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COMMENTARY

Concept Map-Assisted Learning: An Effective Strategy for Building Knowledge Structures

Xiaoqiao Cheng

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"Never believe for a second that your weak, within all of us we have a reserve of inner hidden strength."
–Victoria Addino

CONCEPTS are generally understood as fundamental building blocks underlying principles, thoughts, and beliefs (Goguen, 2005), playing a central role in all facets of cognition. For students, conceptual understanding is the foundation of the development of disciplinary knowledge. Thorough comprehension of core concepts is critical to the mastery of relevant knowledge and skills and their practical applications (Wang & Miao, 2023). From teachers' point of view, successful conceptual instruction can significantly increase teaching efficacy and aid students in developing legitimate knowledge structures. Through in-depth analysis of concepts, teachers guide students to discover the relations between knowledge, fostering their learning interest and thinking ability (Yan, 2022). In order for students to grasp core concepts more efficaciously, educators have experimented with a wide variety of teaching methods, including cooperative learning, project-based learning, concept mapping, and more (Wang, 2016). Among them, concept mapping is recognized as an effective device for students mastering major concepts and developing connections between new and prior knowledge.

Concept mapping was developed by the professor of education Joseph D. Novak and his co-workers at Cornell University in the 1970s, where they sought to research the changes in children's knowledge of science (Novak & Cañas, 2008). Novak's work was informed by cognitive theories of David Ausubel, who stressed that meaningful learning involved the assimilation of new concepts and propositions into existing cognitive structures (Wu, 2023). Concept mapping has subsequently been adopted as a method to increase meaningful learning in the sciences and other subjects as well as to represent the expert knowledge of researchers, governments, and businesses.

Concept maps are graphical representation tools, used to describe abstract information such as systems, states, structures, or concepts. They can display the relationships between different concepts visually by nodes and links, facilitating the comprehension and organization of sophisticated information structures (Nousiainen & Koponen, 2011). There has been a widespread application of concept maps in various areas. In business management, they are often used to demonstrate organizational lay-out, clarify departmental responsibilities, and showcase operational processes (Zhu, 2022). In scientific research, researchers use concept maps to organize and illustrate complex scientific information, theories, and experimental findings. They are conducive to researchers' understanding of inherent logic of the relatedness between experimental data, supporting the advancement of in-depth research work (Fang et al., 2023).

Concept maps are most heavily employed in the field of education. From basic to higher education, teachers and students often use them to develop knowledge structures and enhance learning. Particularly in STEM education, concept mapping is adopted to help students comprehend complex conceptual relationships. It is also incorporated into certain specific teaching models such as the holistic module learning model, wherein it is used to support students' structured learning (Meng et al., 2023). In vocational education and adult education, concept maps are applied to demonstrate workflow, skill requirements, career development paths, etc. (Chen, 2019)

The Effect of Teaching the Secondary School 7th Grade Cell and Division Unit with Concept Maps on the Academic Success of Students in this issue explores the impact of the use of concept maps in science education on student academic achievements, based on a lesson study among 7th-grade students from a public secondary school in the Central Anatolian Region in Turkey. The analysis results of both quantitative and qualitative data support that the adoption of concept maps in teaching had significantly positive effects on students' learning outcomes, which were achieved by increasing their interest in the lesson, allowing them to learn collaboratively, encouraging self-directed learning, preventing the formation of misconceptions, and making presumably difficult concepts easier to understand, as well as providing fun of learning (Kaymaz & Doğru, 2024). The study provides valuable insights into how to support science instruction using concept maps.

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COMMENTARY

Teaching Research under the "Internet plus" Initiative: Driving Teacher Professional Development in the Digital Era

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"Research is formalized curiosity. It is poking and prying with a purpose."
–Zora Neale Hurston

INFORMATION technology permeates every facet of human society in the internet age. The internet has fundamentally transformed human interactions by providing unprecedented support for interpersonal and inter-organizational communication and information sharing. As the paramount technological tool in the contemporary world, it is instigating social reconstruction (Li, 2017). Currently, the comprehensive impact of the internet on education is intensifying, bringing about digital transformation of education across the globe (Zhong, 2019).

In the "Internet plus" era, information technology has tremendously changed the educational behavior of teachers. The OECD published a report titled "Innovating Teachers' Professional Learning through Digital Technologies" in 2020 that outlines the requirements for improving teacher learning through new technologies. These requirements include ensuring that teachers have access to high-quality ICT, enhancing teachers' digital competence, and encouraging teachers to participate in technology-based learning activities (Minea-Pic, 2020). To sustain and optimize their professional development, it is important for teachers to leverage digital technologies in teaching research. Teachers in the information era are expected be digital instruction designers and executors, digital education resource developers, digital teaching evaluators, internet-based teaching researchers, and knowledge management experts (Zheng & Zhang, 2023). Hence, internet-based teaching research, as a powerful driver for teachers' professionalism, has become a key factor in a nation's digital transformation of education.

In recent years, digitally supported education and teaching research is perceived as a strategic effort for education development in China. The Chinese government has issued a series of papers to promote online education and teaching research. The State Council's (2018) "Opinions on Comprehensively Intensifying the Reform of Teacher Staffing in the New Era" emphasize the needs for transformating teacher education and training methods, promoting the integration of information technology into teacher training, and implementing a hybrid system that combines online and offline research and training. The Ministry of Education of China (2019) released the "Opinion on Strengthening and Improving Educational Research for the New Era's Basic Education", stressing that education and teaching research institutions must actively explore innovative research paradigms in the context of the popularization of information technology. The "Guiding Opinions on Promoting the Construction of New-Generation Educational Infrastructure and Building a High-Quality Supportive System for Education," issued by the Ministry of Education and five other departments in 2021, affirm the necessity of harnessing artificial intelligence to promote teacher professional development and popularizing adaptive learning and online teaching research based on intelligent diagnostics and analytics (Ministry of Education of China, 2021). In its 2023's "Action Plans for Intensifying the Reform of Basic Education Curricula and Instruction," the Ministry of Education of China (2023) proposed to strengthen the provision of professional guidance for teaching research, promote innovation in teaching research methods, and support collaborative teaching research against the backdrop of digital transformation in education.

In the context of the accelerated development of internet technologies, how to realize more open, coordinated, and efficacious teaching research is a challenge faced by teacher researchers as well as a key issue in the building of a novel system of teacher professional development (Li et al., 2023). *Online Teaching Research in China in the Context of Educational Digitization in this issue* gives an overview of the history of online teaching research among Chinese teachers, delves into the promotive factors underlying its development, and pinpoints inadequacies in its current practices (Zhou, 2024). It provides implications for developing high-quality education and teaching research based on internet and information technologies.

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Original Article

The Effect of Teaching the Secondary School 7th Grade Cell and Division Unit with Concept Map on the Academic Success of Students¶

Naim Nail Kaymaz, Arzu Doğru

Aksaray University, Aksaray, Turkey

***Abstract**: This study aims to determine the effect of teaching the "Cell and Divisions" unit in the science course with concept maps on the academic achievement of 7th grade middle school students. In order to achieve the stated purpose, a mixed method approach using an explanatory sequential design was used. The study group of the research consisted of 30 middle school students studying in the 7th grade. Convenience sampling method was used in sample selection. In this five-week long implementation, the control group was taught by the teacher according to the current science curriculum in the textbook, while the experimental group was taught a lesson enriched with concept maps. Quantitative data were obtained with the Science Attitude Scale (SAS) and the Cell and Divisions Achievement Test (CCDAT). The "Semi-structured Interview Form" developed by the researchers was used as a qualitative data collection tool. Descriptive statistics, Mann Whitney U test and Wilcoxon Signed Rank test were used to analyze quantitative data. Qualitative data were analyzed descriptively by content analysis method. In the post-application analysis results, while there was no statistically significant difference between the pretest results of the control and experimental groups, statistically significant results were found in favor of the experimental group in the post-test academic achievement scores. Interviews with the students revealed that concept maps contributed significantly to their learning.*

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Keywords: *Science, Concept Map, Cells and Division, Scientific Attitude, Academic Achievement*

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Conflict of Interests: *None*

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

Introduction

WITH THE emergence of international competition in the fields of science, physics, and technology in the past century, the importance of science education has rapidly increased in various areas (Akdeniz et al., 2000; Tekindur, 2022). Science education stands out among the courses that can provide these characteristics (Aydın & Kılıç-Mocan, 2022). Science education aims to develop problem-solving skills through mental processes rather than memorizing and solving problems (İncekara, 2023).

Although science-related concepts are taught correctly in school, students may need clarification about these concepts in their minds in everyday life (Kutluca, 2021). Therefore, it is necessary to prefer teaching methods that can attract students' interest in science classes and enable them to connect new knowledge with prior knowledge (Çiftçi & Aydın, 2023). Concepts categorize similar objects, people, events, ideas, and processes (Bulut et al., 2021). They are the building blocks of knowledge and enable the categorization of knowledge in the mind. There are numerous concepts and relationships between concepts in science courses. Therefore, teaching concepts is crucial in science education (Aydın & Balım, 2007).

The methods of instruction which are used in a course have a significant impact on obtaining effective results from the learning process. Individuals must reorganize and store their perceptions with previously acquired knowledge for meaningful learning (Ülgen, 1997). Concept maps play an important role in meaningful learning and are one of the methods for associating, structuring, and visualizing information in individuals' minds. Concept maps are tools to facilitate meaningful learning and the transfer of information to long-term memory (Oluk & Ekmek ḉi, 2017).

Concept maps are developed based on David Ausubel's theory of Meaningful Learning. Ausubel believes that new information needs to be integrated with existing information (Çiftçi & Aydın, 2023). Concept mapping is a teaching method that visualizes the interconnected relationships between concepts from general to specific (Akbaş, 2019). As they create concept maps, students learn to connect concepts logically (Turan-Oluk & Ekmek ḉi, 2016). In these learning processes, teachers can observe students' thinking processes. It is possible in this way to identify the concepts in which students are struggling to learn, and corrections can be made regarding their misconceptions (Yıldırım & Çelik, 2022).

The studies in the literature on concept mapping indicate that concept maps enhance students' academic achievement and motivation when created together with students (Aslan, 2022; Bulut, 2021; Demirci & Memiş, 2021; Güçlüer, 2006; Sarıkaya et al., 2010; Üstün, 2003). However, it is observed that the number of studies on using the concept mapping technique for the

7th-grade cell and division unit is insufficient in the literature. Furthermore, studies indicate that students find it challenging to understand the processes related to cell division as concepts such as chromosome, homologous chromosome, and chromatid are confusing (Knippels et al., 2005). Additionally, cell and division topic can be challenging for students in terms of visualizing and structuring concepts in their minds (Aksakal et al., 2015).

Orak (2022) investigated the impact of concept mapping-based education based on a constructivist approach on students' academic achievement and attitudes in terms of teaching the topic of renewable energy sources in science. The research indicated that the experimental group receiving concept mapping-based education had a higher score increase. The studies by Elmas et al. (2022) and Bulut et al. (2022) reported that teachers rarely use concept maps for assessment purposes. Elmas et al. (2022) attributed it to the teachers' inclination towards traditional assessment methods. They stated that it was due to the large class sizes and limited time.

Considering that the current education system values the relationships between information more than rote memorization, this study explores the importance of concept maps and their impact on student learning by investigating their effect on student achievement. This study can be beneficial for all fields within the evolving education process. This research aims to answer the following question: What is the effect of teaching the "Cell and Division" unit to 7th-grade middle school students using concept maps on their academic achievement?

The research subproblems which were formulated within the scope of the defined problem statement are as follows:

1. Is there a statistically significant difference between the attitudes of the experimental and control groups towards science classes?
2. Is there a statistically significant difference between the experimental and control groups' pretest scores regarding academic achievement?
3. Is there a statistically significant difference between the academic achievement pretest and post-test scores of the control group?
4. Is there a statistically significant difference between the experimental group's academic achievement pretest and post-test scores?
5. Is there a statistically significant difference between the experimental and control groups' post-test scores in terms of academic achievement?
6. What are students' opinions regarding teaching the cell and division topic using concept maps?

Figure 1. Early Models of Pro-Environmental Behavior.

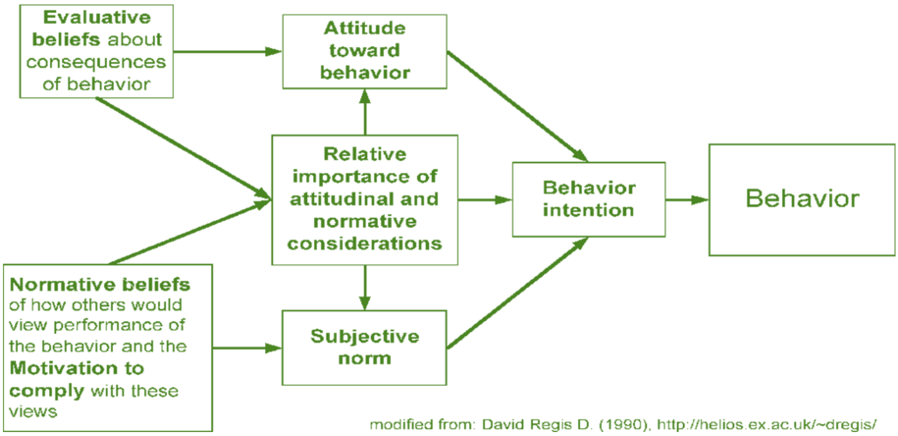

Figure 2. Theory of Reasoned Action (Ajzen & Fishbein, 1980).

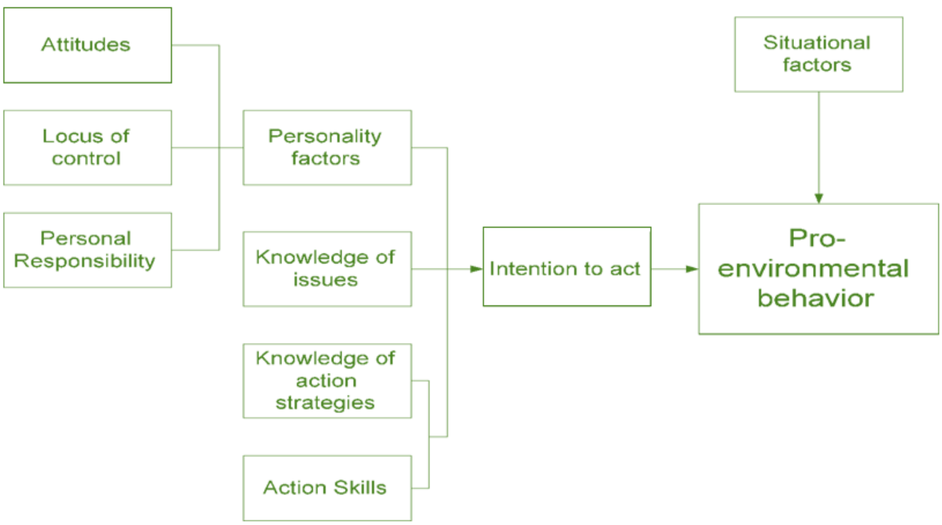

Figure 3. Models of Predictors of Environmental Behavior (Hines et al., 1986).

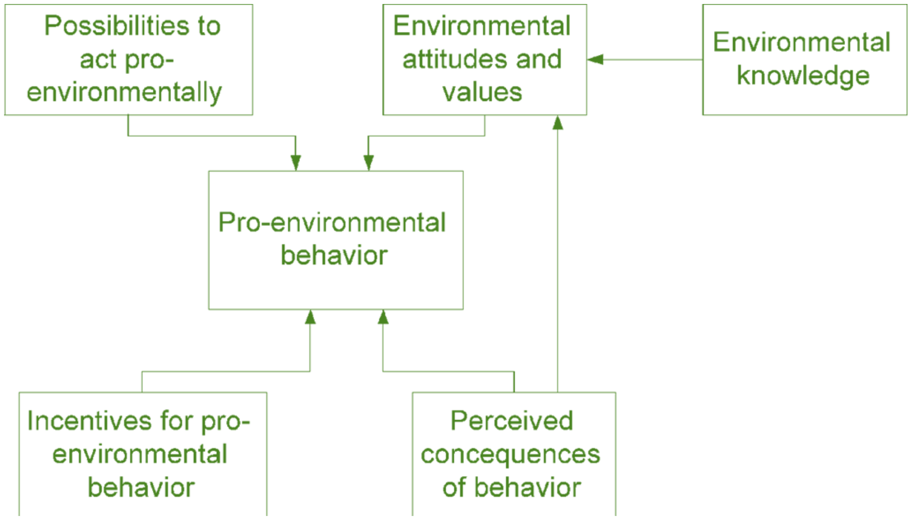

Figure 4. Model of Ecological Behavior (Fietkau & Kessel, 1981).

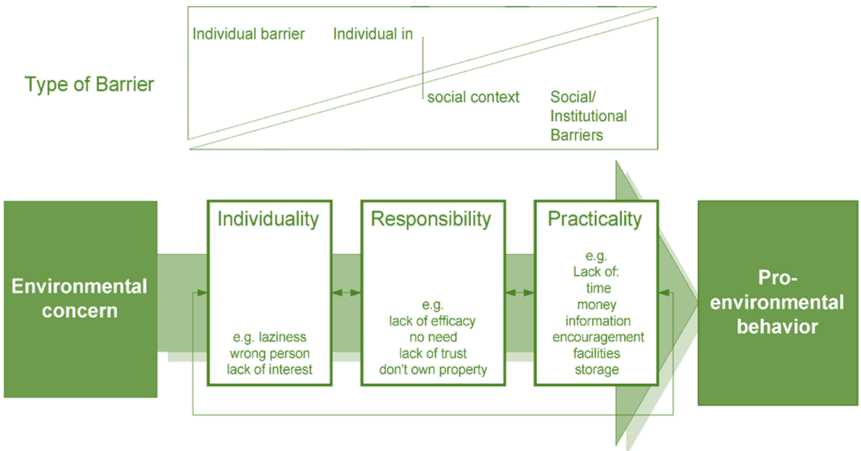

Figure 5. Barriers between Environmental Concern and Action (Blake, 2007).

