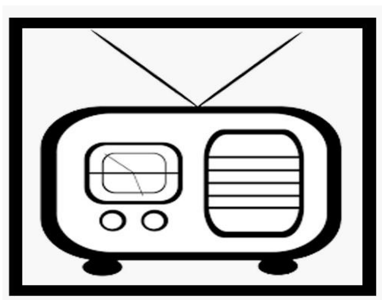
A) Yalnız I **B)** I ve II **C)** II ve III **D)** I, II ve III

26.

Şekildeki tokmakla defe vurulduğunda, diğer defin arkasındaki asılı olan iki küçük topun hareket edildiği görülüyor.

Yapılan bu gözleme göre aşağıdakilerden hangisine ulaşılabilir?
A) Ses bir enerji türüdür.
B) Ses dalgalar halinde yayılır.
C) Ses, gazlarda çok hızlı yayılır.
D) Ses boşlukta yayılamaz.

27.



Kadriye, yukarıdaki gibi radyo ve kutu kullanarak bir düzenek hazırlıyor. Kadriye kutuyu **aşağıdaki malzemelerin hangisiyle kaplarsa radyonun sesini diğerlerine göre daha fazla duyar?**

A) Kâğıt **B)** Pamuk **C)** Demir **D)** Tahta

ORIGINAL ARTICLE

A Case Study of the Efficacy of Group Sandplay Therapy in Improving Parent-Child Relationships

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Abstract: *Group sandplay therapy is a useful instrument for healing family rifts. This article is a case study where the group sandplay therapy method was used to address the client's conflicts with his family members. The therapy outcomes show that group sandplay therapy is efficacious in enhancing communication and interaction between family members, improving interpersonal relationships within a family, particularly the parent-child relationship, and alleviating parent-child tensions as barriers to effective home education.*

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Keywords: *Group Sandplay Therapy, Sandplay Therapy, Parent-Child Relationship*

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AI Declaration: *The author affirms that artificial intelligence did not contribute to the process of preparing the work.*

SANDPLAY THERAPY (SPT) is a method of psychotherapy in which the client is free to choose toys from a toy rack and uses a special tray filled with fine-grained sand to build a representation of their inner world in the presence of the therapist (Zhang, 2006). The efficacy of SPT in correcting psychological and behavioral abnormalities in children has been well acknowledged (Wu, 2022). Individual SPT and group SPT are the two forms of SPT. In group SPT (also referred to as restrictive group SPT), a group of people (often four to eight people) share a sand tray and a set of toys and perform the play according to prescribed rules (Wei, 2020). Group sandplay can exert therapeutic effects on both the group and individuals by affecting the interpersonal relationships between group members as well as the notions, emotions, and behavior of individuals within the group. Its therapeutic effectiveness has been validated by research (Zhang, 2006). Family SPT is a special application area of Group SPT (Xu & Zhang, 2007). This article is a case study of the efficacy of group SPT for a family with an eight-year-old boy who was experiencing school entry anxiety and being plagued by abnormal parent-child relationships. The family received six consecutive sessions of SPT, and the differences in their emotions, behaviors, and parent-child relationships before and after therapy were evaluated.

Background Information on the Case

Demographic Information of the Client

B, the client, was an eight-year-old boy of Zhuang nationality and a first grader at a primary school. He shared a home with his parents and a four-year-old younger sister, S. B’s parents were both ordinary full-time office workers. In the past six months, B’s mother, M, has been on frequent business trips. The economic status of the family (L) was at the average level in China. There was no history of major physical and mental illnesses or personality disorders in the family.

Behavioral Problems of the Client

B exhibited certain separation anxiety symptoms when he started his primary school attendance. His abnormalities include lingering in bed in the morning, refusing to go to school using paid transit service but insisting his father (F) drive him to school, repeating “I don’t want to go to school” as his most frequent topic, showing extreme aversion to school attendance, being unable to listen attentively at class, and particularly having difficulties with his Chinese language lessons, ranking the last in the first few unit quizzes. B's parents were deeply worried about his performance and signed him up for the after-school tutoring class, which resulted in his spending two extra hours at school. B was extremely unhappy about this arrangement, but his parents forced him to carry on with the tutoring class. After coming back home, B had to review his lessons under the supervision of M. B dallied on purpose and could not finish the task until 11 p.m. on most school days. Delaying and replying defiantly were B's frequent reactions to his parents' requirements.

Pre-Therapy Psychological Evaluation

The Psychological State of the Client

The client, B, was physically healthy with intellectual, emotional, and behavioral development levels consistent with his age. His low spirits and anxiety were triggered by his primary school attendance, but this is not yet a generalized issue. His social functioning remained basically normal. B's behavioral deviations were rooted in his current problematic relationship with his parents. The parent-child relationship is the most influential factor for a child's development in the home setting, posing direct impacts on the development of their social and psychological competence.

Evaluation of Parent-Child Relationships in Family L

A Negative Parent-Child Relationship

From the interviews with the family members, it was found that the parents often ignore, disregard, or distrust their children's words. This was particularly evidenced by the interaction between B and his parents: The father ignored B's request for not attending school or after-school tutoring altogether as if he had never heard of it, with the belief that B would adapt naturally to school after a certain period of time; the mother, on the other hand, insisted that B should study harder, disregarding his emotional needs and failing to provide emotional support in a timely manner.