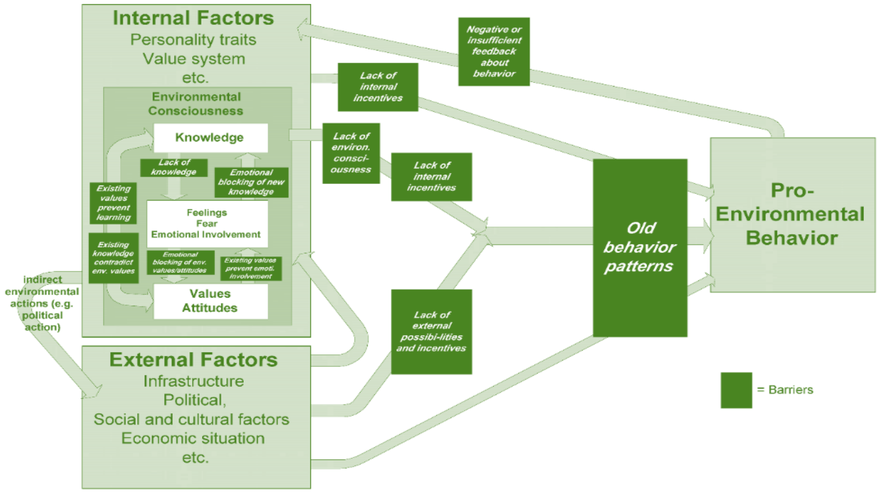

Figure 6. Model of Pro-Environmental Behavior (Kollmuss & Agyeman, 2002).

Method

Research Design

This study employed a mixed-methods approach using an explanatory sequential design. Mixed methods involve quantitative and qualitative methods to obtain more reliable data on the research topic (Şimşek, 2015). In an explanatory sequential design, quantitative data is collected and analyzed first, followed by qualitative data acquisition.

Individual quantitative and qualitative data analyzes are integrated and interpreted in the discussion section (Cresswell, 2008). A quasi-experimental method was employed to test the effectiveness of the application. It aims to determine the application's impact on the participants.

Study Group

The research was conducted with 7th-grade students from a public middle school in the Central Anatolian Region in Türkiye. Fifteen students were in the control group, and 15 were in the experimental group. The groups were formed as two classes so that the academic achievement levels were balanced based on the average scores from previous years. The study was conducted during the fall semester of the 2021-2022 academic year. In the qualitative phase of the study, interviews were conducted with the students in the experimental group to determine their opinions on the concept mapping technique.

Data Collection Tools

Science Attitude Scale (SAS)

Before starting the study, an attitude test was applied to the students in the experimental and control groups to assess their attitudes towards the science course, as the differences in the attitudes between the groups could potentially affect the effectiveness of the applied method. The Science Attitude Scale (SAS), developed by Keçeci and Kırbağ-Zengin (2015), was used with the necessary permissions obtained from the developers. The scale consists of 31 five-point Likert-type items. The response options for the test are "strongly disagree, disagree, neither agree nor disagree, agree, strongly agree." The reliability of the scale was calculated as 0.90 by the developers. Additionally, our reliability assessment for the scale yielded a value of 0.92, indicating reliability.

Cell and Division Achievement Test (CDAT)

In order to obtain quantitative data at the beginning of the study, measure the students' prior knowledge of the topic, and assess their final achievement at the end of the research, a multiple-choice CDAT scale (Coşkun, 2019) was used after the necessary permission was obtained from the author. CDAT scale consists of 25 items and was used to collect quantitative data. The test development studies by Coşkun (2019) defined the reliability coefficient of the test as 0.78 through KR-20 analysis. Our reliability calculations yielded a KR-20 reliability coefficient of 0.80. It indicates that the test is reliable.

Interview Form

The qualitative data in the study was obtained through semi-structured interviews. After the researchers developed the semi-structured interview form to collect qualitative data, it was reviewed by two field experts. Then, the final version of the interview form was applied to the 15 students in the experimental group. The form which was used in the interview aims to gather students' opinions on the concept mapping technique and includes questions such as "What benefits did this technique provide for you?", "Did you encounter any difficulties with this technique?" "Do you think there are any negative aspects of the teaching method we applied in this unit that you did not like?" Experts in the field reviewed the questions in the interview form to ensure their suitability for the primary purpose of the thesis. It also serves to ensure its content validity (Eroğlu, 2009). Additionally, the coefficient of agreement between the experts was calculated to be 0.86.

Data Collection

This study collected quantitative data with a single-group quasi-experimental method. Before the implementation, the class of 30 students was divided into two groups of 15 students, each according to their science course averages in the previous years. Before the implementation phase, an attitude test was administered to both groups to determine the student's current attitudes towards the science course. Then, the "Cell and Division Achievement Test" (CDAT) was applied as a pretest. The pretest scores showed that students in both groups had similar prior knowledge about the topic. The same teacher taught the selected topic in both control and experimental groups for 20 lesson hours for five weeks, starting from the lesson following the test. In the experimental group, the concept mapping technique was introduced to the students, concept maps were actively used at every stage of the lessons, and students were encouraged to create their maps. The lessons in the control group were taught according to the existing science curriculum in the textbook. The CDAT was administered again as a post-test to determine the academic achievement levels of the students in the control and experimental groups. After the quantitative data were collected, statistical analyzes were performed. Qualitative data were then collected to explain the results of the quantitative data. The researchers prepared A semi-structured interview form to collect qualitative data.

Data Analysis

The data analysis in the study was conducted using the IBM-SPSS v25 software package. First, the variables' conformity to the normal distribution was tested.

According to the Shapiro-Wilk test, the data obtained from the CDAT pretest, CDAT post-test, and Science Attitude Scale were found to have a normal distribution within the single group and the control and experimental groups. However, the Shapiro-Wilk test indicated that the post-test results as a single group did not exhibit normality. Some of the histogram graphs showed results close to the standard distribution curve, and the division of skewness-kurtosis values by their standard errors resulted in a value of + - 1.96 (George & Mallery, 2016; Tabachnick & Fidell, 2006). However, considering the size of the data set, it is more appropriate to use non-parametric tests for groups with less than 20 samples (Büyüköztürk, 2011). In this regard, the Wilcoxon test was used to determine the difference between the pretest and post-test within the groups, and the Mann-Whitney U test was used to determine the difference between the control and experimental groups in terms of the pretest, post-test, and Attitude Scale. According to Fritz, Morris, and Richler (2012, p.12), the effect size (r) is calculated to state the statistical difference in Mann-Whitney U and Wilcoxon Marked Rows tests. Cohen (1992) stated that an r value of 0.10 should be considered small, 0.30 moderate, and 0.50 large effect size. The square of the effect size (r^2) is used to determine how much of the difference in the dependent variable results from the independent variable (Cohen, 1988).

In the evaluation of qualitative data, the students' statements were transcribed and subjected to descriptive content analysis. The interview data were evaluated individually for each student, and example student statements were directly presented.

Findings

The first research question investigated whether there is a statistical difference between the experimental and control groups' attitudes towards science. **Table 1** shows the results of the Mann-Whitney U Test conducted to determine the difference between the experimental and control groups in terms of their attitudes towards science.

According to **Table 1**, it has been determined that there is no statistically significant difference in the attitudes towards science of the experimental (Median Rank = 16.37, $p > 0.05$) and control (Median Rank = 14.63, $p > 0.05$) group students.

The second research question investigated whether there is a statistically significant difference between the pretest scores of the experimental and control groups in terms of academic achievement. **Table 2** presents the results of the Mann-Whitney U Test conducted to determine if there is a difference in the pretest scores between the experimental and control groups regarding their achievement in CDAT.

As seen in **Table 2**, no statistically significant difference was determined in the achievements obtained from the pretest CDAT between the experimental group (Rank Sum = 14.93, $p > 0.05$) and the control group (Rank Sum = 16.07, $p > 0.05$) of students.

The third research question investigated whether a statistically significant difference exists between the control group's academic achievement pretest and post-test scores. **Table 3** presents the results of the Wilcoxon Test, which was conducted to determine whether there is a difference between the control group's post-test and pretest scores regarding their achievement in CDAT.

The pretest and the post-test scores of the control group were examined in **Table 3**. It can be stated that CDAT post-test achievements are

Table 1. Mann Whitney U Test Result on the Attitudes of Experimental and Control Groups towards Science Course.

Variable	Group	N	Avg. Rank	Total Rank	*U*	Z	p
Attitude	Control	15	14.63	219.50	99.500	-0.541	0.595
	Experimental	15	16.37	245.50			

Table 2. Mann Whitney U Test Results for Pretest Scores Obtained from CDAT by Experimental and Control Groups.

Variable	Group	N	Avg. Rank	Total Rank	U	Z	p
CDAT	Control	15	16.07	241.00	104.000	-0.357	0.744
	Experimental	15	14.93	224.00			

Table 3. Wilcoxon Test Results for the Control Group's Post-Test and Pretest Scores in CDAT.

Variable	Pretest Post-Test	N	Avg. Rank	Total Rank	Z	p
Control	Negative Rank	5	4.17	12.50	-2.315*	0.021**
	Positive Rank	10	7.85	78.50		

**Based on the Negative Ranks; **p<0.05*

significantly higher than pretest achievements ($z = -2.315$, $p < 0.05$). The calculated effect size is $r = 0.60$, indicating a large effect. Additionally, 36% of the difference (r^2) can be attributed to the independent variable (teaching method). Therefore, it can be concluded that the lessons taught according to the current science curriculum in the textbook impact students' learning of the subject.

The fourth research question investigated whether a statistically significant difference exists between the experimental group's academic achievement pretest and post-test scores. Wilcoxon Test results are provided in **Table 4** to determine if there is a significant difference between the post-test and pretest scores of the experimental group in terms of CDAT achievement.

According to **Table 4**, the pretest and post-test scores of the experimental group were examined. It can be stated that the students' CDAT post-test achievements are statistically significantly higher than their pretest achievements ($z = -3.421$, $p < 0.05$). The calculated effect size is $r = 0.88$, indicating that the implemented intervention has a substantial effect. Furthermore, 77% of the difference (r^2) can be attributed to the independent variable (concept mapping application). Therefore, it can be concluded that the concept mapping instructional model is effective for students.

The fifth research question investigated whether there is a statistically significant difference between the experimental and control groups' post-test scores in terms of academic achievement. The results of the Mann-Whitney U Test, which was performed to determine whether there is a difference between the post-test results of the experimental and control groups in their achievements in CDAT, are given in **Table 5**.

According to **Table 5**, CDAT post-test achievements in the Experiment (Rank Mean = 23.00, $p < 0.05$) and Control (Rank Mean = 8.00, $p < 0.05$) groups show a statistically significant difference. The calculated effect size is $r = 0.86$, indicating the application has a substantial effect. 74% of the difference (r^2) is due to the process applied (concept mapping application). Given these results, it can be stated that teaching cells and division supported by the concept mapping applied to students is more effective than the current science curriculum in the textbook.

The sixth research question investigated students' opinions regarding teaching the cell and division topic using concept maps. The findings of how students found the technique applied in the course are given in **Table 6**.

Table 6 analyzes students' answers to the interview question: "How did you feel about the course processing technique we applied in the cell and division unit?" The most frequency-generating code ($f = 11$) was "easy and persistent". The code ($f = 2$) that generated the second highest frequency was "fun". In addition, the expressions ($f = 1$) "concise and concise" and ($f = 1$) "visualizer" were also expressed by one student each. In this regard, the following examples can be given to students' answers:

"I think that this technique was fun." (S8)

"... it is impressive that it presents the subject visually" (S2)

"... presents the subject shortly and concisely." (S12)

"... a technique that makes us easy to grasp and minimises forgetting." (S1)

The findings for the benefits of the applied technique are given in **Table 7**.

According to the information in **Table 7**, the student answers to the interview question "What benefits the applied technique has provided you?"

Table 4. Wilcoxon Test Results for the Post-Test and the Pretest Scores of the Experimental Group in CDAT Achievement.

Variable	Pretest Post-Test	N	Avg. Rank	Total Rank	Z	p
Experimental	Negative Rank	0	0.00	0.00	-3.421*	0.001**
	Positive Rank	15	8.00	120.00		

Table 5. The Results of Mann Whitney U Test on the Difference between the Post-Test Results of the Experimental and Control Groups in Their Achievements in CDAT.

Variable	Group	N	Avg. Rank	Total Rank	U	Z	p
CDAT	Control	15	8.00	120.00	120,000	-4,690	0.000*
	Experimental	15	23.00	345.00			

Table 6. Findings on How Students Regard the Technique Used in the Course.

Code	F
Easy and Lasting	11
Short and concise	1
Illustrative	1
Entertaining	2

Table 7. Findings for the Benefits of Applied Technique.

Code	F
Visualization of learning	8
Connection building within the topic	2
Simplification of the subject	1
Facilitation of learning	1
Encouraging the student	3

are examined. The most frequency-generating code (f = 8) was "visualization of the subject", and the second most frequency-generating code (f = 3) was "encouraging the student". The third code (f = 2) that created the most frequency was "connection building within the topic", and the fourth code (f = 1) that formed the least frequency was "simplification of the subject" and "facilitation of learning". In this regard, the following examples can be given to students' answers:

"It encouraged me to learn about the topics in this unit, so it motivated me." (S13)

"It has a facilitating effect on the subject." (S1)

"... has a visualizing effect." (S11)

"Thanks to the arrows on the map, I learned how words relate to each other." (S9)

"It gave a simplifying effect on the subject." (S5)

The findings on why the applied technique is useful are given in **Table 8**.

Table 8 examines the student answers to the interview question "Why do you think this technique is useful?" The most frequency-generating code (f = 9) was "revealing different views", and the second most frequency-generating code (f = 2) was "providing easy learning". The third most frequent codes (f = 1) are "providing a fun learning environment" and "providing detailed learning". In this regard, the following examples can be given to students' answers:

"... enabled us to learn the information in detail." (S8)

"... allowed us to learn topics easily..." (S13)

"... topics become much fun" (S15)

"Information becomes more permanent" (S10)

"It is useful because different ideas are united in one picture." (S6)

The findings for the disadvantages of the applied technique are given in **Table 9**.

Table 8. Findings on Why the Applied Technique is Useful.

Code	F
Revealing different views	9
Providing permanent learning	2
Creating a fun learning environment	1
Providing easy learning	2
Providing detailed learning	1

Table 9. Findings on the Disadvantages of the Applied Technique.

Code	F
There is no negative aspect.	13
Complicated	1
Time-consuming	1

Table 10. The Findings on the Effects of the Negative Aspects of the Applied Technique on Student Learning.

Code	F
It did not affect me negatively	13
I was hard at first	1
It took time	1

Table 11. Findings on Where Students were Challenged Most When Applying the Technique.

Code	F
I had no difficulty	13
I had a hard time understanding	1
It took too much time	1

Table 9 analyzes the students' answers to the interview question: "Are there any negative/disliking aspects of the technique we applied in the cell and divisions unit?" The most frequency-generating code (f = 13) was "no negative aspect", and the second most frequency-generating codes (f = 1) were "complex" and "time-consuming". In this regard, the following examples can be given to students' answers:

"... it takes time to draw a concept map." (S14)

"Some concept maps are complex." (S15)

"Not negative this technique never..." (S12)

The findings on the negative effects of the applied technique on student learning are given in **Table 10**.

Table 10 analyzes the student answers to the interview question: "Did these negatives affect your learning? If yes, how did it affect you?" The most frequency-generating code (f = 13) was "no negative aspect", and the second most frequency-generating codes (f = 1) were "I was hard at first" and "it took time". In this regard, the following examples can be given to students' answers:

"Concept maps took much time." (S2)

"At first, I had a hard time understanding concept maps." (S1)

"... my learning was unaffected." (S15)

The findings on where students were challenged most when applying the technique are given in **Table 11**.

Table 11 analyzes the students' answers to the interview question: "Where did you have the most difficulty?" The most frequency-generating code (f = 13) was "I had no difficulty", and the second most frequency-generating codes (f = 1) were "I had a hard time understanding" and "It took too much time". In this regard, the following examples can be given to students' answers:

"... ... it takes time to draw a concept map." (S2)

"I had a hard time understanding some concept maps." (S1)

"... I can state that I had no difficulty." (S3)

Table 12. Findings on Whether This Technique Was Useful When Used by Students while Studying at Home.

Code	F
It was absolutely useful	11
It was partly useful	3
It would definitely be useful if I had used it	1

Table 13. Findings on Whether Students Want to Use the Applied Technique in Other Units of Science Course.

Code	F
All science topics	9
Force and movement	1
Systems in our body	2
Matter and its nature	2
Conduction of electricity	1

After learning the applied technique, the findings on whether this technique was useful when used by students while studying at home are given in **Table 12**.

Table 12 shows the answers to the question, "Do you think it is useful to use the applied technique when studying at home?" The most frequency-generating code (f = 11) was "It was absolutely useful", and the second most frequency-generating code (f = 3) was "It was partly useful". The third most frequency-generating code (f = 1) was "it would definitely be useful if I had used it". In this regard, the following examples can be given to students' answers:

"... I did not use it, but I think it would definitely be useful if I had used it." (S2)

"It benefited me in some ways" (S10)

"It was definitely useful when I used it..." (S9)

The findings of whether students want to use the applied technique in other units of science course are given in **Table 13**.

Student answers to the interview question "Do you want this technique to be used in other units in science course?" are analyzed in **Table 13**. The most frequency-generating code (f = 9) was "all science topics", and the second most frequency-generating codes (f = 2) were "systems in our body" and "matter and its nature". The codes that generated the third highest frequency (f = 1) were the units of "force and movement" with "conduction of electricity". In this regard, the following examples can be given to students' answers:

"I would like it to be used in the unit conduction of electricity." (S1)

"I would like it to be used in the unit matter and its nature."

"I would like it to be used in the unit systems in our body" (S12)

"I would like it to be used in the unit force and movement." (S6)

"I would like it to be used in all topics of science." (S13)

In addition, the experimental group students identified concept maps as a useful technique during the interview. While 13 students did not regard concept maps as a challenging technique, two students stated they had little difficulty. Fourteen students stated that they used the concept maps technique while studying at home, but one student stated that they did not use it at home.

Discussion and Conclusion

The present research investigated the effect of teaching the "Cell and Division" unit in the science lesson of secondary school 7th-grade students with concept maps on the academic achievement of the students. Since students' attitudes towards the course could affect their academic achievement, both groups' attitudes to the course were evaluated before the study. As a result of the analysis, no statistically significant difference was obtained between the groups. According to this result, it was found that the students in both groups had equal attitudes towards the science course. Therefore, it is acceptable that the difference that may arise from teaching will result from the method.

In comparing the control group's achievement in cell and division pretest and post-test averages, a statistically significant increase was determined in the students' post-test achievement averages compared to their pretest achievement averages. This increase in student achievement concludes that teaching the topic based on the current science curriculum in the textbook is effective for students' academic success. The comparison between the experimental group's cell and division pretest and post-test averages concludes an increase in student achievement with a statistically significant difference when teaching the topic with the support of concept maps. This increase in student achievement reveals that teaching the topic with a concept map is effective for student academic success.

The current science curriculum in the textbook and the teaching model supported with concept maps effectively affect students' success. However, the relationship between the post-tests of the control and the experimental group should be examined to determine which model is more effective on student achievement.

The analyses were studied to determine whether the experiment and control groups observed a statistical differentiation in their cell and division post-test scores. The findings revealed that the academic achievements of the experimental group in which concept maps were used were more positively influenced than the current science curriculum in the textbook.

The students stated that they found concept maps to be a fun technique that provides easy and persistent information shortly and concisely, facilitating learning with visuals. All the students who participated in the interview regarded concept maps as useful. The findings demonstrated that 87% disagreed that there may be a negative aspect of concept maps. About 93% of the participants said they used concept maps while studying at home. As all participants provided the name of a topic for which concept maps can be used in science courses, the students found this technique useful.

According to Bahar, Johnstone, and Hansell (1999), students are challenged in biology due to the abstraction of the concepts of biology and the complexity of their relation to each other. Lewis and Wood-Robinson (2000) argue the necessity of teaching genetic terminology in an order as the structure of information and then the interpretation of information for quality education.

In the present study, the topic of cell and divisions was instructed with the support of concept maps. It was observed from the analysis of quantitative findings that the experimental group knew the concepts of cell divisions and phases of cell divisions. Based on these results, it may be concluded that the concept-maps-assisted education contributed positively to students' academic success. In this regard, the present study parallels the study by Bahar, Johnstone, and Hansell (1999) and Lewis and Wood-Robinson (2000).

Banet and Ayuso (2000) and Stewart (2011) reported that chromosome and gene relationships are difficult to learn, and the current methods and books must change. Özatlı (2006), Özdemir (2005), Saka and Akdeniz (2006), and Temelli (2006) state that students have difficulty learning the concepts of cells, DNA, chromosomes, and genes and cannot make distinctions between these concepts.

In the present research, the students found it challenging to establish relationships between chromosome, gene, DNA, and nucleotide concepts. When our data was examined, it was understood that students could not identify the relationships between these concepts during the pretest stage, where their test results were low. Based on the results of the post-test, it was observed that the experimental group students were more able to establish these inter-conceptual relationships than the control group. When more concept maps are included in textbooks, students will also enhance the level of their inter-conceptual relationship. In this regard, the present study coincides with researchers such as Banet and Ayuso (2000), Stewart (2011), Özatlı (2006), Özdemir (2005), and Temelli (2006). The students stated during the interviews that they found concept maps useful and used them fondly while studying. Therefore, it can be concluded that giving more space to the concept maps in the lessons will be useful. This qualitative result supports quantitative results.

Gözmen (2008) emphasized that teaching techniques in the teaching of biology subjects should be supported by questions/answers to consolidate knowledge. Şahin and Ulucan (2023) concluded in their studies that rather modern and different teaching techniques should be preferred for students to learn concepts. In the present study, the achievement test averages of the experimental group are statistically higher than that of the control group. These results are in parallel with the work done by Gözmen (2008) and Şahin and Ulucan (2023). In addition, concept maps were described as a useful method by students in the interviews. These results also support the quantitative data in the present study. Gözmen (2008) emphasized that the science textbooks in our country are lacking in supporting the goals of science education, and they consequently do not provide opportunities for meaningful learning. Therefore, they concluded that activities and teaching supported with different techniques will positively contribute to the students.

In the present study, the experimental group students indicated they enjoyed being educated with the concept map. It can be said that this element affects the increase in students' achievements in this group. In this context, the present study is similar to the study by Gözmen (2008). In addition, the answers to the interview questions include the students stating that they achieved permanent learning with the concept maps. Another significant conclusion from the interviews is that, as the same teacher conveyed the topic to both groups, the difference resulted from the technique used. This determination indicates that the present qualitative results support the quantitative results of the present study.

Karacı and Güleç (2019) stated that using concept maps moves students forward in terms of academic achievement compared to traditional methods. Oluk and Ekmekçi (2017) stated that it is appropriate for students to create a concept map with their knowledge in order to observe the relationships among the science concepts. It has been determined in the present study that the students who created concept maps were more successful academically than the other students. Since there was a discussion environment in the groups trying to create concept maps, the students could state their ideas freely. It has been observed that the students who learn the concepts incorrectly had the chance to learn correctly from their classmates. Therefore, our study contains results similar to the studies by Karacı and Güleç (2019) and Oluk and Ekmekçi (2017). The experimental group students indicated in the interviews that they often used concept maps to answer questions. In addition, the fact that they stated they had used this technique while studying at home reveals that concept maps are an important factor in understanding the subject. Qualitative data obtained in this context support the quantitative data in the present study.

In their study, Taşkın (2017) stated that using more sensory organs in learning enables a more permanent learning experience. In concept-map-assisted education makes use of multiple sensory organs in learning. Thanks to the discussion environment during the formation of concept maps with students, they are thought to learn the topic fully, correctly, and permanently.

The present study shows a significant increase in the academic achievements of students in a positive direction as a result of the concept map-assisted educational applications. Accordingly, the present results have been produced in parallel with the studies by Taşkın (2017). It was also noted in the interviews with students that the concept maps affect students due to their visual form, which increases success. The qualitative data obtained in this context supports the quantitative data in the present study.

Bolat and Karamustafaoğlu (2021) noted that students liked the concept maps technique. Students enjoyed creating a concept map in groups, increasing their willingness to continue the course. In the present study, the students enjoyed the science course supported with concept maps. In addition, the students stated in the interviews that they would create concept maps themselves while studying, which indicates that they enjoyed this technique. In this regard, the present research has provided similar results to Bolat and Karamustafaoğlu's (2021).

Bulut, Turan-Oluk and Ekmekçi (2021) stated that the concept map technique improves students' point of view in science classes based on student interviews. In the interviews of the present study, the students stated that they learned to look at the topic from different perspectives thanks to concept maps. They also noted that the concept map technique is useful because it is persistent and relational, providing different points of view and detailed learning. They stated that they use concept maps indirectly in remembering information. Therefore, it may be said that the present finding parallels the study by Bulut, Turan-Oluk, and Ekmekçi (2021).

The students' attitudes towards science courses in the experimental and control groups in the present study are equal. In the present research, a 15-student control group studied the unit cell and divisions based on the science curriculum, while a 15-student experimental group studied it with concept maps. The research results concluded that the group supported with concept maps was more successful in academic achievement. It is assumed from the qualitative data that using concept maps may have increased success because it makes the lesson fun. In addition, creating concept maps for students enables them to see their shortcomings and allows them to manage learning processes. Accordingly, those in the experimental group were able to learn new information from their classmates and found the opportunity to correct their misconceptions.

It may be observed that there is no difference between the control and experimental groups in terms of their pretest results ($p > 0.05$, **Table 4.2**). In the post-test after the application, statistically significant results were obtained between the groups in favor of the experimental group ($p < 0.05$, **Table 4.7**). When the CDAT results of the control and experimental groups were compared, it was noted that eight problems marked incorrectly in the control group were marked correctly in the experimental group. Following the interviews conducted to explain this phenomenon, it was concluded that the element which caused this difference was the course processing technique itself. The quantitative data also supports the greater success of the experimental group in the unit "Cell and Division" with concept maps. The quantitative results coincide with the qualitative data, revealing the concept maps' effect. In this regard, the quantitative data in the present study also support the qualitative results obtained.

When the results are evaluated as a whole, it may stated that teaching lessons with concept maps increases students' interest in the lesson, allows them to learn together, encourages self-learning, prevents the formation of misconceptions, provides pleasure from learning, causes easier understanding of lessons presumed as difficult, and consequently leads to a positive effect on course achievement. When more concept maps are included in textbooks, students will also enhance the level of their inter-conceptual relationship. Thus, many of the topics regarded as difficult could be easier to learn, and meaningful learning will be achieved as well. In this respect, it is assumed to be beneficial for teachers to use this technique when teaching and to include it more in textbooks.

Recommendation

The following recommendations are presented as a result of the present study.

1. Since this study was conducted briefly, possible attitude changes could not be revealed. The science attitude scale may be applied in the form of a pretest and post-test before and after application in future studies. Students' initial attitudes towards science and after the application may be compared.
2. The study sample was limited to 30 students studying in the Central Anatolian Region in Turkey. Future studies may be planned with a greater number of students.
3. The present study is limited to the unit "Cell and Divisions" in the 7th grade science curriculum. Similar studies may be carried out in different units and topics in the science curriculum at different grades.
4. The present study compares science education supported with concept maps with the current science curriculum in the textbook. The effect of the concept mapping method is comparable to other techniques and methods based on constructivism and student-centred education.

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ORIGINAL ARTICLE

Identification of the Students' Misconceptions about the Digestive System

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Abstract: *The aim of this study is to determine the students' misconceptions about the digestive system. In this quantitative research, the study group comprised totally 259 sixth-, seventh-, and eighth-grade students. The data were collected through a three-tier diagnostic test and analyzed in terms of scientific knowledge, the lucky guess, lack of knowledge, and misconception levels of students on digestive system. According to the findings, 20.1% of the students' answers were in the scientific knowledge category and 9.1% were in the lucky guess category. On the other hand, 39.7% of the answers were in the lack of knowledge category and 26.0% were in the misconception category. The most prominent findings in the study were the students' misconceptions in a few questions, especially about physical and chemical digestion. In addition, some students did not fully understand the distinction between the excretory and digestive organs and the functions of some accessory. They also gave incorrect answers about the organs where the digestion of proteins, carbohydrates and fats begins and ends. At the end of the study, suggestions were made to eliminate the misconceptions.*

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Introduction

ONE OF THE most important problems of science education is the misconceptions and lack of knowledge that arise since science concepts are not learned in a meaningful and in-depth way in learning environments (Taban & Kiray, 2021). Research on the concept learning and teaching is one of the most important areas in science education (Al khawaldeh & Al Olaimat, 2010). Because some researchers have stated that students come to the classroom with different ideas about science and the natural world, especially in science lessons (Al khawaldeh, 2013). In order to reach a meaningful understanding, students should be associated with their current knowledge and new knowledge, and it should be ensured that they establish effective connections between them. If effective connections are not established between existing knowledge and new knowledge, the development of concepts in students' minds can be prevented (Novak, 2002). In other words, if the concepts are not grasped correctly and scientifically, they turn into information that has no scientific basis. This information, which is likely to cause learning difficulties, is named in different ways such as preconcepts, alternative concepts, misconceptions, and misunderstandings etc. (Dry, 1998; Gilbert, 1977; Novak, 2002; Tapia et al., 2019). In this study, the term "misconception" was preferred. Since misconceptions are resistant to change and negatively affect students' learning performance, it is very important to identify the misconceptions held by students in order to ensure effective learning (Bekkink et al., 2016). Since the last forty years, many researchers around the world have been conducting research to identify misconceptions held by students at different grade levels and in different topics of science. These studies show that misconceptions continue to be one of the main problems affecting science teaching today (Taban & Kiray, 2021). Therefore, in school science teaching, ideas need to be presented in ways that are both authentic representations of the scientific concepts, and yet simple enough to be meaningfully understood by the learners (Nahum et al., 2010). Yet, the broad scope of biology and the complexity of the topics increase the likelihood of students developing misconceptions (Al khawaldeh, & Al Olaimat, 2010; Andariana et al., 2020).

When the studies in the literature to identify or remove students' misconceptions about biology subjects are examined, it seems that there is an important literature that has a long history of study and reveals various concepts and misconceptions held by students at different education levels. In these studies, although it has been determined that students developed misconceptions about important biology subjects, it is noteworthy that less focus was placed on organ systems in the studies (Al khawaldeh, & Al Olaimat, 2010).

Most of the biology subjects in the curricula of almost every country focus on systems of the human body (Dry, 1998). Research into students' understanding of systems has shown that they have trouble understanding fundamental issues of biology, such as internal organs, organ systems, and their functioning (Reiss et al., 2002).

Every system in our body is interrelated. Therefore, learning the organ and functioning of each system can be effective in learning the other system (Ürey & Çalık, 2008). For example, since the subject of 'Digestive System' is closely related to subjects such as excretion and endocrine system, correctly teaching the subject of 'Digestive system' to students will make it easier to learn other subjects correctly (Çuşin et al., 2020). To give an example on this subject, it has been determined in the literature that some students define the intestine as an excretory organ. These false pre-knowledges detected in students may cause new misconceptions while learning the subjects and concepts related to the excretory system. Therefore, all systems in the body can be considered as a system, and the issues of each system can be evaluated analytically (Cerrah Özsevgeç et al., Ünal, 2012).

In the literature, there are studies to identify students' misconceptions about the 'Digestive System' (Ahi, 2017; Cakici, 2005; Carvalho et al., 2003). In some of the studies, students defined the 'Digestive System' as an open-ended tube, while others defined the stomach as a balloon with no mouth or mouth (Adriana & Andrea, 2017). Some students stated that the stomach is the most important organ of the 'Digestive System' (Carvalho et al., 2003; Çuşin et al., 2020). In the study by Çuşin et al. (2020), the students stated that fluids go to the small intestine and solids to the large intestine during digestion and, melting of sugar in the mouth is a digestive event. On the other hand, Dry (1998), Güngör and Özgür (2009) and Çuşin et al. (2020) revealed that students have established a wrong relationship between the 'Digestive System' and the 'Urinary System'. In another study, Cakici (2005) identified different misconceptions that students perceive the digestive process as the melting of foods instead of breaking them down. As different examples of the misconceptions determined (Cerrah Özsevgeç et al., 2012; Çuşin et al., 2020; Dry, 1998): "physical digestion takes place only in the mouth", "digestion is completed in the anus", "gallbladder holds liquid waste", "large intestine transmits wastes to kidneys" etc.

In the light of these studies, it can be said that the organs of the digestive system, their functions and the digestive mechanism are problematic issues for students at different education levels, and this problem continues today. This situation can be caused by different reasons such as drawings or confusing information in textbooks, teacher-centered teaching methods, cultural interactions of students, media and daily language (Cerrah Özsevgeç et al., 2012). Therefore, it can be said that the sources of misconceptions are quite high. In order to prevent students from holding misconceptions, it is of central importance to understand the concepts correctly and to raise awareness against misconceptions (Taban & Kiray, 2021). This is especially important for students at lower levels of education. For example, in the context of our country, the digestive is taught in various courses from primary school to high school. The subject of 'digestion' as a system is first covered in the 6th grade science course. In high school, the digestive system is taught at the 11th grade level. Therefore, the misconceptions that arise in the lower levels of the teaching process may affect the students' mastery of the concept at the high school or university level in later years. This magnifies the problem and hinders adequate scientific literacy, which not only affects future citizens, but also the challenge of educating future scientists (Tapia et al., 2019). Therefore, it is important to determine the learning difficulties or misconceptions of the students from the lower stages of the teaching process. On the other hand, there are many diseases of our age. One of these is cancer. The top 3 most common cancer types in our country in 2020 are lung cancer, breast cancer and colorectal (large intestine) cancer. Colon cancer has a rate of 9.1% among all cancer cases. This rate should not be underestimated and among the reasons, the risk of colon cancer is increased in those who eat a diet rich in animal fat and low in calcium, folate and fiber. A diet low in fruits and vegetables also increases the risk (Global Cancer Observatory, 2023). At this point, teaching school children the importance of the digestive system and the health of the digestive system from an early age will prepare individuals for a healthier future. To achieve this, it is important to first determine students' awareness levels about the digestive system and identify misconceptions.

On the other hand, different techniques or measurement tools such as drawings (Adriana, & Andrea, 2017; Andersson et al., 2020; Carvalho et al., 2003; Çuġin et al., 2020; Reiss et al., 2002), open-ended questions (Cakici, 2005; Cerrah Özsevgeç et al., 2012), interviews (Adriana, & Andrea, 2017; Ahi, 2017; Cakici, 2005; Cerrah Özsevgeç et al., 2012; Teixeira, 2000), diagnostic tests (Andariana et al., 2020; Bozdağ, 2017; Özkan, 2017) are used to detect misconceptions held by students. In most of the studies, it is seen that drawings are used to identify students' misconceptions (Andersson et al., 2020). However, as stated by Taban and Kiray (2021), these methods have some deficiencies in revealing misconceptions. It is also important that this study is carried out by using the three-stage diagnostic test, which is one of the most recommended methods for the detection of misconceptions. It is claimed that a three-stage diagnostic test among these techniques is highly capable of detecting the misconceptions held by students in a more valid and reliable way compared to other techniques and even two-stage diagnostic tests (Karpudewan et al., 2015). Therefore, this study was determined the students' misconceptions by using a three-stage diagnostic test. In addition to misconceptions, determining the scientific knowledge and the lack of knowledge ratios of students on digestive system is also important for understanding how deep this subject was learned by students. For this aim, the following questions were sought in this research:

- What are the students' scientific knowledge, lucky guess, lack of knowledge and misconception percentages about Digestive System?
- What are the students' common misconceptions about the Digestive System?

Method

In this study, a survey method based on a quantitative research paradigm was utilized. In survey studies, researchers determine a large sample group and collect data by using tests, surveys/scales or by conducting interviews. Survey studies are frequently used, especially in research conducted in the field of education (McMillan & Schumacher, 2010).

Participants

The study group comprised sixth, seventh and eighth grade students from a city located in the east of Turkey. The ethic board of the institute approved the study. A three-tier diagnostic test was applied to totally 259 volunteer students (48.6% female and 51.4% male) at the end of the second semester during the academic year 2021/2022 (**Table 1**). In determining the sample, the rule of Bryman and Cramer (2001) that "the sample should be at least five times the number of items in the scale" was considered.