Frequent Parent-Child Conflicts

There could be three or four parent-child conflicts every day in Family L. The parents' irresponsible behaviors towards their children included intimidation, being overly harsh, corporal punishment, and verbal abuse, among others. B felt awful about his life: "It is not fun attending the school. Neither the teachers nor classmates are nice. My parents are even worse. You have to get to school early in the morning and come home late in the afternoon with a lot of homework. My parents are very cruel to me, often yelling at me and sometimes even beating me." At the same time, the parents complained that

B dallied on purpose while doing homework or stopped to play games before finishing it off, which really drove them mad.

Poor Parent-Child Communication

Despite their natural love for the kids, the parents often treated them in a harsh or coercive manner and disciplined them through dictation or prohibition. In B's eyes, his dad was always busy, working overtime on weekends, and never caring about his schoolwork. On the contrary, his mom was deeply concerned about his school performance but never satisfied with his test grades, especially those of Chinese; he was not allowed to spend time playing after the primary school enrolment. On the other hand, the parents thought that B had poor learning habits, resulting in low learning efficiency. He could not finish his day until 12 p.m. every night but had to wake up at 6:30 a.m. in the morning to go to school on time. Inadequate sleep was detrimental to his growth and study. They could not help but resort to dictation or coercion when reasoning with him did not work.

The Intervention Process

Given B's emotional and behavioral issues and the less-ideal parent-child relationship in B's family, the therapist chose to administer group SPT to Family L. The therapy scheme included six sessions for six weeks (one session scheduled for each week). During the SPT time, B continued to attend school but did not receive any other therapy.

The First Session

The Therapy Process

This was Family L's first access to SPT. The therapist allowed them time to play with the sand and perceive its touch. The family showed tremendous interest in sandplay, particularly the two kids, who could not wait to play with the sand tray. The therapist gave them a few minutes of group SPT orientation, including the roles of the therapy, its purposes and objectives, and the rules for its execution. The order of turns in conducting sandplay was determined by lot-drawing, which turned out to be in the sequence of B-M-S-F and was agreed upon by all of them.

To start with, B spaced out 10 balls along the edges of the sand tray. After that, M placed four coconut trees on the right side of the sand tray, S put six marine animals (starfish, squids, and whales) in the upper portion of the tray, and F laid a motorcycle next to the whales. Five more rounds of manipulation in the same sequence (B-M-S-F) followed. In this first trial of sandplay, they all had a lot to express with the toys, especially the kids, who wanted to handle as many toys as possible in each round. When the session terminated, the kids felt like playing more but had to give up because the tray was full. The family agreed to dub this sand tray picture “A Wonderful World” after discussion.

The Therapist’s Observation

During the therapy, each family member paid little attention to other ones, and there was no effective parent-child interaction; everybody concentrated on filling the sand tray with their own favorite toys. There were overt conflicts between them, particularly between B and his sister, S. For instance, when S laid out a handful of marine animals on the beach, B did not like the arrangement because he thought they could not survive without staying in the water. However, S refused to compromise on her idea, and B stuck to his belief that aggressive land animals like dinosaurs were better options.

The Second Session

The Therapy Process

Because of the disruption caused by the holiday season in early October, the second session did not take place until nine days later. The therapist reiterated the rules for the therapy, and the sequence was redefined as B-S-F-M after the second lot-drawing. In the first round of operation, a lawn was placed in the upper right corner of the tray by B, a colosseum in the left of its middle portion by S, and a Kungfu panda next to the colosseum by F, followed by a small lake dug by M in the center of the upper portion of the tray. At the request of the kids, the number of rounds was increased to eight for this session. In the discussion period after completing the miniature work, family members shared their intentions for the choice of toys and their perceptions of the choice of other members. This time, all family members agreed to name it “A Shared Community.”

The Therapist’s Observation

In the second session, all participants selected quite a few toys different from those used in the first session. The attention paid to each other remained little. Nevertheless, no obvious conflicts occurred during the sandplay. A few simple parent-child interactions occurred with one between B and M (B placed a small rainbow in the lake dug by M), one between S and M (S put two boats in the lake), one between F and S (F placed a Kungfu panda next to the colosseum set by S), two between B and F (B set up the national flag in front of the Tiananmen Square erected by F and put a smaller rainbow in the middle of the larger one added by F), and one between B and S (B grilled the fish on S's stove).

The Third Session

The Therapy Process

All participants had come to a satisfactory understanding of the therapy's procedures by the third session. The third session of sandplay ran in the order of B-S-F-M.

Discussion and Observation

There were serious conflicts between participants in this session. The crocodiles, seals, bears, and other beasts of prey in the sand tray posed a serious threat to S's sphere. S was desperate to protect her area by enclosing it to the right of the sand tray. B attempted to communicate with S and placed three bridges behind the fences. However, S reinforced her defense by deploying more mountains, fences, and the bird-nest-like stadium. M tried to get connected to B's world by planting pine trees and lotus flowers there. The therapist asked B, "Does the crocodile prey on humans?" "Yes" "Then why did you put so many beasts of prey there?" "For fights." "Did you win?" "No." "Are there any alternative solutions to conflicts apart from fighting?" At this point, B was brought into deep contemplation. In addition, the sand tray picture also showed some traces of conflict between B and F: B's Ultraman approached F's soldier, attempting to kill him.

In the fourth round of sandplay, something more dramatic happened. S took the cat away from the shell where it had stayed with the mermaid and placed it inside the bird nest-like stadium, which aroused strong opposition from B. Yet S had no intention of giving in. The therapist did not intervene immediately but waited and observed the parents' reactions. It turned out that the father had no idea what to do while the mother was trying to calm down the boy. The mother, then, asked the father to bring the girl back to the sand tray and coaxed her into completing the play. Finally, with the therapist's consent, the cat was placed in the bird-nest-like stadium. The therapist asked S, "Why did you want to move the cat?" "Because it's my favorite." "Isn't it safer for it to stay with the mermaid?" "No, it's not safe there. The cat should stay in the bird nest-like stadium." "Okay, let all of us protect it. Do you feel like carrying on with the play?" "Sure." During the negotiation process, the father and mother became aware of the parent-child communication issue that existed in their home education. In the end, the family reached an agreement to name this sand tray picture "War and Peace."