Data Collection Tool

The three-stage diagnostic test was originally developed by Bozdağ (2017) and it was in accordance with the curriculum in force before 2018. But Turkish national science curriculum was updated in 2018. Therefore, test was examined by two field experts in terms of both knowledge of the misconceptions and the compatibility of the questions with the learning outcomes in the curriculum. In line with expert opinions, questions 6 (Q6) and 9 (Q9) in the original test were not included in this study. The reliability coefficient of the test (Cronbach Alpha = α) was 0.71 for the first stage of the test, 0.75 for the two stages, and 0.78 for the entire test, that is, for the three stages. As a result, the three-tier diagnostic test contained 10 three-tier items in this study. The first tier is the question part consisting of four multiple choice options with the correct answer together with the distracters containing possible misconceptions. The second tier is the multiple-choice part where the reasons for the answers given in the first stage are included. In the second stage, there is an open-ended option where students can write the reasons they want.

Table 1. Demographic Characteristics of the Sample Group.

Grade level	Gender	School 1	School 2	School 3	School 4	School 5
6th Grade	Female	12	11	7	13	5
	Male	19	10	14	9	10
7th Grade	Female	13	8	5	8	12
	Male	8	12	8	10	9
8th Grade	Female	11	9	8	-	4
	Male	-	11	7	-	6
Total		63	61	49	40	46

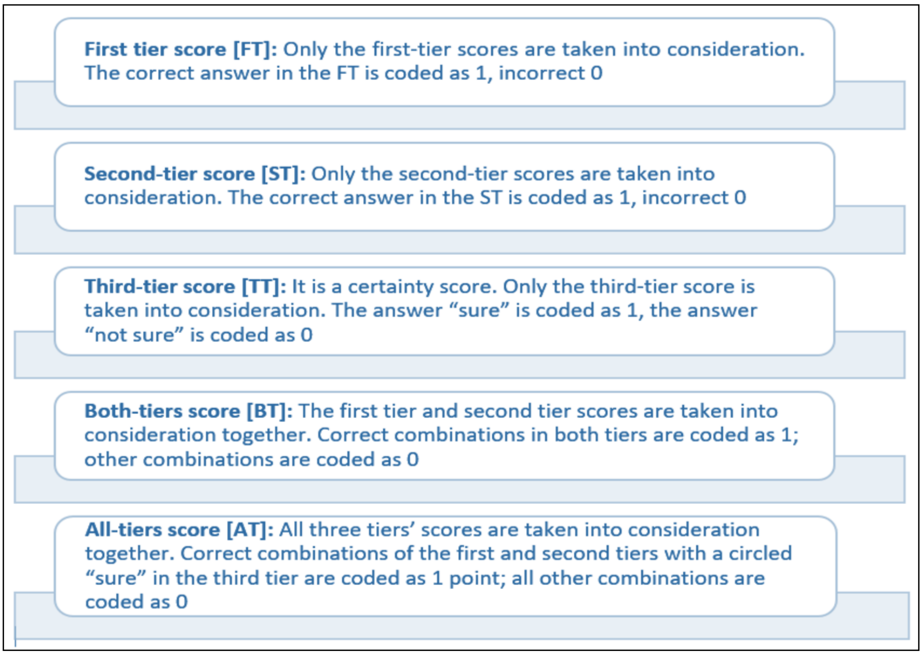

Figure 1. The Test's Definitions of the Contents by Tiers.

The third tier is the self-confidence stage, in which the degree of confidence in the answers given in the first and second stages is asked.

Data Analysis

All statistical analyses were performed in Microsoft Excel and IBM SPSS 20. The data were analyzed in two different ways in terms of both the test's definitions of the contents by tiers and the students' conceptual knowledge. The test's definitions of the contents by tiers were scored like Milenković et al. (2016) in **Figure 1**.

In addition, very few students marked the open-ended questions (option E) in the second stage of the test, but their answers did not address any misconceptions and included statements such as "I don't know". Therefore, only the frequency value was calculated for open-ended questions and scored as "0".

As a result, according to the above criteria suggested by Milenković et al. (2012), the students' answers were defined as scientific knowledge, lucky guess, luck of knowledge, false positive, false negative and misconceptions (**Table 2**).

In subsequent analyses, it was calculated the percentage value of each response category in order to determine the students' conceptual knowledge. When calculating percentages, false positive and false negatives were categorized into misconceptions. And thus, the data obtained from the test were categorized according to the students' answers, and four different categories were created, similar to the study of Suwono et al. (2021). These were: scientific knowledge (SK), the lucky guess (LG), lack of knowledge (LK), and misconception (M).

Validity Analysis

False Positive (FP) and False Negative (FN) percentages were previously calculated for the content validity of the procedure applied in the analysis of the misconceptions held by the students about the digestive system. In relevant literature, it is recommended that the percentages of FP and FN do not exceed 10% for content validity of three-tier test evaluation (Milenković et al., 2016). According to the findings of present study, the FP percentage was 2.15%, and the FN was 2.23% (**Table 3**). Since the FP and FN percentages are within the recommended range, it can be said that the test is suitable for identifying students' misconceptions.

On the other hand, it was used a common method proposed by Cataloglu (2002) construct validity of the test. For this aim, the correlation between BT and TT scores was calculated for the method of providing evidence for the construct validity of the test. As a result, a positive correlation was found between BT and TT scores ($r = 0.367$; $n = 259$; $p = 0.00$). The correlation between BT and TT scores is shown graphically in **Figure 2**.

Figure 2 shows an increase in the number of correct answers in both stages with increasing confidence level. However, in addition to the few very high scores on the test, it is clear that many students are unsure of their answers. This important finding means a lack of trust, as stated by Milenković et al. (2016). On the other hand, when we look at the **Figure 2**, most of the students have low BT, but their confidence level is high. Therefore, low cor-

Table 2. All Possibilities of Responses.

All tier (AT)			
Both Tier (BT)			
First Tier (FT)	**Second Tier (ST)**	**Third Tier (TT)**	**Category**
Correct	Correct	Strongly sure or sure	Scientific knowledge
Correct	Correct	Not Sure or undecided	Lucky guess
Correct	Incorrect	Strongly sure or sure	Misconception false positive
Correct	Incorrect	Not Sure or undecided	Luck of knowledge
Incorrect	Correct	Strongly sure or sure	Misconception false negative
Incorrect	Correct	Not Sure or undecided	Luck of knowledge
Incorrect	Incorrect	Strongly sure or sure	Misconception
Incorrect	Incorrect	Not Sure or undecided	Luck of knowledge

Table 3. Percentages of FP and FN.

Variables	Questions										Mean (%)
	1	2	3	4	5	6	7	8	9	10	
FP	2.3	1.5	3.5	2.3	2.3	3.5	1.9	1.9	1.5	0.8	2.15
FN	3.5	0.8	1.9	2.3	5.4	2.3	1.5	1.2	1.5	1.9	2.23

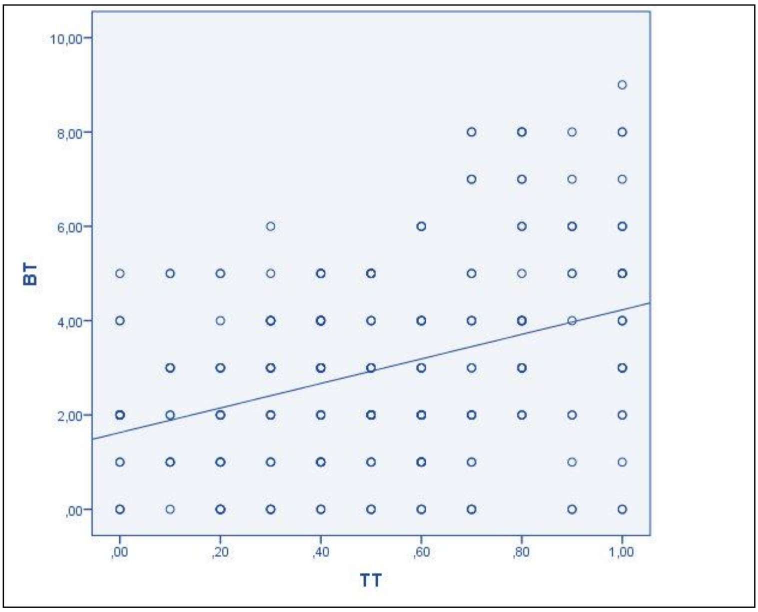

Figure 2. Scatterplot of BT versus TT.

relation was calculated between BT and TT. The reason for this may be the misconceptions of the students (Crocker & Algina, 2008).

Results

The Analysis on the Test's Definitions of the Contents by Tiers

The findings of the analysis on the test's definitions of the contents by tiers can be seen in **Table 4**.

The findings from **Table 4** indicated that the correct answer percentages gradually decreased from FT to AT. However, despite the gradual decrease in the response rate from BT to AT; TT rates continue to be higher. Accordingly, it was determined that the mean of correct answer percentage, which was 34.8% in the FT, was 29.5% in the BT and 20.1% in the AT. This difference of 5% between FT and BT scores can probably be attributed to the presence of false positives and false negatives. On the other hand, an average difference of about 9% was obtained between BT and AT. This difference may be due to lucky guessing or a lack of confidence. The approximately 14% difference between FT and AT scores can be attributed to lucky guess, lack of knowledge and misconceptions (Milenković et al., 2016). In summary, in the light of the findings, it can be said that the test successfully detected the misconceptions of the students about the digestive system.

The Prevalent Misconceptions Hold by Students

In this study, the student's percentage of SK, LG, LK and M are listed in **Table 5**. As seen in **Table 5**, 20.1% of students are in the category of SK, 9.1% are in the category of LG, 39.7% are in the category of LK, and 26.0% are in the category of M. According to the findings, LK has the highest percentage among the four categories. However, it is noteworthy that many students have misconceptions (26.0%).

In terms of SK, the highest percentage values belonged to Q2 (52.1%) and Q7 (49.4%) and the lowest values belonged to Q3 (9.3%) and Q6 (9.7%). When the findings were analyzed in terms of M, it was found that while the highest percentage value was in Q3 and Q4 (37.1%), the lowest value was in Q7 (14.7%).

In the study, misconceptions held by students were analyzed according to the tiers in order to see the misconceptions more clearly and they are presented in **Figure 3**. In **Figure 3**, it clearly can be seemed that the percentage of misconceptions decreases as the number of tier increases.

Table 4. Results of the Analysis of Correct Answers by Tiers.

Question	Score averages by test-tier, N = 259			
	FT	BT	AT	TT
Q1	30.5	25.5	18.5	49.4
Q2	67.2	61.4	52.1	72.2
Q3	23.2	17.4	9.3	51.7
Q4	22.8	19.3	12.0	54.1
Q5	30.9	24.7	13.1	47.9
Q6	24.3	17.8	9.7	40.2
Q7	64.9	60.6	49.4	67.6
Q8	27.4	21.6	11.6	41.3
Q9	28.2	22.4	11.6	40.9
Q10	28.6	23.9	13.5	41.3
Mean	34.8	29.5	20.1	50.7

Table 5. Analysis of Students' Conceptual Knowledge.

	Student test response categorizations, % (N = 259)			
Question	SK	LG	LK	M
Q1	18.5	6.2	43.6	23.6
Q2	52.1	7.7	18.5	17.4
Q3	9.3	8.1	38.2	37.1
Q4	12.0	7.3	38.6	37.1
Q5	13.1	11.6	40.5	27.0
Q6	9.7	7.7	51.7	24.7
Q7	49.4	11.2	21.2	14.7
Q8	11.6	10.0	48.6	26.6
Q9	11.6	10.8	48.3	26.3
Q10	13.5	10.4	48.3	25.1
Mean	20.1	9.1	39.7	26.0

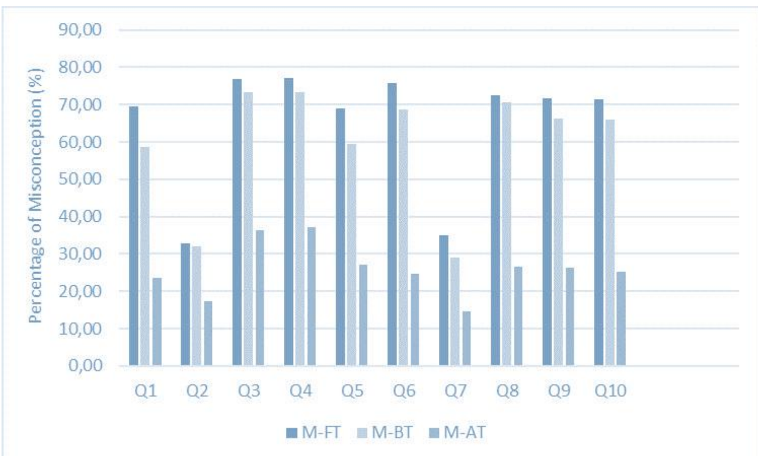

Figure 3. Analysis of Misconceptions by Tiers.

Many studies indicate that if the misconception rate (M-AT) is 10% or more, it should be considered significant (Bozdağ, 2017; Caleon & Subramaniam, 2010). When the findings in **Figure 2** are examined, it is understood that all the questions in the test showed the prevalence of misconceptions. It is understood from the findings in **Figure** 2 that all of the questions in the test show the prevalence of misconceptions. Especially Q3 and Q4 (37.1%) are the items that show the prevalence of misconception the most. The misconceptions related to these questions were summarized in **Figure 4-12**.

According to the findings in **Figure 4**, the percentages of correct answers were 30.5% for FT and 36.3% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option A.

According to the findings in **Figure 5**, the percentages of correct answers were 67.2% for FT and 62.2% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option C.

According to the findings in **Figure 6**, the percentages of correct answers were 23.2% for FT and 20.8% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option C.

According to the findings in **Figure 7**, the percentages of correct answers were 22.8% for FT and 23.2% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option D.

According to the findings in **Figure 8**, the percentages of correct answers were 30.9% for FT and 34.4% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option A.

According to the findings in **Figure 9**, the percentages of correct answers were 24.3% for FT and 24.7% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option B.

According to the findings in **Figure 10**, the percentages of correct answers were 64.9% for FT and 66.8% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option A.

According to the findings in **Figure 11**, the percentages of correct answers were 27.4% for FT and 23.6% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option C.

According to the findings in **Figure 12**, the percentages of correct answers were 28.2% for FT and 27.8% for ST. When the students' incorrect

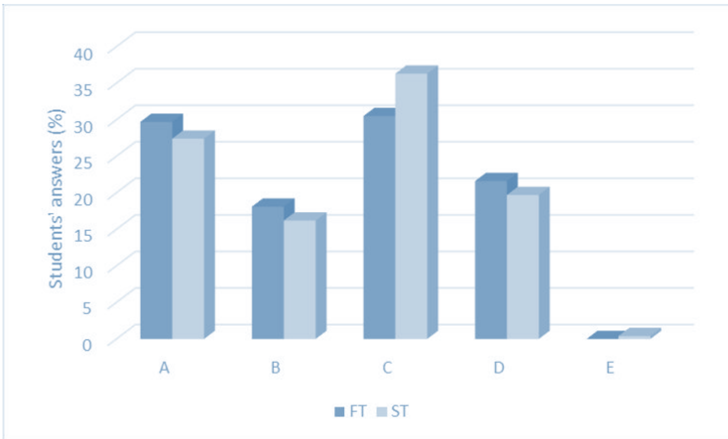

Figure 4. The Correct Answer for Q1 is C. *FT: First Tier, ST: Second Tier.*

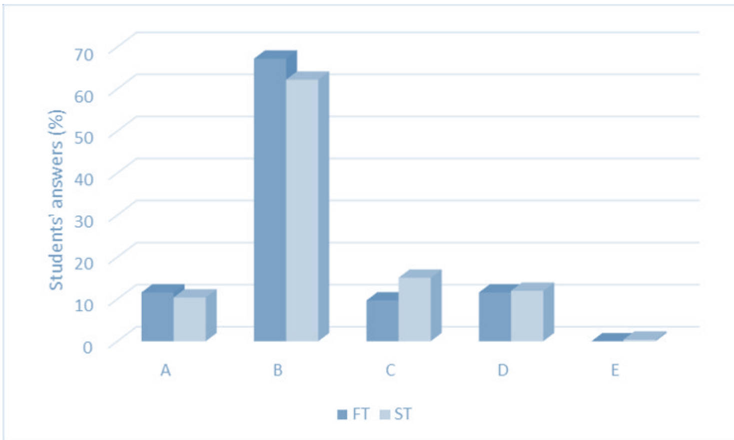

Figure 5. The Correct answer for Q2 is B.

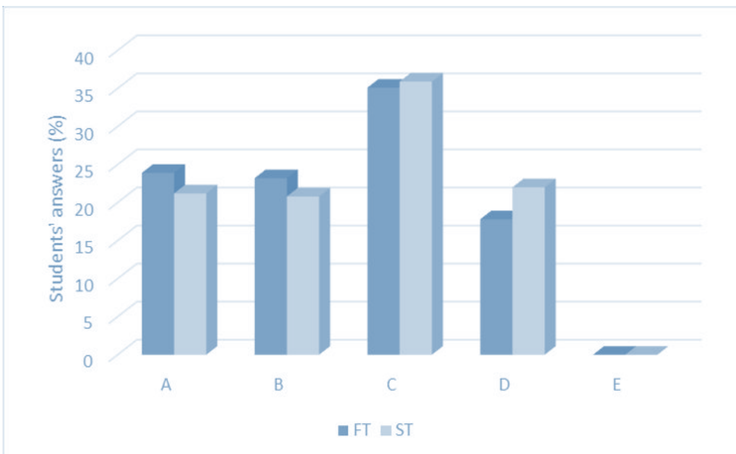

Figure 6. The Correct Answer for Q3 is B.