The Fourth Session

The Therapy Process

The fourth session was played out in nine rounds in the sequence of M-S-B-F.

Discussion and Observation

In the conversation about their sand tray picture, B expressed his dissatisfaction with the layout and removed the helicopter from the top of the office building, but later put it back. This indicated that B wanted to break free from F's control but recognized the limitations of his own power. F wanted to pull the small house out of the sand, but S stopped him, warning, "Don't touch my house!" This was a signal of S's strong awareness of boundaries. M and F interacted affectionately, working together to build a home in the upper left corner of the tray, which was full of joyful and warm atmospheres. No significant confrontations arose between the family members in this session. Neither did they occur in the following sessions. This time, the miniature work in the sand tray was named "Free from Worries."

The Fifth Session

The Therapy Process

Due to M's business trip to Thailand, the fifth session was postponed until three weeks later. The therapist repeated briefly the instructions, and Family L conducted the operation in the sequence of B-S-F-M based on the results of the "rock-paper-scissors" game. They created a harmonious image and dubbed it "A Beautiful Memory."

The Therapist's Observation

This session was a fun experience for the family. M's last trip to Thailand, where the Buddhist tradition is prevalent and elephants and tigers are common, gave the sandplay an exotic touch. The sand tray layout showed no signs of confrontation. Instead, parent-child interactions significantly increased. B laid F's high-speed train on the railway track; B's jet was placed next to F's passenger plane; M planted trees in front of B's buildings, such as the police office; S was in a good mood and initiated quite a few conversations with F and M. There was no conflict between B and S, either. S put M's strawberry on her table. B built a home with four family members, among which the parents stayed together, but the older brother and his younger sister kept a certain distance between them, concentrating on what they liked to do without any mutual interference.

The Sixth Session

The Therapy Process

The last session was one week behind the schedule because of the kids' school weekend activities. It was played out in the order of B-S-F-M.

Discussion and Observation

All participants were in high spirits and felt pleased with the last miniature work. They gave positive comments to each other's contributions to the work and saw every toy as integral and representative of their real intentions. The honing of relationships in the previous five sessions resulted in more tacit interaction between the family members and increased their attention to each other's needs. The sand tray model showcased preliminary integration, marked by common goals and signs of joint efforts. The last sand tray image was named "A Spiritual Paradise."

The Efficacy of the Intervention

Participants' Self-Evaluation

F, the father, reported that after the six sessions of therapy, B's perception of school attendance changed. B no longer talked about his unwillingness to go to school but was still resistant to the after-school tutoring. He was able to get up on time for morning calls and would not cry after leaving home. He could now listen rationally to F. M, the mother, said that B's defiant behavior had substantially lessened. B could now better understand his parents' expectations of him. Despite his occasional delays, he could follow his parents' instructions according to their timely prompts. Meanwhile, F and M were now less focused on B's academic results but more on his personal thoughts and needs, giving him more understanding and spiritual comfort. Yelling and screaming gave way to decent conversations in their home. B, the client, reported that he was not afraid of school attendance any more now that teachers' lectures had become comprehensible and his parents' attitudes towards him had changed.

The Therapist's Evaluation

The follow-up interviews confirmed that the intervention had reached its expected objectives. First off, parent-child conflicts have been substantially reduced in Family L. The parents could regulate their emotions better than before, keeping their temper with the kids when the latter misbehaved. They could listen calmly to B’s explanation for his dislike of attending school and help him with his homework when necessary. The frequency of the parents yelling at B has considerably decreased. As a result, the parent-child tensions in Family L have significantly eased. The parents could now rationally communicate with B about his day-to-day school experiences and the progression of his schoolwork, as well as possible challenges that might necessitate their help. B could now confide in his parents his concerns about the current transitional period and feel free to talk through with them his perceptions of teachers, classmates, and after-school services. Most importantly, group SPT successfully helped B to release his anxiety caused by the school transition and to get psychologically ready for full engagement in the new educational setting.

Others’ Evaluation

According to B’s class teacher, B, after the therapy, stopped asking her repeatedly when he would be dismissed and go home, as he had done before. He was now attentive in class and willing to help teachers and the class with all sorts of chores. His average academic level remained around B+.

Conclusion and Reflections

The therapeutic outcomes of Family L demonstrate that group SPT has significant positive effects on improving parent-child relationships in a family. The case in discussion also shows that the family needs to go through four stages in group SPT to reach mutual understanding and harmony between family members.

Stage One: Self-Concentration

In the first two sessions of SPT, there were few associations between discrete scenes in the sand tray, and the arrangement of toys was in a disorganized state. The dynamics in the sand tray were inconsistent in direction, and the picture showed a lack of cohesion and shared motivation among its creators. The reason was that there was little interaction among the family members; each of them was self-centered, concentrating on their own feelings and thoughts.

Stage Two: Paying Attention to One Another

Following the initial sandplay experiences, explicit conflicts emerged between S and B, mainly due to their stubbornness and zero-compromise mentality, resulting in both being dissatisfied with the final work. The conflicts between the parents and children, particularly between B and F, were also manifested in the sand tray image. The therapist intervened and skillfully mediated conflicts to moderate parent-child and inter-sibling relationships.

Stage Three: Communication and Mutual Understanding

With increased confrontations and conversations in sandplay, the family members had more effective communication by candidly representing their thoughts and feelings, as well as their expectations of each other. Although there remained disputes due to disagreements between participants, they were all minor. Reconciliation could be reached through communication with patience and reasonable guidance from the parents.

Stage Four: Adjustment and Integration

After the processes of self-concentration, paying attention to others, communication, and mutual understanding, the family members deepened their comprehension of each other and learned to think from different perspectives. A more tacit relationship was developed, enabling them to create a sand tray miniature work with enhanced integrity, increased associations, and an explicit, uniform theme.

To sum up, group SPT assists the client in establishing connections with their family, consciously and unconsciously, in relaxed, safe, and resistance-relief atmospheres (Wei, 2020). It is also effective in encouraging self-exploration and self-conception in family members. Thus, group SPT has the potential to help foster healthy family relationships by promoting positive communication and other healthy interaction patterns between parents and children, supporting participants in taking on normal roles in the family, and highlighting the importance of harmonious development of the mental health of individuals as family members.

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REVIEW

The Construction and Application of Smart Classrooms in China: A Literature Review Based on 93 Studies

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***Abstract**: The smart classroom, as a product of advances in information technology, has garnered wide attention in academia in recent years. Using the method of literature review, this article delves into the construction and application of smart classrooms in China on the basis of 93 prior studies retrieved from the database of the China National Knowledge Infrastructure. Research results show that there is a lack of uniform evaluation criteria for the construction of smart classrooms despite the prominent advancements in their systems and facilities, and that in the dimension of applications, there has been growing interest in the alignment between smart classroom technologies and instructional needs but a dearth of research on teaching activity design for smart classroom instruction. Recommendations are also proposed based on the issues detected, with a view to contributing to the widespread deployment and ongoing optimization of smart classrooms.*

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Introduction

BASED ON the development of information technology (IT), including the internet, the Internet of Things, cloud computing, and big data, the smart classroom integrates physical and virtual spaces with the potential of creating interaction-reinforcing teaching and learning environments, providing individualized services for teachers and students, and realizing intelligent classroom management (Cheng, 2015). In a smart classroom, the combination of technologies and teaching elements, such as instructional strategies and models, can significantly enhance the teacher's instructional standards and students' learning experience (Dimitriadou & Lanitis, 2023).

In the past decade, smart classrooms have garnered increasing attention in the Chinese education community; educational institutions at all levels in China have made serious investment in smart classroom development and achieved considerable outcomes. As a result of the extensive application of artificial intelligence, big data, and other cutting-edge technologies, the digital transformation of education has become an inevitable trend in educational development and reform. In this context, it is foreseeable that the smart classroom will undergo greater development. How to leverage smart classrooms to meet the needs of digital education, improve the quality of education, promote educational equity, and nurture new-generation talent has become a vital research topic in academia (Li, 2024).

Recently, smart classroom research has proliferated both in China and abroad. Prior literature reviews have focused on the technological frameworks and features of the smart classroom rather than on the specific construction and application processes. For instance, Saini and Goel (2019) reviewed the use of various technologies and facilities in smart classrooms and identified in the literature four major facets of teaching and learning experience related to them: smart content, smart interaction, smart assessment, and smart physical environment. Cheng et al. (2024) introduced the conceptual framework of the smart classroom by describing its "smart" nature in five aspects: physical environment and spatial arrangement; content presentation and resource sharing; classroom interaction and feedback; perception and recognition of student learning engagement; and instructional evaluation and management. Despite many reviews like these on the technological characteristics of smart classrooms and the specific technologies involved, there are few surveys on their construction and application processes. In light of this, the present study focuses on presenting the current state of the construction and application of the smart classroom in China by reviewing the published research findings, pinpointing issues arising in the said processes, and proposing targeted suggestions with the intent of contributing to the ongoing enhancement of small classrooms in the digital transformation of Chinese education.

Research Design

Research Questions

(i) What is the status quo of the construction of smart classrooms in China?
(ii) What is the current state of the application of the smart classroom in China?
(iii) What are the application outcomes of smart classrooms?

Research Methodology and Process

This study is a literature review, sourcing literature from the China National Knowledge Infrastructure (CNKI), an authoritative database in China. With the assistance of CKNI's professional retrieval feature, the search was conducted using "smart classroom" and "smart teaching environment" as subject terms coupled with words like "construction," "design," "application," and "outcomes." To ensure the academic quality of the included literature and its relevance to the research questions, only articles written in Chinese and published by journals listed in "A Guide to the Core Journals of China" and the Chinese Social Science Citation Index were included in the screening process. To make the search as thorough as possible, there were no time limits set for the publications. By the deadline of June 5th, 2024, 245 articles had been obtained, among which 93 were identified as valid after removing duplicate and irrelevant studies. Rayyan, a systematic review tool, was adopted in the analysis of the 93 articles (Yu et al., 2022).

The Status Quo of Small Classroom Construction in China

Among the 93 articles included in the literature review, 42 address the design and construction of the smart classroom. We can draw from them information on the definition, system architecture, technologies, and evaluation of the smart classroom.