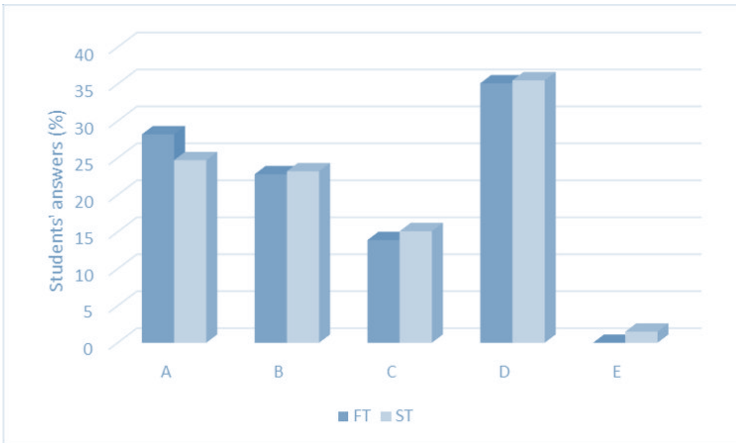

Figure 7. The Correct Answer for Q4 is B.

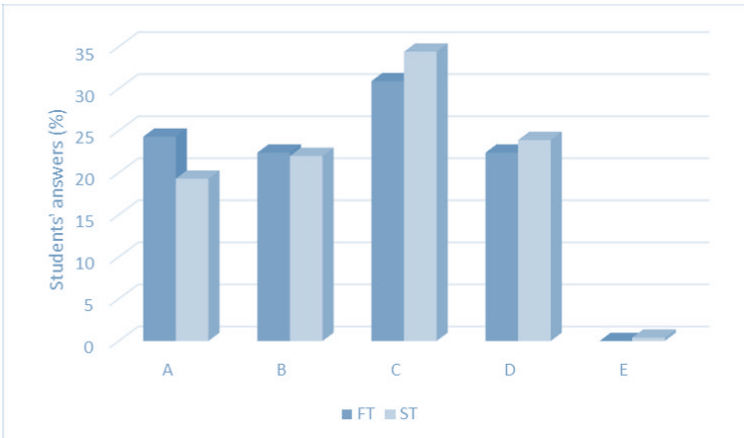

Figure 8. The Correct Answer for Q5 is C.

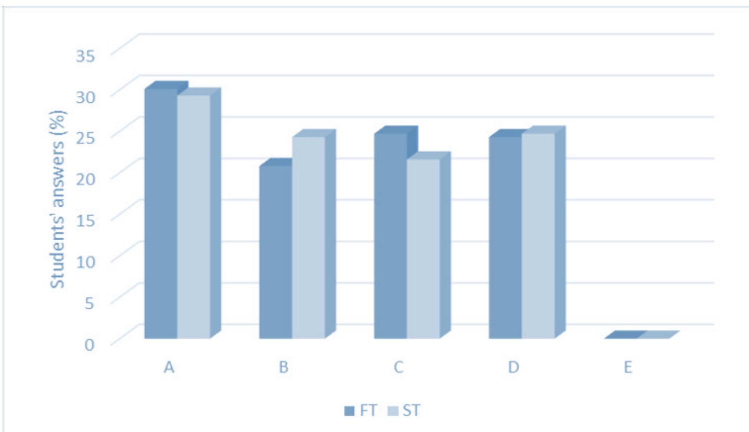

Figure 9. The Correct Answer for Q6 is D.

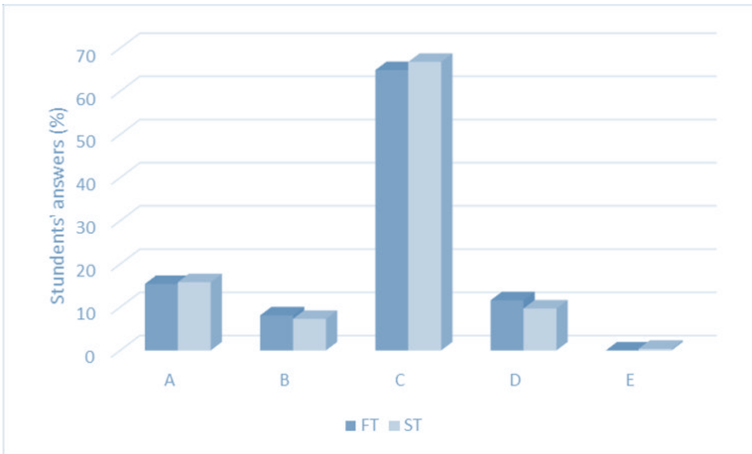

Figure 10. The Correct Answer for Q7 is C.

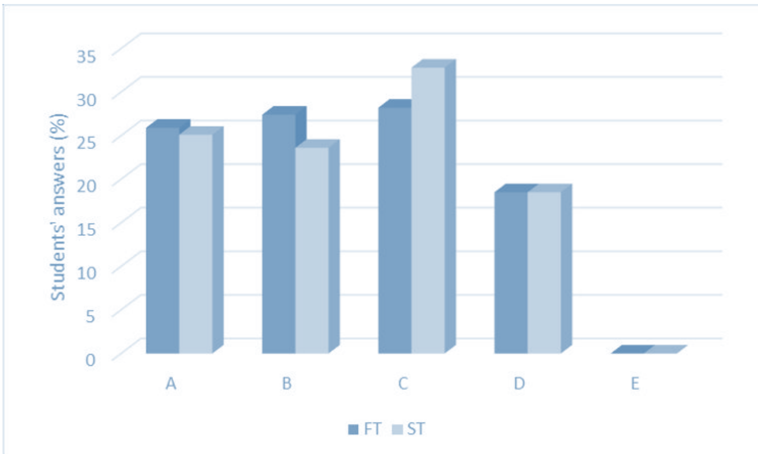

Figure 11. The Correct Answer for Q8 is B.

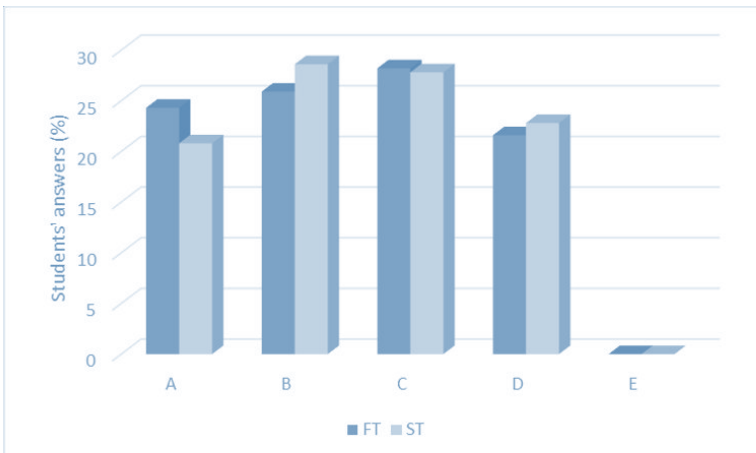

Figure 12. The Correct Answer for Q9 is C.

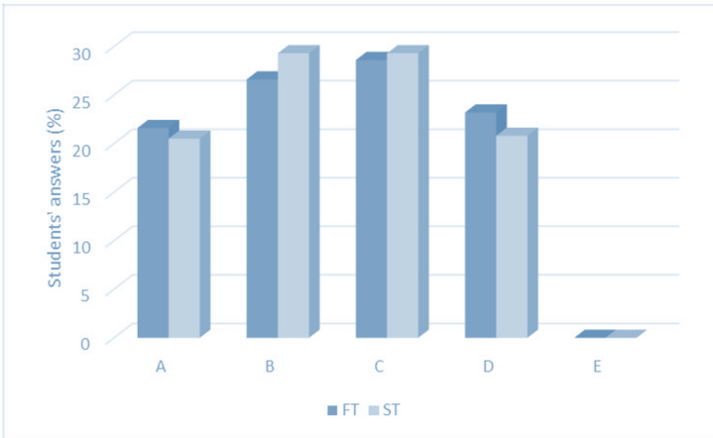

Figure 13. The Correct Answer for Q10 is C.

answers were examined, it was seen that they had the most misconception in option B.

According to the findings in **Figure 13**, the percentages of correct answers were 28.6% for FT and 29.3% for ST. When the students' incorrect answers were examined, it was seen that they had the most misconception in option B.

Discussion

The findings from **Table 4** indicated that the ratio of correct answer percentages gradually decreased from FT to AT. These findings are expected as they are in a full agreement with previous studies (Andariana et al., 2020; Bozdağ, 2017; Milenković et al., 2016; Suwono et al., 2021; Taban & Kiray, 2021). For example, in the study conducted by Andariana et al. (2020), the percentage of correct answers given by the students to the FT questions was higher than the ST, because the students could already distinguish the correct concept from the incorrect one. However, in some studies, most of the students could not give the correct answer to the question in the ST (Pascua & Chang, 2015). This situation shows that the students do not understand the concepts sufficiently. According to Pascua and Chang (2015), this is a partial understanding, that is, partial understanding is defined as the fact that students can answer the question in FT correctly, but fail to reason correctly for the ST answer. In other studies, this result was interpreted that students had difficulty in understanding the basic concepts related to the subject due to their tendency to memorize information (Johnston et al. 2015). Additionally, these results likely derived from the fact that answering first-tier multiple-choice questions would be easier than fulfilling the explanations (reason tier) as stated by Suwono et al. (2021). However, despite the gradual decrease in the response rate from BT to AT; TT rates continue to be higher. In other words, students who answer the questions incorrectly are sure of their answers. As stated before, the reason for this may be the misconceptions held by the students or the difficulty of the test (Crocker & Algina, 2008). The reason for these differences observed in the first three tiers may also be due to lack of self-confidence, lack of knowledge or lucky guess (Bozdağ, 2017).

It is accepted that there is a satisfactory level of conceptual understanding if at least 75% of the students choose the correct answer in the evaluation of the conceptual understanding level. If the ratio is between 50-74%, it is considered to be adequate, if it is between 25-49%, low and if it is below 25%, it is considered to have a very low level of conceptual understanding (Bozdağ, 2017; Gilbert, 1977). The results obtained with the three-tier test indicated that 18.3% of the students answered the overall test correctly. Therefore, this result can be evaluated as the students' conceptual understanding is quite low. In the study, it was also determined that the percentage of misconceptions decreases as the number of tier increases. Accordingly, it can be concluded that the three-tier tests are more effective in distinguishing students' misconceptions and lacks of knowledge more accurately than other tests. These findings are in parallel with the studies in the literature (Andariana et al., 2020; Milenković et al., 2016; Suwono et al., 2021). For example, Cheung and Yang (2018) reached similar results in their study and suggested the use of three tier tests as more effective tools to diagnose misconceptions compared to two tier and traditional multiple-choice question tests.

When the findings of the study are examined in detail in terms of each question, it was seen that they had the most misconception in option A for Q1. Accordingly, students think that physical digestion takes place in the esophagus. In fact, the esophagus, which is a muscular tube, delivers food to the stomach through a series of contraction movements called peristalsis. Therefore, students may have developed a misconception by associating the contraction and relaxation of the muscles in the esophagus with the crushing of food and thus exposure to physical digestion. Similar findings that students develop a misconception that physical or chemical digestion takes place in the esophagus were obtained in some studies (Bozdağ, 2017; Cerrah Özsevgeç et al., 2012; Özkan, 2017). However, it should be underlined that studies in which the misconception that physical/chemical digestion takes place in the esophagus are generally conducted at the national level. This finding may also be due to the fact that the esophagus is generally described more superficially among the digestive system structures and organs in the context of our country. For this reason, the importance of not only the basic organs of the digestive system, but also all its structures and organs, and even the accessory organs, should be emphasized and elaborated as a whole upon in the teaching process.

The findings from Q2 indicated that most of the students answered the question correctly. This question is related to the health of the digestive system and includes statements related to daily life. For this reason, it is thought that the correct answer was given by most of the students. On the other hand, it was seen that they had the most misconceptions in option C. Accordingly, students developed a misconception that it is beneficial to drink a lot of water during or just after a meal. Actually, drinking a normal level of water during or after a meal can aid digestion. However, excessive water consumption during or right after a meal tends to dilute the gastric juice. Our stomach is adept at absorbing water, but excess water intake after a meal dilutes the enzymes necessary for digestion. This is responded to by less secretion of digestive enzymes, which can lead to heartburn and acidity (Sengupta, 2019). The reason for the students' misconception about the need to drink plenty of water during or immediately after meals may be due to their association with the vital importance of water and helping digestion under normal conditions, as well as their lack of knowledge about the activity of enzymes. Therefore, while teaching any concept to students in the teaching process, its relationship with other concepts should be emphasized.

The findings from Q3 indicated that the students had the most misconceptions in option C. According to this, the students gave the kidney answer for the organ where water is absorbed the most. As it is known, the digestion of nutrients begins in the mouth and digestion is completed at the end of the small intestine. Digested nutrients and most of the water are absorbed in the small intestine and are prepared to be transported to the cells through the blood and lymph. Waste materials formed as a result of digestion and remaining water reach the large intestine. There is no absorption of nutrients here. The main task of the large intestine is to ensure the reabsorption of remaining water coming here. In the study, students' thinking that most of the water taken into the body is absorbed by the kidneys may be due to the kidneys' removal of some wastes such as urea through the urine and their role in reabsorption. Therefore, students may have developed the misconception that most of the water is absorbed by the kidneys. Similar misconceptions were found in a limited number of studies. For example, Cerrah et al (2012) determined that wastes are transmitted to the kidneys by the large intestine. And also, Dry (1998) revealed that students thought of the kidney as a digestive organ. In a study conducted by Güngör and Özgür (2009), it was determined that a wrong relationship was established between the digestive system and the urinary system by the students. It has been seen from the drawings of the students that the relationship between the digestive and urinary systems is not a relationship that takes place over the circulatory system, but a relationship in the form of direct connections between the digestive and urinary organs. In this case, it is important to correctly comprehend the relationship and distinction between the urinary system and the digestive system in the teaching process. On the other hand, similar to the results of the studies in the literature, it was stated by some students in this study that water is absorbed the most in the stomach. Students developed a misconception by thinking that water should be absorbed by using it here in order to slurry and soften the food in the stomach. Additionally, some students considered the large intestine to be the place where most water was absorbed. In the study conducted by Bozdağ (2017), the students said that water is absorbed more in the large intestine because of its function of reabsorption of residual water. In fact, students may have associated water absorption with the large intestine, as the large intestine is the last place where water absorption occurs and digestive wastes are removed from the body. Here, it is clear that students are confused about the processes of digestion and absorption. Because the large intestine is the last organ of the digestive system, students may have thought that both absorption and digestion are completed in the large intestine. In different studies in the literature, there are findings that students give examples of different organs for the absorption of water. For example, in the study conducted by Özkan (2017), the students stated that water and minerals are absorbed in the accessory organs to digestive.

The findings from Q4 indicated that the students had the most misconceptions in option D. Accordingly, although some students correctly know that mechanical digestion is achieved with chewing in the mouth and churning in the stomach, it was determined that most of them had the common misconception. As stated by Teixeira (2000), people have empirical evidence of where the digestive processes begin as they put food in their mouths. Therefore, it is usual for students to know that digestion begins in the mouth. However, the end point of these processes is not so clear. For this reason, although the place where digestion begins is known by the students, it has been revealed that they have some misconceptions about the organ in which it is completed. As known, the last place of digestion is the small intestine. Since water, vitamins and minerals are not digested, absorption takes place in the large intestine, and the last absorption takes place in the large intestine (Bozdağ, 2017). However, the highest percentage of misconceptions in the study is that digestion begins in the mouth and is completed in the large intestine. The reason for this misconception may be that the students think of the large intestine as the last organ of the digestive system. As a matter of fact, similar results were obtained in many studies and students stated that digestion ends in the large intestine (Bozdağ, 2017; Çuçin et al., 2020; Özkan, 2017). This result shows that the findings that students have confusion about the tasks of the small intestine and large intestine continue today (Andersson et al., 2020). In this case, it is considered important to understand the distinction of the functions of these two organs more accurately and to focus more on these organs during teaching.

In addition to the above, in Q5, students were directly asked about the organs where digestion and absorption take place last. Approximately 30% of the students answered correctly that the last digestion takes place in the small intestine and the absorption takes place in the large intestine. However, when the general evaluation of the other answers is made, it is clear that the majority of the students have misconceptions about the organs where digestion and absorption are completed last. Accordingly, students have misconceptions about the function of small intestine and large intestine as in Q4. This result shows that students experience confusion about the concepts of digestion and absorption, as stated before.

In Q6, the physical and chemical digestion processes of fats are shown on the figure, thus questioning students' knowledge of the function of bile and pancreatic juice. Most of the students thought that both processes were chemical digestion and took place with pancreatic juice. As known, bile is produced by the liver and stored in the gallbladder. During the digestive process, this fluid is released into the first part of the small intestine called the duodenum and aids in the digestion of lipids. Bile salts, the main component of bile, break up large oil droplets into smaller droplets (stage 1 in Q6). Thus, the surface area of lipids increases and the work of enzymes become more accessible. In the following processes, it undergoes chemical digestion with pancreatic and small intestine enzymes. In the study, the students thought that breaking the fat into small pieces (stage 1) and breaking it into its building blocks (stage 2) was a chemical process that took place with pancreatic enzymes. In addition, according to the 6th grade science curriculum, the digestion of fats begins and is completed in the small intestine. However, it has been determined that some students think that the digestion of fats occurs only with bile, and some of them think that saliva is responsible for the physical digestion of fats. According to these results, students have various misconceptions about the role of bile and saliva in digestion, the role of accessory organs such as the pancreas, in addition to mechanical and chemical digestion, which are also detected in the above findings. In the literature, it is seen that similar or different results with the findings of this study were reached. For example, Çucin et al. (2020) identified misconceptions such as "biliary fluid is an enzyme", "bile is produced in the gallbladder", "fats taken with food come to the small intestine without digestion in the mouth and stomach". Additionally, Cerrah Özsevgeç et al. (2012) identified misconceptions such as "fats are digested mechanically in small intestine", "liver turns toxic substance into bile", "liver digests fats mechanically", "pancreas secretes bile". In the study of Güngör and Özgür (2019), students stated that bile is an excretory waste that is thrown out after being used in a vital activity in the body. In study by Uğur (2010) and Bozdağ (2010), the misconception was also determined that bile does not have a role in the digestion of fats. As a result, according to the findings of this study, one of the misconceptions detected in Q6 is that the physical and chemical digestion phenomenon as in the previous questions of the test was not fully comprehended by the students. Similarly, Ahi (2017) stated that the participants could not determine the physical and chemical processes related to the digestive system. As a result, it is thought that one of the main reasons for this result stems from our national curriculum. Because one of the learning outcomes of the digestive system in the 6th grade science curriculum is "Only the definitions of chemical and physical digestion are given without mentioning the chemical digestion equations." is in the form. Therefore, students may have learned physical and chemical digestion by memorizing. As a result, they consider the activity of other organs on digestion as physical or chemical only. In addition, it should be considered that digestive organs as well as the accessory organs are an important part of this system. Because, as in this study, many studies show that students develop more misconceptions about the structure and function of the accessory organs (especially glandular organs such as salivary glands, liver, gallbladder, and pancreas). Therefore, in the teaching process, all the structures and organs of the digestive system should be considered as a whole, and teaching should be done by establishing relationships between concepts.