The Definition and Features of the Smart Classroom

In China, Huang et al. (2012) first defined the smart classroom as a new type of classroom with the capacity for intelligent perception of situations and management of environments, aiming to facilitate the presentation of teaching materials, the acquisition of instructional resources, and in-class interaction. Nie et al. (2013) argued that the smart classroom is a fresh modality of classroom powered by emerging digital technologies, which conflates the physical classroom space with all relevant software and hardware equipment to provide intelligent application services for teaching activities. Based on the analysis of prior studies from China and other countries, Zhang et al. (2014) conceptualized the smart classroom as an intelligent learning setting built on universal computing technologies, the Internet of Things (IoT), cloud computing, and artificial intelligence and highlighted its essential components as intelligent physical and interpersonal spaces, learning instruments, and support for interactions between classroom actors. Amid the advancement of technology and education concepts, researchers have also upgraded their understanding of the smart classroom. Jin and Zhang (2019) described the smart classroom as a combination of “physical space, resource space, and community space” based on the technologies of IoT, big data analytics, and cloud computing, which contribute to the intelligent management of classroom facilities, intelligent enactment of teaching activities, complete recording of the instructional process, diversification of teaching patterns, and big data-supported instructional evaluation and diagnosis.

In addition, researchers have attempted to generalize the features of the smart classroom. To summarize the characteristics of the smart classroom, Huang et al. (2012) advanced the model of "SMART," which stands for “showing” (content presentation), “manageable” (learning environment management), “accessible” (education resource acquisition), “real-time interactive” (instant interaction), and “testing” (situational perception). Nie et al. (2013) proposed the “iSMART” model to incorporate "infrastructure," network “sensors," visual “management," “augmented” reality, real-time “recording,” and ubiquitous “technology.” Wu et al. (2020) argued that the smart classroom is distinguished by four features: integrating technologies, promoting adaptive learning, transforming classroom structure, and supporting personalized learning. According to Cheng (2015–2016), a smart classroom is expected to include as its basic components: multimedia-based teaching materials, resource sharing, diverse teaching modalities, personalized learning, collaborative activities, ubiquitous network connections, intelligent management, and a user-friendly environment. A portion of researchers claimed that the features of the smart classroom are determined by key factors like the digital environment, technology, and resources (Wang & Jiang, 2014; Zhang & Yang, 2018). On the basis of their theoretical and practical explorations, Liu et al. (2023) characterized the functions of the smart classroom as supporting smart teaching, learning, evaluation, management, and research in an educational setting and highlighted five essential elements in the structural model they proposed: physical and virtual environments; content and resources; teaching and learning interaction; assessment and evaluation; and data governance.

The literature review demonstrates that technology, management, resource service, and support for teaching and learning are the key terms in popular concepts of the smart classroom. In this study, we define the smart classroom as a new paradigm of classroom that leverages plural information technologies to enhance teaching environments, equipment, and activities, facilitate the presentation and sharing of teaching resources, and support intelligent teaching and learning. As a state-of-the-art educational practice, the smart classroom is not only about the adoption of cutting-edge technologies but, more importantly, about the innovation of instructional models and evaluation methods.

The Smart Classroom Architecture and Technologies

There are primarily three approaches to the architecture of the smart classroom system in the existing literature. The first approach is to design the system based on the established smart class models or frameworks (He & Huang, 2018; Cui et al., 2020; Cheng, 2021; Zhou et al., 2022). For example, Liu et al. (2018) utilized Huang et al.'s (2012) "SMART" model as a framework of reference in formulating their smart classroom system; Hu and Wang (2018) consulted the smart class learning experience theory and focused on the three core dimensions of learning space, information technology, and instructional methods in the construction of a smart classroom system. The second approach is based on the hierarchical structure of the IoT from a technological standpoint (Chen & Xu, 2014; Yan & Gui, 2016; Zhou, 2018). Guo et al. (2013), for instance, developed a smart classroom system with four layers: hardware, virtual reality, education service, and external cloud service, drawing on the three-layer structure of the IoT marked by the perception, transmission, and application layers. The third approach is based on consideration of the needs of practical teaching manipulation (Shi, 2017; Zhang et al., 2018). Xu et al. (2023), for example, argued that a smart classroom system should include four levels: environmental convergence, teaching-learning interaction, quality management, and equipment operation and maintenance, to meet the requirements of actual teaching scenarios.

To realize its projected multi-dimensional functions, builders of the smart classroom have adopted a wide variety of technologies and devices. For example, IoT technology has been heavily used in smart classrooms to economize on resources and manpower and increase the efficiency of equipment management (Wang & He, 2021; Li et al., 2022). The use of IoT significantly improves the interconnectivity between various devices in the classroom, providing real-time feedback on their running status and automating the adjustment of the classroom environment. To make classroom management, including attendance taking, more intelligent and efficient, AI-assisted image recognition technology and electronic class badge technology have been widely adopted (Hu et al., 2018). These technologies can automate the recognition of student identities and the recording of their class attendance, simplifying management processes (An et al., 2017). Also, smart blackboards, virtual desktops, 4K recording technology, online class oversight mechanisms, and normalized recording systems have become integral technological components of the smart classroom, which have greatly facilitated the preparation, presentation, and sharing of teaching materials (Yu & Liu, 2017; Liu & Qian, 2019; Hu et al., 2019). Technologies and techniques like these have enabled instructors to present teaching content more intuitively to students while encouraging shared management of teaching resources between teachers and students. Furthermore, in order to promote teacher-student, inter-student, and human-machine interaction, devices and technologies, such as video conferencing software, interactive electronic whiteboards, real-time response systems, and sound reinforcement systems, have been widely employed (Wang et al., 2015; Xie et al., 2018; Cui et al., 2020), to enrich means of teacher-student interaction. In addition, to support instructional assessment, intelligent technologies, such as voiceprint recognition, electronic examination rooms, and learning analytics, have also been incorporated into the technical architecture of smart classrooms (Pan et al., 2018). With these technologies, the teacher can discern students' learning progression in real-time, adjust instruction strategies in a timely manner, and improve their teaching efficacy.

Meanwhile, builders of smart classrooms have harnessed a wide range of technologies to meet the diverse needs of different learners. For example, mobile internet technology and mobile terminal applications are incorporated to support students' mobile learning, making learning less subject to temporal and spatial constraints (Zhu et al., 2018). Technologies such as cloud computing and big data have been used in the smart class to analyze students' learning data to enable teachers to provide tailored teaching to them (Yu et al., 2020). Also, virtual reality and cloud rendering AR/VR have been applied to smart teaching to suit the learning styles of different student groups (Tang et al., 2021). Additionally, research has paid attention to the role of wearable technology in the education of persons with special needs as well as the training of special majors in that it helps individualize teaching for the special education group and enables teaching practices in special major training to be carried out in a safer manner (Liu et al., 2016).

Our survey suggests that there is a lack of uniform standards for the architecture of the smart classroom due to the variations in its definition, which is unfavorable for its popularization. It also finds that smart classroom builders in China place a biased emphasis on the potent functions of the chosen technologies and devices over the actual needs of classroom instruction.

Moreover, they have a strong preference for cutting-edge technologies in structuring the smart classroom system without paying proper regard to the importance of infrastructure and basic facilities.

The Evaluation and Optimization of the Smart Classroom

The lack of a conclusive definition and uniform architecture of the smart classroom has resulted in a dearth of standardized evaluation criteria. Certain researchers evaluated the smart classroom's effects according to students' learning experiences. Sun and Tang (2019), for instance, sought to assess the effectiveness of a smart classroom in five dimensions: the learning activity, physical environment, resource acquisition, teaching-learning interaction, and content presentation, drawing on the learning experience scale developed by Hu et al. (2016). For smart classrooms built on the IoT, Liu and Chen (2020) proposed a full lifecycle costs-based evaluation method to examine the advantages and disadvantages of various smart classroom design schemes from the aspects of network topology, fixed costs, operating costs, maintenance costs, failure costs, and component abandonment costs. Referring to the "Guidelines for the Construction of Smart Classrooms in Primary and Secondary Schools in Guangdong Province (Trial)," Yin et al. (2020) developed an evaluation framework consisting of seven indicators: infrastructure; environment and layout; intelligent recording and broadcasting; teaching and resource platforms; intelligent regulation and sensor systems; software and hardware tools and mobile terminals; and training programs. In addition, some studies came up with optimization strategies for the sustainable operation of smart classrooms. Shao et al. (2023), for example, recommended creating an integrative management platform to improve the efficiency and quality of the operation and maintenance of smart classrooms. They explored ways to achieve centralized monitoring, prompt reaction, and efficient management of smart classrooms by integrating various operation and maintenance management instruments and technologies.

Our review finds that there are relatively few studies on smart classroom evaluation in China. Nevertheless, given the huge investment that a smart classroom demands, an effective evaluation framework is conducive to the supervision of its construction process and the legitimate utilization of education resources. Therefore, more research is needed in this regard in order to produce more scientific evaluation standards and efficacious optimization strategies to ensure the sustainable development of smart classrooms.

The Application of the Smart Classroom in Chinese Education

Fifty-one studies included in the literature review are dedicated to research into the application of the smart classroom in Chinese education. On the basis of these studies, we seek to give an overview of the application of the smart classroom in China, examine the effects of the integration of the smart classroom with various teaching modalities as well as its impacts on the teaching and learning processes, and summarize the factors affecting its use in the current Chinese education settings.

A Brief Overview of the Application of the Smart Classroom in China

Currently, the smart classroom has been applied in all education levels, from basic to tertiary, and in a wide range of disciplines in the domains of humanities, social sciences, and natural sciences. The practical purposes of the smart classroom are primarily two-fold: (1) to be coupled with established teaching models to augment education effects. For instance, Chai et al. (2022) combined the smart classroom with the hybrid teaching model and explored the benefits of the combination for optimizing students' learning experiences. (2) to provide support and services for every step of the instructional process. For example, Zhang (2015) examined the roles of the smart classroom in enhancing teachers' instructional strategies, increasing students' deep learning, and improving classroom outcomes through learning analytics. In their investigations of the smart classroom's applications, researchers have shown considerable interest in the teaching-learning interactions in a smart teaching environment. Some researchers have looked into the attitudes of teachers and students towards the smart classroom and the factors affecting their readiness and behavior in its use (Li, 2015). Thorough exploration of these factors is conducive to the further popularization of smart classrooms.

Different from the aforementioned studies on the construction of the smart classroom, which focus on emerging technologies and their possible usage for smart instruction, research on the application of the smart classroom concentrates more on the alignment between technologies and instructional needs while also paying attention to the novelty of technologies and their special features.