In Q7, the students were asked about the effect of swallowing the food taken by mouth without chewing it on digestion. As known, chewing increases the surface area of foods, allowing the enzymes to break down food more effectively. Accordingly, most of the students are aware that the contact surface of enzymes increases with chewing. However, when the incorrect answers of the students are examined, it is seen that some students think that the food was not digested in the stomach without chewing. Students associated these views with the thought that there would be no chemical digestion in the stomach without physical digestion. Some students thought that the food would be digested more quickly because it would go to the stomach without being swallowed. Therefore, it can be said that there are a few misconceptions here. For example, the students could not fully grasp the concept of physical and chemical digestion as determined in the previous questions. They also think that there is only chemical digestion in the stomach. On the other hand, they ignored the effect of chewing on enzyme activity. Few findings have been found in the literature regarding the effect of chewing on digestion. For example, in the study conducted by Uğur (2010), it was found that the absence of chewing does not affect digestion in the stomach. Özkan (2017) determined that the students thought that physical digestion takes place only in the mouth.

In addition to the above, in Q8, Q9 and Q10, students were asked questions about the digestion of carbohydrates and proteins. Although some of the students gave correct answers, many misconceptions were also detected. Some students do not know which organic substances (protein, fat, carbohydrate) are rich in the food types given in the questions. This result shows the importance of putting a little more emphasis on healthy nutrition in the curriculum and presenting more examples from daily life. In addition, most of students gave incorrect answers, especially about where protein and carbohydrates are digested. Various misconceptions were identified in the literature on the digestive system. However, majority of these studies is on structure of digestive organs (Ahi, 2017; Cerrah Özsevgec et al., 2012; Çuçin et al., 2020; Harahap et al., 2019; Özkan, 2017; Teixeira, 2000). A limited number of studies on misconceptions about organs where each of the nutrients (carbohydrate, protein, etc.) is digested and separated into building blocks have been reached (Özkan, 2017). As a result, according to the findings of this study, it is clear that students have confusion about the organs in which different foods are digested. This shows that they do not fully understand the function of the digestive system organs. Therefore, as stated by Núñez and Banet (1997), in order to understand the digestive system clearly rather than individual organs, it is necessary to teach the system as a whole and to teach by establishing relationships between concepts.

Conclusion

As a result of the general evaluation of the findings of the study, it can be said that the students who answered the test had serious difficulties in understanding and explaining the concepts related to the digestive system and developed misconceptions. In the study, it was found that some students were not sure of their answers in the third stage questions despite their correct answers to the first and second stage questions. This finding is in line with the findings of some studies in the literature (Andariana et al., 2020; Milenkovic et al. 2016; Suwono et al., 2021). As Suwono et al. (2021) stated, students' lack of confidence in their answers indicates that their understanding of concepts is not strong enough and their confidence in the concept is low. Regarding this issue, Dry (1998) suggested creating a classroom environment in which students can exchange thoughts and ideas without fear of being mistaken in order to bring alternative concepts to the fore. The teacher can then address the misconceptions and cause students to be dissatisfied with the existing framework of knowledge. Students will begin to reconstruct their framework to incorporate the new knowledge they have just received.

The most obvious findings reached in the study were the students' misconceptions in a few questions, especially about physical and chemical digestion. In addition, some students did not fully understand the distinction between the excretory and digestive organs and the functions of some the accessory. They also gave incorrect answers about the organs where the digestion of proteins, carbohydrates and fats begins and ends. It is suggested that students should be taught these concepts in a way that will enable them to learn in-depth and meaningfully, and that appropriate teaching methods and models should be used. It is recommended that the building blocks of organic compounds, the physical and chemical digestion process are given in more detail, and the information should be removed from the superficiality, and for this, the program should be updated. Ahi (2017) recommended reviewing the teaching of body functions, including the digestive system and other systems, in education programs.

Another finding is that most of students have misconceptions as well as lack of knowledge about the subject. As stated before, the subject of the digestive system is taught in the 6th grades in the secondary education curriculum. Therefore, the reason for the lack of knowledge identified in the study may be that the students in upper grades forgot some of the concepts due to the scientific disconnection they experienced in the following periods. Because, according to the forgetting curve put forward by Ebbinghaus as a result of his studies on the permanence of knowledge, people forget the information they have learned over time, and the rate of remembering what has been learned at the end of a one-month period can decrease to 20% (Ebbinghaus, 1885). Of course, in order to make a definite judgment on this issue, comparisons should be made at each grade level. In our study, 8th grade students could not be reached in some schools due to the LGS exam (High School Entrance System), and enough samples could not be reached because some students did not want to answer the questions. Therefore, the findings were not evaluated according to grade levels.

This study has some methodological limitations. The use of experimental methods in similar studies to be conducted in the future may provide clearer explanations for the reasons for similar findings. Andariana et al. (2020) recommended the active and meaningful learning model as one of the applicable learning models in this situation. According to Andariana et al (2020), an active and meaningful learning model can provide a high-quality learning experience that can facilitate students' understanding, reasoning, and realization of knowledge. On the other hand, this research was limited to a total of 259 middle school students. For further studies, similar studies can be conducted with high school or higher grade levels and a larger sample size. Finally, the results of this study are limited to the data collected by a three-tier diagnostic test about digestive system. In future studies, three-tier concept tests for different biology topics can be developed and applied to students.

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ORIGINAL ARTICLE

What do the Data Say? A Case Study with Pre-Service Teachers

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Abstract: *Data literacy, which is considered among 21st century skills, is becoming increasingly important. In particular, incentives for data-driven decision-making draw attention to data literacy. Data literacy is also critical for teachers who need to use data in educational settings. Therefore, there is a need for data on whether teachers are equipped with data literacy competencies before their service. In this study, pre-service teachers' data literacy competencies were examined. The case study approach was used in the study, which was conducted as qualitative research. The study group consisted of 61 pre-service teachers studying in three different undergraduate programs. Data were collected through the "What do the data say?" activity instrument. Rubrics were used to analyze the data. The findings of the study showed that while there was no difference in terms of using data and data communication, there was a statistically significant difference between the programs in terms of data recognition, comparing data and establishing relationships between data competencies, as well as total data literacy. In addition, it was found that the majority of pre-service teachers were partially inadequate or inadequate in terms of using data, data communication and total data literacy. Nearly half of them were partially inadequate or inadequate in comparing data and establishing relationships between data. The results indicated that pre-service teachers have certain deficiencies regarding data literacy.*

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Introduction

THE ROLE of data in our lives has increased dramatically over the last two decades. It is estimated that the amount of data generated reaches about 35-40 zettabytes (Çetin & Özkaya, 2019; Erdemir, 2018). The amount of data produced every two days is stated to be greater than that produced from the beginning of time to 2003 (Marr, 2020). Furthermore, the variety and complexity of data have increased compared to the past due to technological advances (Gibson & Mourad, 2018). Apart from its applications in the fields of economics and statistics, data is utilized in all areas of life, from education to health, from the environment to professional working areas and daily life (Fontichiaro et al., 2017). This requires individuals to analyze, interpret, and manage data, use data when making decisions, collect data when necessary, know the methods of collecting and transmitting data, and think based on data to solve problems. For this reason, being data literate is necessary. In the 21st century, data literacy is considered among the important skills and the understanding of its importance is increasing (Fontichiaro et al., 2017; Valencia, 2021).

Data literacy refers to accessing and understanding data; interpreting the information from the data; developing data-driven inferences and explanations; using data as part of evidence-based thinking; evaluating the data critically; formulating and answering problems/questions based on data; using appropriate data, tools, and presentations to support an idea; using data to solve real/authentic problems and communicating solutions; and paying attention to ethical issues when using data (Calzada-Prado & Marzal, 2013; Vahey et al, 2006; Vahey et al., 2012). The framework of data literacy can expand depending on the context. For example, the understanding of data literacy may vary depending on the goals of an individual or organization. The nature of datasets, the intended use of data, and the roles of those who deal with data (e.g., scientists, makers, readers, and communicators) lead to different definitions of data literacy (Wolff et al., 2016). Matthew (2016) points out that the concept of data literacy involves uncertainty and that it would be useful to consider data literacy as a capability. From this perspective, it is possible to talk about data literacy competencies (Wolff et al., 2016).

There are different explanations in the literature on what data literacy competencies are. Data literacy competencies, which are commonly discussed in the aforementioned explanations and need to be used frequently, can be examined as follows: Data recognition, using data, comparing data, data cleaning, selecting data, data source, data quality, data transformation, data collection, data analysis, data presentation, data communication, and data ethics (Temel-Aslan, 2022a; Mandinach et al., 2011; Matthew, 2016). These competencies are introduced below.

Data recognition: Identifying the type of the data (e.g., quantitative or qualitative data) includes being able to determine what the data is about, the context of the data, changes in the data, patterns, and any discrepancies (Hunter-Thomson, 2019; Temel-Aslan, 2022b). Using data: It includes being able to evaluate the data critically; form questions, claims, and arguments based on data; make decisions based on data; use data to support an idea; use data when identifying/presenting a problem/problem or creating a solution to the problem/problem; and being aware of the inference space when using data (Hunter-Thomson, 2020; Matthew, 2016, Temel-Aslan, 2022a). Comparing data: It includes being able to compare two or more groups of data; knowing which methods to use when making comparisons (e.g., arithmetic mean, standard deviation, or proportional reasoning); and reasoning and making inferences based on such comparisons (Reaburn, 2012; Ünlü, 2022). Data cleaning: It involves identifying, correcting, or removing incorrect, corrupt, incorrectly formatted, irrelevant, inconsistent, duplicate, or incomplete data in the dataset (Erwin, 2015; Rahm & Hai Do, 2000). Selecting data: It involves deciding what data is needed to address a particular question or problem (Kjelvik & Schultheis, 2019). Data selection requires identifying the appropriate type and source of the data and the appropriate tools for collecting data (The Office of Research Integrity [ORI], 2021). Data source: It includes being able to determine from which source the data is obtained or will be obtained (e.g., the primary source or secondary source), critically evaluate the data sources, select the correct and reliable ones among the data sources, know the ways to reach the data sources, compare the data from different data sources, and document the sources used (Calzada-Prado & Marzal, 2013; Dong et al., 2009; Rabianski, 2003). Data quality: It includes being able to determine whether the data reflects reality and is reliable, being aware of what information is needed about the quality of the data (for example, data quality dimensions such as accuracy, completeness, and consistency), knowing how to obtain this information, and valuing the data in terms of data quality (DAMA UK Working Group, 2013; Jesilevska, 2017; Shankaranarayan et al., 2003; Wang & Strong, 1996). Data transformation: It includes knowing how to visualize data representations and data; being able to select and use appropriate visualization methods and tools; and being able to convert data from one format (e.g., a table) to another format (e.g., a graphic) (Hunter-Thomson, 2019; Jones et al., 2000). Data collection: It includes being able to collect data and create data, knowing which technology to store and share data and how to use it, obtaining data from sources, evaluating the quality of that data; finding and using purposeful external data repositories; and importing data from data sources (Calzada-Prado & Marzal, 2013; Ertaş-Kılıç, 2022b; Gibson & Mourad, 2018; Nelson, 2015). Data analysis: It includes being familiar with basic data processing, analysis tools, methods, and techniques of the discipline or research area to which the data relates; understanding the impact of these tools, methods, and techniques on data; being able to select and apply appropriate tools and techniques for data analysis; being able to evaluate the results of the analysis and compare them with other findings; and determining an appropriate workflow for repeated analyses of data (Ertaş-Kılıç, 2022a; Mandinach & Gummer, 2016; Nelson, 2015). Data presentation: It includes being familiar with data presentation methods and tools; being able to plan and implement how the data will be presented in a form that is understandable; being able to evaluate the advantages and disadvantages of different methods of presentation; knowing the general rules of data presentation methods; and being able to recognize errors and gaps in data presentation (In & Lee, 2017; Royal Geographical Society, n.d.; Unwin, 2008). Data communication: It includes knowing the methods and tools of synthesizing, visualizing, and representing data; knowing how to communicate with data (for example, reporting and presenting data); knowing which technology to use to share data and how to use it; explaining the presentation of data in different formats (e.g., table or graphic); understanding how data can be used as evidence during discussion and use (data as evidence); being able to evaluate the strengths, weaknesses, and limitations of the data; understanding and expressing the relationships between data; knowing the tools that can be used to transmit data (e.g., websites [multimedia], short videos, text-based information, comic books, games, or audio stories) (D'Ignazio & Bhargava, 2015; Gibson & Mourad, 2018; Keray-Dinçel, 2022; Maybee & Zilinski, 2015; Sander, 2020). Data ethics: It generally involves collecting, analyzing, storing, sharing, protecting, and using data ethically (Floridi & Taddeo, 2016). Although the boundaries of the competencies described above are unclear, there may be a transition between competencies. Considering competencies in this way can facilitate a better understanding of them. In this study, four competencies that are thought to be more frequently used are included: 'data recognition', 'using data', 'comparing data and establishing relationships between data', and 'data communication'.

Teaching individuals' data literacy competencies is an important expectation for formal education. In the context of education in Türkiye, data literacy is mostly considered either within the scope of information literacy or as a learning area of mathematics (Akcan & Gençyürek-Erdoğan, 2019; Ministry of National Education [MoNE], 2018a; Yabanlı et al., 2013). However, when the scope of data literacy and its widespread use are taken into consideration, the necessity of looking at data literacy with an interdisciplinary understanding emerges. The prediction that data literacy will have a more important role in many professions supports this perspective. For this reason, within the framework of formal education in schools, in addition to teaching the basic contents and experimental methods related to the disciplines, it is also necessary to develop the data literacy competencies of the students (Schüller, 2020; Temel-Aslan, 2022a). In this development effort, using an interdisciplinary approach is necessary rather than considering it as a learning area of mathematics alone. Although the importance of data literacy is directly or indirectly included in educational programs (MoNE 2018a, 2018b, 2018c), whether an understanding of the subject is reflected in classroom practices needs to be determined.

This study aims to assess some data literacy competencies of pre-service teachers, shedding light on their potential to teach data literacy in the future. It also seeks to reflect on how they can enhance their understanding of teaching and improving data literacy in their classroom practices, as well as the role of their past learning experiences in acquiring and developing data literacy competencies.

Method

In this study, a qualitative research method known as the case study approach was employed to assess the data literacy competencies of pre-service teachers. Case studies aim to provide comprehensive, systematic, and in-depth insights into specific situations of interest (Patton, 2014). This approach places a strong emphasis on examining roles and relationships within a given context, whether it involves an environment, individual, or process as a whole (Yıldırım & Şimşek, 2013). Within the scope of this study, the case study method was utilized to conduct a thorough examination of select data literacy competencies among pre-service teachers. It's important to note that the data collected through the chosen tools were analyzed without seeking generalization.

Participants

The study group, consisting of 61 pre-service teachers, was selected using the convenience sampling method. These pre-service teachers are enrolled at a state university located in the Central Anatolia region of Türkiye. It was determined that the pre-service teachers who participated in the research did not receive any direct training on data literacy before this research. Among these pre-service teachers, 22 of them are studying Science Education, 20 of them are in Turkish Language Education, and 19 are in Mathematics Education programs. PISA (Program for International Student Assessment), an international monitoring research in education, was taken into account in selecting the participants from the specified programs. As it is known, PISA is an international research conducted by OECD (Organisation for Economic Co-Operation and Development) in three-year cycles, evaluating the knowledge and skills acquired by students in the 15-year-old group. In PISA applications, students' reading skills and literacy in mathematics and science are evaluated (OECD, 2023). When the proficiency levels in the mentioned areas are examined, it is understood that students are expected to be data literate. For example, text types are included when defining different dimensions to measure reading skills. In this context, it is stated that texts may contain lists, tables, graphs, diagrams, advertisements, plans, catalogues, indexes and that such texts require a different reading approach. In addition, the topic of "uncertainty and data" is included in mathematics, and "interpreting data and findings scientifically" in science (MoNE, 2019). Considering these explanations, it can be said that students are expected to develop an understanding of data literacy in all three areas of the PISA research. The role of teachers is important in developing students' data literacy competencies. Within the framework of formal education in Türkiye, teachers who carry out the education and training process at the secondary school level in these fields are selected among the teacher candidates who graduated from mathematics, science, and Turkish Language Education departments. For this reason, teacher candidates studying in the mentioned departments were determined as participants. From this point on, pre-service teachers studying in the Department of Science Education are abbreviated as PST, those studying in the Department of Mathematics Education as PMT, and those studying in the Department of Turkish Language Education are abbreviated as PTLT.

Data Collection Tools

"***What do the Data Say?" Activity Instrument***: The activity instrument, prepared at the undergraduate level, includes the topic of earthquakes. In the introduction section of the instrument organized under the title of "What do the data say?", information was given about earthquakes, one of the natural disasters that take place on Earth. The text includes information about earthquakes, how they occur, and how their magnitudes are measured. In other parts of the activity, data are provided on the earthquakes that took place in 2020 in Türkiye and their immediate surroundings, magnitudes, and distribution according to the month, and questions are asked about this data. The data presented in the table and graph are obtained by Boğaziçi University, Kandilli Observatory, and the Earthquake Research Institute Regional Earthquake-Tsunami Monitoring and Evaluation Center and is publicly available (Kandilli Observatory, and the Earthquake Research Institute, 2021).