The Effects of the Integration of the Smart Classroom and Various Instructional Models

Existing research has explored the effects of the combination of the smart classroom and established teaching modalities such as the blended learning model, the APT (Assessment, Pedagogy, Technology) teaching model, the flipped classroom, and the cooperative learning model. According to Cheng et al. (2021), the practice of blended learning in a smart classroom can boost students' self-directed learning and teamwork abilities by converging online and offline learning spaces and leveraging the interaction between learning methods, evaluation, and reflection. Wen et al. (2022) argued that the smart classroom contributes to customizing teaching in the implementation of online and offline hybrid learning by providing timely, precise, and individualized data. As per Zhang et al. (2017), the APT teaching model can maximize the smart classroom's outcomes as an intelligent education environment distinguished by connectivity, interactivity, and mobility, significantly enhancing students' inquiry ability and metacognitive level. Zhang et al. (2018b) argued that the APT teaching model in a smart learning environment helps heighten students' problem-solving awareness and skills and foster their innovation and critical thinking abilities. In the flipped classroom model supported by smart classroom technologies, the latter's instant feedback system enables the teacher to follow students' learning progression in real time while also instigating active engagement in learning in students (Shi et al., 2019). In his investigation of the effect of the smart classroom on junior secondary physics education based on the "teacher-led, student-centered" instruction pattern, Xue (2014) discovered that the smart class's learning analytics could assist students in diagnosing their inadequacies and remedying them in a prompt manner and that, as a result, students in a smart classroom tend to exhibit higher levels of concentration and agency. In addition, research also shows that smart classroom instruments and technologies have positive effects on the traditional teaching style. For instance, the smart classroom's electronic writing board can make lecture-based teaching more efficient; its multi-screen display system can make teacher demonstration-based instruction more intuitive, thereby increasing the efficacy of traditional teaching practices (Lyu et al., 2019).

On the other hand, research on the effects of the smart classroom on cooperative learning is far from conclusive. Some researchers asserted that the smart classroom could provide strong technical support for students' collaborative learning and was effective in enhancing their agency and engagement in collaborative activities (Xu et al., 2017; Zhou et al., 2018). Others argued that smart classroom technologies had only slight boosting effects on the overall process of cooperative learning with no significant advantages in this regard, despite there being a moderate increase in student interactive behavior in group study in a smart classroom compared with an ordinary one (He et al., 2017; He et al., 2018a; He et al., 2018b; He et al., 2018c). The variations in research findings can be the result of differences in research methods, variables, and data processing tools. Wang et al. (2015) and (2016) sought to examine the said divide from a differential perspective, pointing out that mere changes in the use of a certain technology or device could disrupt the functioning of other technologies employed. This implies that, in a sophisticated smart teaching environment, minor changes in the use of technology may pose a significant impact on the overall teaching outcomes. The high interdependence between smart classroom technologies demands that teachers should not only be proficient in using each separate technology but also be aware of the mutual influences between them.

The Impacts of the Smart Classroom on Class Enactment

First off, the smart classroom has a positive impact on teachers' instruction by providing multi-faceted intelligent support and services. Specifically, the flexibility of the smart space gives teachers a super creative experience in the teaching process; intelligent data management is beneficial for the formation of an individualized and flattened teaching environment, generating numerous opportunities for teachers' innovation in teaching methods (Li, 2015). The ongoing application of smart classroom technologies can substantially enhance the teacher's digital competence while optimizing their instruction (Li et al., 2024). Also, in teacher training on the use of the smart classroom, the demonstration of leading teachers can effectively motivate ordinary teachers to further bolster their teaching techniques (Zhang, 2015). At the same time, some studies emphasize that the majority of teachers need to change their teaching styles and increase their capability of manipulating the smart class to realize its teaching-enhancement effects (Mao et al., 2018). Jiang et al. (2019) noted that the current readiness of teachers to transform their instruction to suit the smart teaching environment is insufficient and that changes in teacher evaluation mechanisms are necessary to urge them to adapt to the new teaching paradigm.

Furthermore, the benefits of the smart classroom for students' learning are many. Ni's and Lyu's (2017) study found that students showed stronger interest in learning in a smart class than in a conventional one. According to Yang et al. (2024), students exhibited higher levels of engagement in a smart classroom, cognitively, emotionally, and behaviorally (Zhang et al., 2019; Leng & Yi, 2020). The easy access to abundant digital education resources in the smart classroom also helps students improve their learning efficiency (Zhang et al., 2018). Furthermore, smart classroom technology-assisted teaching activities can elicit deep learning among students (Lu & Yang, 2022), contributing to morphing their simple, linear thought into a more sophisticated thinking style that emphasizes connections in knowledge (Wang, 2019) and enhancing their ability to construct knowledge in more creative ways (Huang et al., 2020). In addition, Peng et al.'s (2021) study suggests that improved impressions of the learning environment in the smart classroom are significantly beneficial for heightening students' self-efficacy. Nevertheless, some researchers claimed that the smart class might pose certain negative impacts on students' learning. For example, it is impossible for students to upgrade their learning methods when their use of the smart classroom is limited to the sharing of teaching materials, whereas the roles of smart classroom technologies in information processing and knowledge construction are disregarded (Zhai et al., 2016; Liu et al., 2020). Another issue in the smart classroom is that students are more interested in the format of instruction than in the course content (Wang, 2019), which is not conducive to their mastery of curriculum subject matter. Also, Zhang (2021) is concerned that the disciplines for student knowledge memorization in the smart classroom may objectify students, producing a false impression of personalized learning.

Additionally, the smart classroom has its advantages in encouraging in-class interactions (Huang, 2013). The smart classroom's interactive technology helps expand the scope of interaction between class actors and enrich teaching and learning approaches, thereby boosting individual and collective knowledge construction and increasing teaching and learning outcomes (Chen et al., 2019). In the meantime, big data-based teaching analytics in the smart class has the potential to optimize the frequency and content of teacher-student and inter-student interaction, thus enhancing students' agency in the classroom as well as their active engagement in learning, both emotional and behavioral (Zhang et al., 2016). Nonetheless, there are also issues with in-class interactions in a smart teaching environment. Despite the smart classroom's emphasis on the notion of student-centeredness (Jiang et al., 2019), it is still important for the teacher to be proficient in posing proper questions and providing reasonable directions and feedback. The current inadequacies in the openness and frequency of questions posed by smart class teachers lead to students' passive reactions and insufficient chances to conduct in-depth discussions in the smart classroom (Liu & Chen, 2021). Li et al. (2018) argued that the interactions occurring in the smart classroom did not significantly outperform those in the traditional classroom, when technological support mainly benefits the teacher rather than the students, resulting in a lack of substantive interactions between them (Chen et al., 2019). Given this, Li and Xu (2018) recommended drawing on the theories of constructivism, situated learning, and collaborative learning in designing learning activities to ensure students' rights to discourse (Xie, 2022) and enhance their interactive behavior in the smart classroom.

To sum up, the literature shows that the smart classroom not only helps ameliorate teachers' instruction and students' learning, but also enhances the interaction between class actors. Meanwhile, the issue of how to fully harness its advantages and circumvent its drawbacks requires more exploration in practice. As technology advances, the smart classroom will also be continuously upgraded. The adjustment of application strategies to optimize smart classrooms' roles in education necessitates further research.

Factors Affecting the Application of the Smart Classroom

A portion of the studies included in the review examined the factors affecting the willingness of teachers and students to use the smart classroom. According to Chen et al. (2020), factors like performance expectations, peer influence, and facilitation conditions can have significant positive impacts on teachers' intention to use smart classroom technologies, whereas outdated education notions and rigid teaching methods are hindrances to their application of the smart classroom. Also, the smart teaching climate of the school, targeted smart teaching training, and innovative teaching strategies are factors contributing to encouraging the use of the smart classroom among teachers (Pan, 2018; Wang et al., 2021). Among students, their seating preferences and learning environment preferences relate to their learning motivation and styles in the smart classroom, and the instructional strategies adopted by the teacher determine students' learning satisfaction in the smart teaching environment (Xu et al., 2018; Zhang et al., 2020; Liu et al., 2021). Li's (2022) study suggested that expanding the opportunities for interactions in the smart class and adopting more suitable teaching methods, such as the multi-scale teaching model, could stimulate students' learning motivation.

On top of the said factors, the structure of in-class teaching (Guan et al., 2019) and the nature of the discipline (Jiang et al., 2018) also determine the intensity of smart classroom use. Specifically, in low-structured teaching that emphasizes classroom generation, such as instruction in the humanities, technology only serves as an instrument for student learning, and in this situation, students themselves hold a dominant position in the learning process. In highly structured teaching, such as instruction in science subjects, the teacher is highly dependent on technology for information presentation and analysis, and, as a result, technology must be incorporated into specific tasks based on prescribed teaching objectives. In addition, some studies emphasized that the intensity of the functioning of the smart classroom depends on its specific purposes in the teaching practices (He et al., 2018c). Therefore, when selecting technological media in the construction stage of the smart classroom, it is overwhelmingly important to consider their relevance to concrete instructional needs and not to focus on pursuing high-performance equipment (He et al., 2020). Equally important for the functioning of the smart classroom is the quality of the digital infrastructure. Issues like network connection failures (Wang, 2019) can pose direct threats to the efficacy of the smart classroom, impairing the smart class experience of the teacher and students.

Conclusion

The purpose of this study is to present the current state of the construction and application of the smart classroom in China via a review of 93 journal articles. Our survey shows that existing research has put forward several well-recognized definitions of the smart classroom and has summarized its basic features; that the builders of the smart classroom have experimented with various architectures of its system, leveraging cutting-edge technologies; and that researchers have also developed certain evaluation frameworks for assessing its outcomes. There remain issues with the development of the smart classroom, such as the lack of widely accepted criteria for its construction and evaluation, overemphasis on the performance of technologies with disregard to the actual needs of teaching, and more attention paid to the novelty of technologies than to the standard of infrastructure, which is the bedrock of the functioning of technology. Therefore, it is necessary to stress that the fundamental role of the smart classroom is to support teaching and learning with appropriate technologies rather than introduce state-of-the-art ones, and that the construction of the smart classroom should be based on the instructional needs (Hu et al., 2019). In the meantime, schools and communities should make more investment in the construction and maintenance of digital infrastructure to ensure the stable, normal enactment of the smart class. Also, more in-depth conversations about the definition of the smart classroom in academia are required in order to generate a widely accepted conception of it and develop relatively uniform evaluation standards accordingly.

According to our survey, the smart classroom has been applied to all education levels and multifarious disciplines. Researchers have investigated teachers' and students' attitudes towards the use of the smart classroom and explored the effects of various instructional models in the smart teaching environment. Our review reveals that, despite its challenges, the smart classroom generally yields positive effects. However, it is crucial to consider the interactions between various technologies within the smart classroom, given its complex technological composition and mutual dependence. Among all the factors influencing the smart classroom's outcomes, the teacher's educational philosophy and teaching methods have the most significant impact, not only on the quality of instruction but also on the academic progress of students. To further improve the application outcomes of the smart classroom, it is imperative to provide smart class training to teachers to increase their competence in this regard. Furthermore, the design of smart class-based teaching activities, a crucial step in implementing the smart classroom, remains largely unexplored in existing research, a factor that significantly influences the smart class's effectiveness in improving teaching quality and boosting student academic achievements. Therefore, to fully meet the increased needs of education, future smart classroom research should concentrate on exploring the principles, methods, and evaluation criteria for designing instructional activities in a smart teaching setting, fully utilizing smart classroom technologies.

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(The 93 Studies included in the literature review are marked with asterisks)

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