There are five stages in the activity. In phase I, the data were presented in tables and there were 12 questions related to this data. In phase II, the data were presented as a graph and eight questions were formed to analyze this data. The questions in phase III were designed to analyze the data presented in tables and graphs in stages I and II together. There were three questions in this stage. In phase IV, the data were presented as a map, one of the data visualization types. This map is the earthquake hazard map of Türkiye for 2020, created by the Disaster and Emergency Management Presidency [AFAD], (2021). An argument was put forward regarding this map, which was supposedly shared on social media, and students were asked to answer two questions about this argument. In the final phase of the study, pre-service teachers were tasked with adopting the role of a journalist. Specifically, they were required to communicate the information derived from the data regarding the earthquake to their readers. This was to be accomplished by incorporating the tables, graphs, and maps provided in the earlier stages along with informative text. The aforementioned phases aim to determine the main competencies of the pre-service teachers in "recognizing the data, comparing the data, and establishing a relationship between the data, using the data, and data communication" and the sub-competencies given in the table with questions created about the data (data presented in the form of tables, graphs, and maps). In the activity aimed at determining how pre-service teachers perform in the aforementioned data literacy competencies, the competencies to be measured and the questions related to them are given in **Table 1**.

The activity, which was prepared by the researchers, was presented for the opinion of three academicians who are experts in the fields of mathematics, Turkish, and science education. The content of the text and the scope of the questions were re-evaluated and readied for a preliminary study. In the preliminary study, the activity was applied to three pre-service teachers, rearranged with the feedback of the students, and finalized. The main application's data were gathered once, and the activity's implementation took about 90 minutes.

Data Analysis

Scoring the Answers of the Competencies of Recognizing the Data, Comparing the Data, and Establishing Relationships between the Data

In the analysis of the questions designed to assess competencies related to data recognition, data comparison, and data relationship establishment (questions in phases I, II, III, and IV), responses were scored on a scale of 0 to 3. The scores and criteria for evaluating the questions are given in **Table 2**.

After all of the questions had been scored, the data was re-evaluated by a different researcher to ensure consistency, and the intraclass correlation coefficient was used to determine the degree of agreement between the as-

Table 1. The Competencies Assessed by the Activity and the Corresponding Questions.

Competencies to be measured by the activity	
Recognizing data	a) Recognize data presented in tabular form (Phase I: Questions 1, 2, 3)
	b) Recognizing graphically presented data (Phase II: Questions 1, 2, 3)
Comparing data and establishing relationships between data	a) Comparing the data presented in tabular form and establishing a relationship between the data (Phase I: Questions 4, 5, 6, 7, 8, 9, 10, 11)
	b) Comparing data presented graphically and establishing a relationship between data (Phase II: Questions 4, 5, 6, 7)
	c) Comparing data presented in different formats (Phase II: Question 8)
Using data	a) Generating data-based claim (Phase III: Question 1)
	b) Evaluate the claim generated based on data (Phase I: Question 12; Phase III: Question 2)
	c) Identify data associated with the claim (Phase III: Question 3)
	d) Generating arguments based on data (Phase IV: Question 2)
	e) Evaluate the argument generated based on the data (Phase IV: Question 1)
Data communication	a) When creating the text, provide all relevant or requested data (Phase V: Question 1)
	b) Specify the data source when creating the text (Phase V: Question 1)
	c) Include relationships/comparisons between data when creating text (Phase V: Question 1)
	d) To be able to express what the data says when creating the text (to be able to identify the area of inference) (Phase V: Question 1)
	e) Creating a data-driven argument while creating the text (Phase V: Question 1)
	f) Distinguish between data and opinions when creating the text (Phase V: Question 1)
	g) Organization of knowledge (Phase V: Question 1)

Table 2. Evaluation Criteria and Scoring for Answers.

	Criteria	Scoring
Incorrect	Unacceptable (All explanations are incorrect, unacceptable, or without an answer.)	0
Partially incorrect (errors are in the majority)	Partially acceptable However, the majority of responses contain errors (The explanations contain accurate and acceptable parts, but they also contain incomplete parts).	1
Partially correct (rights are in the majority)	Partially acceptable However, there are deficiencies (The explanations are accurate and acceptable, but they have deficiencies).	2
Correct	Acceptable (All explanations are true and acceptable.)	3

Table 3. Intraclass Correlation Coefficients between Raters for Competencies and Total Data Literacy.

Competencies	Assessors	n	$\bar{X}$	ss	r_{xy}
Recognizing data	1	61	11.28	3.19	0.941
	2	61	11.31	3.06	
Using data	1	61	6.84	2.89	0.930
	2	61	6.31	2.67	
Comparing data and establishing relationships between data	1	61	19.70	4.76	0.921
	2	61	19.59	4.95	
Data communication	1	61	8.13	4.95	0.898
	2	61	4.51	3.25	
Total data literacy	1	61	45.98	10.81	0.935
	2	61	41.72	9.38	

Table 4. Level Scores According to Data Literacy and Sub-Competencies.

Competencies	Max. points	Min. points	Inadequate	Partially inadequate	Partially adequate	Adequate
Recognizing Data	18.00	0.00	0.00-4.49	4.50-8.99	9.00-13.49	13.50-18.00
Using Data	18.00	0.00	0.00-4.49	4.50-8.99	9.00-13.49	13.50-18.00
Comparing Data and Establishing Relationships between Data	39.00	0.00	0.00-9.74	9.75-19.49	19.50-29.24	29.25-39.00
Data Communication	21.00	0.00	0.00-5.24	5.25-10.49	10.50-15.74	15.75-21.00
Total Data Literacy	96.00	0.00	0.00-23.99	24.00-47.99	48.00-71.99	72.00-96.00

sessors (see **Table 3**). Consensus was achieved among the assessors' regarding the scores they assigned.

Scoring the Answers for Data Communication Competency

The data of the answers in phase V within the scope of data communication competency of the pre-service teachers participating in the research were evaluated using an analytical rubric. The rubric used was developed by determining the issues to be considered when sharing data and creating an informative text based on the data by examining the literature on data communication. The rubric consists of seven criteria and four grades. The lowest score that can be obtained from the rubric is 0 while the highest is 21. Data communication competency was assessed according to the total score obtained from the rubric. The rubric was examined by three academicians working in the fields of science, Turkish, and mathematics education. After the necessary edits and corrections were made, the rubric was used for data analysis.

Reliability

To ensure reliability during the scoring of the rubric, two different raters scored the answers, and agreement between them was calculated using the intraclass correlation coefficient. This statistic was preferred because it allows determining the interrater reliability coefficient based on both competencies and the total score (Kutlu et al., 2010). A common opinion of the raters was obtained on the different scores given by them. The intraclass correlation coefficients demonstrating alignment between raters regarding competencies and total data literacy are presented in **Table 3**.

According to **Table 3**, the interrater reliability coefficients are above .89 for competencies and total data literacy. This value shows that the agreement between the assessors and the reliability of the results are high (Howell, 1997; Kutlu et al., 2010; Şencan, 2005).

Analyzing Data Related to Data Literacy Competencies

In the study, the total scores for each of the competencies measured under the scope of data literacy, as well as the 'total data literacy' score derived from the sum of these competency scores, were analyzed. As the scores did not show normal distribution for all three sections and the group sizes were less than 30, non-parametric statistics were used to analyze the data (Büyüköztürk, 2012; Evrekli et al., 2011). As the number of groups was 3, the Kruskal–Wallis H test for unrelated measurements was applied.

To better understand pre-service teachers' data literacy status, each data literacy competency score and the total data literacy score were divided into four equivalent score intervals. Since the rubrics were structured in four grades, four score ranges were determined (Özçakır-Sümen & Çalışıcı, 2019). The level for each score range is defined. Thus, pre-service teachers were divided into level groups according to the scores they obtained from the relevant competency. The findings are presented in graphs. Table 4 shows the maximum and minimum scores that can be obtained from data literacy, competencies, and the level groups according to the scores.

The level groups in **Table 4** are determined as inadequate, partly inadequate, partly adequate, and adequate. Inadequate refers to either completely or substantially incorrect answers to questions about data literacy; partially inadequate refers to answering questions about data literacy in such a way that errors are in the majority; partially adequate refers to answering questions about data literacy in such a way that corrects are in the majority; adequate level refers to answering questions about data literacy either completely or largely correctly.

Research Ethics

Participants were informed about the purpose of the research and their rights in the research. They were also notified that they had the freedom to withdraw from the study at any point, without providing a reason, and without facing any difficulties. The data were securely stored, analyzed with strict confidentiality, and reported anonymously. Furthermore, in accordance with ethical regulations, approval for this study was obtained from the Human Research Ethics Committee of the university to which the authors are affiliated.

Results

This section presents descriptive and inferential statistical findings. The results of the descriptive analysis of data literacy of pre-service teachers according to departments are given in **Table 5**.

According to Table 5, the averages of the total data literacy scores of PST ($\bar{X}$ = 47.86) and PMT ($\bar{X}$ = 48.47) are similar to each other. The mean score of data literacy for PTLT ($\bar{X}$ = 39.55) is lower than other departments. Descriptive analysis results for data literacy competencies are presented in Table 6.

According to **Table 6**, the mean scores of PST and PMT are similar to each other in the competencies of recognizing and using data among the data literacy competencies of pre-service teachers. The average scores of PTLT's competencies for recognizing the data, comparing the data, and establishing relationships between the data are low compared to the other departments. Conversely, the average score of PTLT's competence in using the data is higher than the other departments. In data communication competency, the averages of PST, PMT, and PTLT differ slightly from each other.

The Kruskal–Wallis H test results for pre-service teachers' total data literacy and data literacy competencies by departments are presented in **Table 7**.

As per **Table 7**, the scores of pre-service teachers on data recognition competency differ significantly according to the departments (χ^2 [SD = 2, n

Table 5. Descriptive Analysis Results for Total Data Literacy Scores of Pre-Service Teachers by Departments.

Departments	n	Max.	Min.	$\bar{X}$	ss
PST	22	62	24	47.86	9.30
PMT	19	71	22	48.47	12.06
PTLT	20	53	17	39.55	9.58

Table 6. Descriptive Analysis Results of Pre-Service Teachers' Data Literacy Competency Scores by Departments.

Data Literacy Competencies	Departments	N	Max.	Min.	$\bar{X}$	ss
Recognizing data	PST	22	18	7	12.27	2.51
	PMT	19	18	7	12.79	3.03
	PTLT	20	13	1	8.00	3.08
	Total	61	18	1	11.03	3.54
Comparing data and establishing relationships between data	PST	22	31	13	22.27	4.30
	PMT	19	27	14	21.16	3.99
	PTLT	20	25	6	16.85	4.88
	Total	61	31	6	20.15	4.94
Using data	PST	22	14	2	6.32	2.34
	PMT	19	11	0	6.47	2.99
	PTLT	20	12	0	7.20	2.93
	Total	61	14	0	6.66	2.73
Data communication	PST	22	14	0	7.00	5.18
	PMT	19	18	1	8.05	4.92
	PTLT	20	16	0	7.50	4.65
	Total	61	18	0	7.49	4.87

Table 7. Kruskal-Wallis H Test Results of Data Literacy Competencies and Total Data Literacy by Departments.

Competencies	Departments	n	Row average	sd	$\chi2$	p	Difference
Recognizing data	PST	22	37.09	2	16.90	0.000*	PST-PTLT, PMT-PTLT
	PMT	19	39.68				
	PTLT	20	16.05				
Comparing data and establishing relationships between data	PST	22	38.05	2	8.50	0.002*	PST-PTLT, PMT-PTLT
	PMT	19	34.74				
	PTLT	20	19.70				
Using data	PST	22	27.73	2	1.56	0.368	
	PMT	19	30.24				
	PTLT	20	35.33				
Data communication	PST	22	28.84	2	1.19	0.716	
	PMT	19	33.37				
	PTLT	20	31.13				
Total data literacy	PST	22	35.48	2	4.39	0.016*	PST-PTLT, PMT-PTLT
	PMT	19	35.66				
	PTLT	20	21.65				

= 61] = 16.90, $p < 0.05$). When the order averages are taken into consideration, the scores of PMT for the competency of recognizing the data are the highest among the departments, followed by PST and PTLT. The competency scores of PMT and PST in recognizing the data did not significantly differ, but there was a significant difference between the scores of pre-service teachers in these two departments and those obtained by PTLT. When the scores of pre-service teachers on the competency of comparing data and establishing relationships between data are compared, a significant difference according to the departments is observed (χ^2 [SD = 2, n = 61] = 8.50, $p < 0.05$). Considering the order of averages, PST obtains the highest score in the competency of comparing and establishing relationships between data, followed by PMT and then PTLT. While there was no significant difference between the scores obtained by PMT and PST from the competency of comparing the data and establishing a relationship between the data, the difference between the scores received by the pre-service teachers of these two departments and those obtained by PTLT was significant. The scores of pre-service teachers in data use and data communication competencies did not significantly differ among the departments.

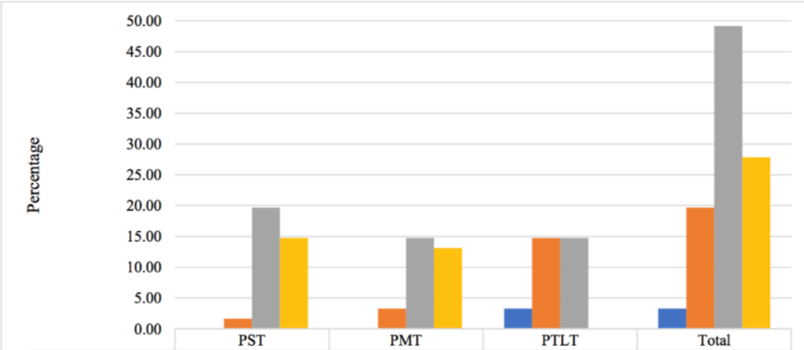
The results of the analysis show that the total data literacy scores of pre-service teachers differ significantly by departments (χ^2 [SD = 2, n = 61] = 4.39, $p < 0.05$). When the order averages are taken into consideration, the total data literacy scores of PMT are the highest among the departments, followed by PST and then PTLT. While there was no significant difference between the data literacy scores of PMT and PST, the difference between the scores of the pre-service teachers of these two departments and those of PTLT was significant.

Level Groups Determined According to the Scores of Pre-Service Teachers from the Data Literacy Competencies and Total Data Literacy

Level Groups for the Competency of Recognizing Data

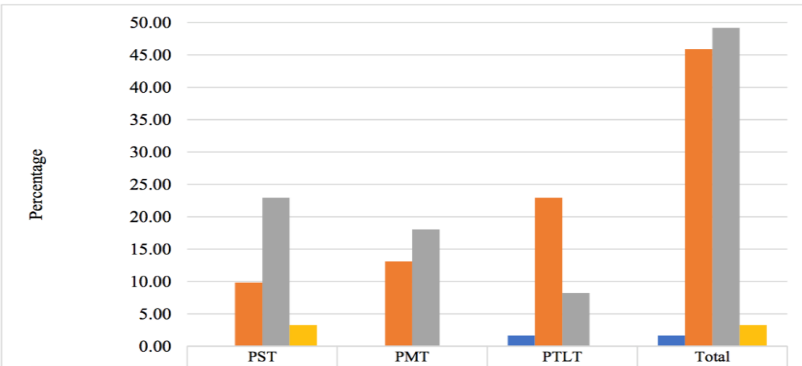
The results pertaining to the level groups established based on pre-service teachers' scores in data recognition competency are presented in **Figure 1**.

According to Figure 1, 3.3% (n = 2) of the pre-service teachers were at the "inadequate" level in terms of data recognition competency and both these pre-service teachers were PTLT. Meanwhile, 19.7% of the pre-service teachers were at the "partially inadequate" level. Of these pre-service teachers, 1.6% (n = 1) were PST, 3.3% (n = 2) were PMT, and 14.8% (n = 9) were PTLT. Furthermore, 49.2% (n = 30) of the pre-service teachers are at the "partially adequate" level. Of these pre-service teachers, 19.7% (n = 12)



	PST	PMT	PTLT	Total
inadequate	0.00	0.00	3.28	3.28
partially inadequate	1.64	3.28	14.75	19.67
partially adequate	19.67	14.75	14.75	49.18
adequate	14.75	13.11	0.00	27.87

Figure 1. The Levels of Pre-Service Teachers According to the Competency Score of Recognizing Data by Departments



	PST	PMT	PTLT	Total
inadequate	0.00	0.00	1.64	1.64
partially inadequate	9.84	13.11	22.95	45.90
partially adequate	22.95	18.03	8.20	49.18
adequate	3.28	0.00	0.00	3.28

Figure 2. The Levels of Pre-Service Teachers According to the Competency Score of Comparing Data and Establishing Relationships between Data by Departments.

were PST, 14.8% (n = 9) were PMT, and 14.8% (n = 9) were PTLT. Finally, 27.9% (n = 17) of the pre-service teachers were at the “adequate” level. Of the pre-service teachers at this level, 14.8% (n = 9) were PST and 13.1% (n = 8) were PMT. There is no PTLT at this level.

Level Groups for the Competency of Comparing Data and Establishing Relationships between Data

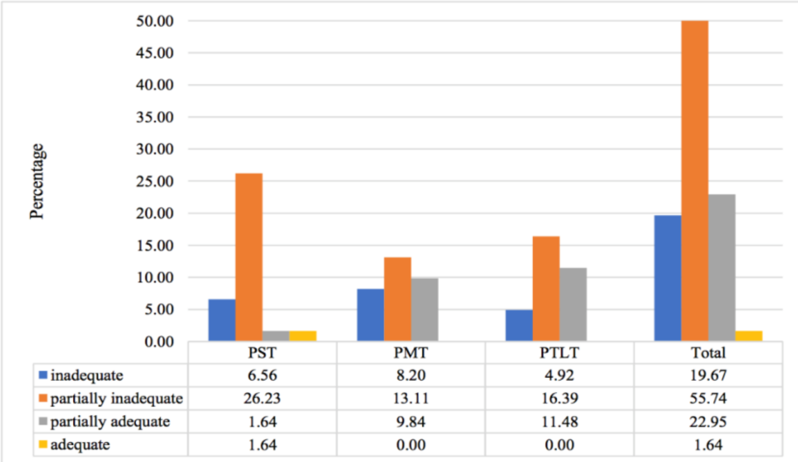
The findings regarding the level groups determined according to the scores of the pre-service teachers in the competency of comparing data and establishing relationships between data are given in **Figure 2**.

According to **Figure 2**, 1.6% (n = 1) of the pre-service teachers were at the “inadequate” level in terms of the competency of comparing data and establishing relationships between data, and they are PTLT. In addition, 45.9% (n = 28) of the pre-service teachers were at the “partially inadequate” level. Of these pre-service teachers, 9.8% (n = 6) were PST, 13.1% (n = 8) were PMT, and 23% (n = 14) were PTLT. Further, 49.2% (n = 30) of the pre-service teachers are at the “partially adequate” level. Of these pre-service teachers, 23% (n = 14) were PST, 18% (n = 11) were PMT, and 8.2% (n = 5) were PTLT. Finally, 3.3% (n = 2) of the pre-service teachers were at the “adequate” level. Both the pre-service teachers at the proficient level were PST. There was no pre-service teacher at this level from the other departments.

Level Groups for the Competency of Using Data

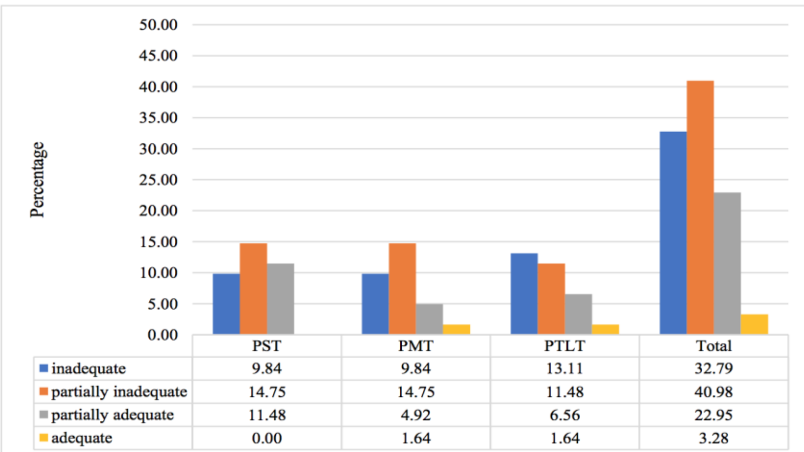
The findings regarding the level groups determined according to the scores of the pre-service teachers on the competency of using data are given in **Figure 3**.

As per **Figure 3**, 19.7% (n = 12) of the pre-service teachers were at the “inadequate” level in terms of competence in using data. Of these pre-service teachers, 6.6% (n = 4) were PST, 8.2% (n = 5) were PMT, and 4.9% (n = 3) were PTLT. Meanwhile, 55.7% (n = 34) of the pre-service teachers were at the “partially inadequate” level. Of these pre-service teachers, 26.2% (n = 16) were PST, 13.1% (n = 8) were PMT, and 16.4% (n = 10) were PTLT. Further, 23% (n = 14) of the pre-service teachers were at the “partially adequate” level. Of these pre-service teachers, 1.6% (n = 1) were PST, 9.8% (n = 6) were PMT, and 11.5% (n = 7) were PTLT. Finally, 1.6% (n = 1) of the pre-service teachers were at the “adequate” level. The pre-service teacher at the proficient level was PST. There was no pre-service teacher at this level from the other departments.



	PST	PMT	PTLT	Total
inadequate	6.56	8.20	4.92	19.67
partially inadequate	26.23	13.11	16.39	55.74
partially adequate	1.64	9.84	11.48	22.95
adequate	1.64	0.00	0.00	1.64

Figure 3. The Levels of Pre-Service Teachers According to the Competency Score of Using Data by Departments.



	PST	PMT	PTLT	Total
inadequate	9.84	9.84	13.11	32.79
partially inadequate	14.75	14.75	11.48	40.98
partially adequate	11.48	4.92	6.56	22.95
adequate	0.00	1.64	1.64	3.28

Figure 4. The Levels of Pre-Service Teachers According to Their Data Communication Competency Scores by Departments.

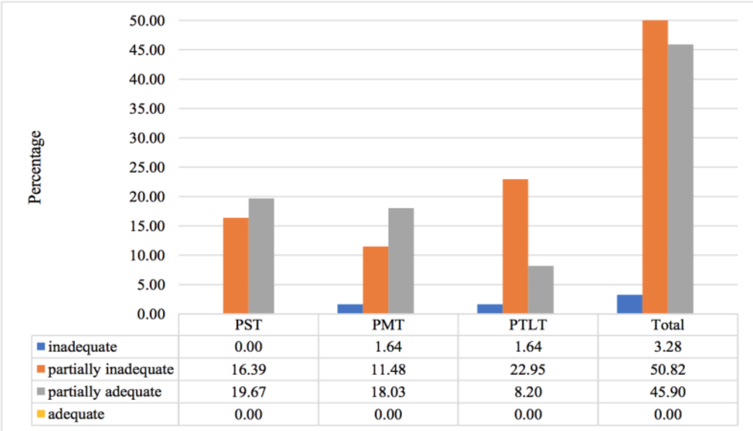


Figure 5. Pre-Service Teachers' Levels Determined According to Their Total Data Literacy Scores.

Level Groups for Data Communication Competency

The findings regarding the level groups determined according to the scores of pre-service teachers on data communication competency are given in **Figure 4**.

According to **Figure 4**, 32.8% (n = 20) of the pre-service teachers were at the "inadequate" level in terms of data communication competency. Of these pre-service teachers, 9.8% (n = 6) were PST, 9.8% (n = 6) were PMT, and 13.1% (n = 8) were PTLT. Meanwhile, 41% (n = 25) of the pre-service teachers are at the "partially inadequate" level. Of these pre-service teachers, 14.8% (n = 9) were PST, 14.8% (n = 9) were PMT, and 11.5% (n = 7) were PTLT. Further, 23% (n = 14) of the pre-service teachers were at the "partially adequate" level. Of these pre-service teachers, 11.5% (n = 7) were PST, 4.9% (n = 3) were PMT, and 6.6% (n = 4) were PTLT. Finally, 3.3% (n = 2) of the pre-service teachers were at the "adequate" level. Of the pre-service teachers at this level, 1.6% (n = 1) were PMT and 1.6% (n = 1) were PTLT. There were no pre-service teachers at this level in PST.

Level Groups for Total Data Literacy

The findings regarding the level groups determined according to the total data literacy scores of pre-service teachers are given in **Figure 5**.

According to **Figure 5**, 3.3% (n = 2) of the teachers were "inadequate," 50.8% (n = 31) were "partially inadequate," and 45.9% (n = 28) were "partially adequate" in terms of general data literacy. There was no pre-service teacher who could be evaluated at the "adequate" level. While there was no PST with "inadequate" data literacy level, there was one (1.6%) pre-service teacher in PMT and one in PTLT. Of the teacher candidates whose data literacy level was "partially inadequate," 16.4% (n = 10) were PST, 11.5% (n = 7) were PMT, and 23% (n = 14) were PTLT; and 19.7% (n = 12) of the pre-service teachers at the "partially adequate" level were PST, 18% (n = 11) were PMT, and 8.2% (n = 5) were PTLT.

Discussion and Conclusion

In this study, the status of PST, PMT, and PTLT in terms of total data literacy with some data literacy competencies (assessed by the sum of the scores obtained from these competencies) were determined. The scores obtained by the pre-service teachers in the competencies of recognizing, comparing, and establishing a relationship between the data among the data literacy competencies included in the study significantly varied across departments. This difference was observed between PMT and PTLT (in favor of PMT) and PST and PTLT (in favor of PST) but not between PMT and PST. In terms of using data and data communication competencies, the scores received by the pre-service teachers did not significantly differ according to the departments (**Table 7**). The results of the study show that the total data literacy scores of pre-service teachers significantly differ according to the departments. Accordingly, when PMT and PST were compared in terms of total data literacy score, the average score of PMT was higher but the difference between them was not significant, PTLT had the lowest average score, and a significant difference existed between the scores of PMT and PST and those of PTLT (see **Table 5** and **Table 7**).

In light of the findings above, it can be inferred that the differences between PTLT, PST, and PMT in favor of the latter two are due to these departments being reinforced with data (e.g., laboratory courses for PST and basic mathematics for PMT), surveys and measurement results (e.g., Research Methods in Education), and graphics or tables (e.g., Chemistry I and Physics I for PST; Analysis I and Statistics for PMT). This suggests that PTLT remains behind PST and PMT in offering data-rich learning environments where the students' data literacy can be improved, albeit to a limited extent. In other words, there are differences in the nature of the subjects that pre-service teachers study and learn. It can be said that PST and PMT are more interested in data due to the experimental and mathematical nature of their subjects (Merk et al., 2020, Zeuch et al., 2017).

To better understand the data literacy status of pre-service teachers, their competency scores were also analyzed from a different perspective, in which level groups were identified. The findings regarding the level groups showed that more than half the pre-service teachers were partially inadequate (50.8%) or inadequate (3.3%) in terms of total data literacy; the rest were partially adequate (45.9%), and there was no pre-service teacher who could be considered adequate. The findings indicate that PTLT has the lowest level of data literacy in terms of the determined levels among the departments. When evaluated in terms of data literacy competencies, the majority of pre-service teachers are partially adequate (49.2%) or adequate (27.9%) in data recognition competency. The levels of PST and PMT are close to each other, and the lowest level is seen in PTLT. In terms of the competency of comparing data and establishing relationships between data, approximately half of the pre-service teachers were partially adequate (49.2%) or adequate (3.0%); while the other half was approximately partially inadequate (45.9%) or inadequate (1.6%). In this competency, the proficiency level of PST is higher, followed by PMT, and the level of the PTLT is remarkably low. This is also seen in results of the Kruskal–Wallis H test, which indicate that the scores obtained from the competency of comparing data and establishing relationships between data differ significantly among the departments and that this differentiation is between PST-PTLT and PMT-PTLT. In terms of competency in using data, the majority of pre-service teachers were partially inadequate (55.7%) or inadequate (19.7%). In this competency, the proficiency levels of PTLT and PMT are similar and significantly higher than PST. However, the Kruskal–Wallis H test result of the scores obtained from the competency of using data showed no significant difference according to the departments. However, the assessment of the level of competency shows that the vast majority of PST is partially inadequate or inadequate. In terms of data communication competency, the majority of pre-service teachers are partially inadequate (41.0%) or inadequate (32.8%). The findings suggest that pre-service teachers of all three departments are at a similar level in terms of data communication competency.

When the findings are evaluated in general, the majority of pre-service teachers are partially adequate or adequate in terms of data recognition competency; approximately half of them are partially adequate or adequate in terms of comparing data and establishing relationships between data; and the majority are partially inadequate or inadequate in terms of using data and data communication. In terms of total data literacy, more than half of the pre-service teachers are partially inadequate or inadequate. Descriptive statistical results also show that the average of the total data literacy scores received by the pre-service teachers corresponds to about half or less of the highest score that can be obtained. Therefore, the findings reveal that pre-service teachers have deficiencies in data literacy, indicating that the contributions of pre-service teachers' past learning experiences in their acquisition and development of data literacy competencies are quite limited. The Teacher Education Ministerial Advisory Group report prepared in 2014 also supports this conclusion. The report draws attention to the lack of teacher candidates in higher education that possess the knowledge and skills to use data to inform and improve their teaching practices and recommends that teacher candidates be equipped with the skills to collect and analyze data to assess students' learning needs and guide the learning process (Craven et al. 2014).

It is conceivable that the data literacy deficiencies identified among pre-service teachers, as highlighted by the aforementioned findings, could have an impact on classroom instruction. Shreiner and Dykes (2021) concluded in their study that the majority of social studies teachers who participated in their study did not include data literacy practices in their lessons. Some studies also point out that teachers have difficulties in using and interpreting data (Cowie & Cooper, 2016; Gelderblom et al, 2016; Zapata-Rivera et al., 2016). Teachers are expected to use data for teaching purposes in their decision-making processes and when designing their lessons. However, it is stated in the literature that especially pre-service teachers have deficiencies in data literacy (DeLuca & Bellara, 2013; Piro & Hutchinson, 2014). For example, Dunlap and Piro (2016) stated that all of the participants (pre-service teachers) who examined the sample data sets they obtained about schools expressed discomfort in understanding the data, and they expressed this as "I knew nothing about data or what it was", "I didn't know what constituted data. I also didn't know you could read data.", and "I had no ideas about what the numbers meant or really that I needed to be concerned [with the data]." In the literature, some studies address data used in different contexts. McDowall et al. (2021) examined pre-service teachers' uses of data to inform and evaluate their teaching practice and found that while some pre-service teachers demonstrated many of the skills related to data use, others needed support. Although the context for assessing data literacy in this study (data from a natural phenomenon) is different from the context of the studies mentioned above (student data), similar results are pointed to.

Data literacy, which is considered a 21st-century skill, is seen as an important skill that individuals require for success, especially in the current competitive business environment (Valencia, 2021). For this reason, studies and incentives for the development of data literacy within the framework of formal education have increased in recent years (Wolff et al., 2019). Teachers have a key role in improving students' data literacy in schools. Therefore, first of all, teachers are expected to be data literate. Nevertheless, the findings from this study indicate that the participating pre-service teachers exhibit deficiencies in certain data literacy competencies. In line with these findings, teacher candidates need learning experiences that will support data literacy. The findings of the study support the calls in the literature to improve data literacy in pre-service teacher education (Mandinach & Gummer, 2013; Miller-Bains et al., 2022; Reeves, 2017; Reeves & Honig, 2015). This is because it may be later for teachers to learn data literacy competencies while on the job than when they are still pre-service teachers (Mandinach & Jimerson, 2016). Learning environments to support more data literacy should be offered in teacher education such that pre-service teachers can use data when making and communicating decisions about their teaching processes when they begin in their profession (Mandinach & Gummer, 2013) and support their students in being data literate.

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REVIEW

Online Teaching Research in China in the Context of Educational Digitization

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***Abstract**: Against the backdrop of digital transformation in education and the implementation of the "Three Links and Two Platforms Program," teaching research among Chinese teachers has exhibited a growing tendency towards informatization. Information technology has been increasingly leveraged by teachers not only to organize teaching research activities and analyze research data but also to demonstrate their research outcomes. This article aims to give an overview of the history of online teaching research in China and pinpoint the promotional factors underlying its development. Inadequacies in current online teaching research are also discussed.*

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Introduction

THE BASIC education curriculum reform in China calls for the teacher to become a developer and researcher of the new curriculum (Zhu, 2002). Teaching research by the teacher community, an important component of China's five-level education and teaching research system, has played a crucial role in advancing the quality of education (Yang, 2022). The accelerated development of information technology opened up novel paradigms for educational research, giving rise to online teaching research (OTR). OTR, also known as virtual or cyber teaching research, is an unconventional form of teaching research in which teachers employ information and communication technology (ICT) to conduct teaching research free from special constrictions, sharing teaching-related information and resources, and communicating research outcomes online (Li, 2007). OTR occurs in a virtual venue supported by computers and the Internet, thus having the advantages of being more flexible, cost-effective, and efficient compared with conventional teaching research. It is conducive to diversifying teaching research patterns and engaging the maximum number of teachers in instructional research (Xiao, 2007). This article gives an overview of the history of OTR in China, delves into the promotional factors underlying its development, and pinpoints issues with its current practices, with a view to eliciting an in-depth understanding of OTR and propelling its future improvement.

The History of OTR in the Teacher Community

OTR in China first surfaced at the end of the 20th century. In 1997, teachers at Country Garden School in Shunde City, Guangdong Province, began to use the bulletin board system (BBS) to discuss education and teaching issues, welcoming the participation of the public. Under the guidance of leading educational technology experts, chemistry teacher Pan established the "Xiande Chemistry Alliance" and "Xiande Virtual Teaching Research Center" in 1999 in collaboration with a group of like-minded peers. In 2000, he created the first online professional forum on chemistry teaching in China (Huang & Pan, 2002). In July 2003, the Ministry of Education (MoE) of China's Teacher Education Department launched the program "Cyber Alliance of National Teacher Education" (Zhang & Cao, 2003), marking the nationwide rise of online teaching research. Amid the rapid development of network devices such as QQ, blogs, BBS forums, WeChat, Tencent Document, and Tencent Meeting, teachers have continuously explored and practiced new forms of OTR. Generally, OTR among Chinese teachers has gone through three stages: teaching research based on digital-text interaction, online teacher community-based teaching research, and intelligent technology-supported teaching research under the initiative of "Internet plus education."

Teaching Research Based on Digital-Text Interaction

In the early 21st century, teaching research based on digital-text interaction arose because of the popularization of Internet use, relying on widespread, spontaneous teacher blogs and forums (Chen et al., 2003). Blogs, distinguished by their easy use and instant information sharing, have made inter-teacher, teacher-professional researcher and teacher-student parent communication more convenient and smoother. In the meantime, blogging brought about changes to the "centralized" teaching research pattern by motivating teachers to participate in regional teaching research activities on an equal and democratic footing (Wang, 2009).

Blog-based teaching research significantly boosted inter-teacher collaboration and communication, as well as facilitated distance in-service training among them, which generated a profound effect on promoting teacher professional development by using the Internet. According to Hu et al. (2009), teacher blog platforms for teaching research have effectively advanced the building of disciplinary resources and the professional development of teachers by fostering online learning communities for them. On the other hand, it was also noted that the outcomes and quality of blog-based teaching research vary among individuals and various regions. Yan and Li (2010) argued that blog-based teaching research mostly remained superficial interaction between teachers, with issues such as shallow reading of blog texts, unilateral comments without adequate interaction, focusing on the form of platforms but disregarding genuine communication, and a lack of deep concern about actual teaching challenges. They pointed out that blog-based teaching research should transition from personalized demonstrations towards more community-based teaching research (Yan & Li, 2010).

Online Teacher Community-Based Teaching Research

In 2010, OTR, based on teacher online practice communities and online training workshops, among other forms, underwent rapid growth. Online community platforms and computer terminal-based video technology served as important interaction media in teaching research, resulting in new features of the objectives, processes, and interactions of OTR (Wei, 2010).

Regarding research objectives, online teacher community-based teaching research placed more emphasis on improving teachers' IT application abilities, fostering their practical knowledge, and enhancing their instructional competence (Chen et al., 2013). Xu et al. (2014), for instance, discovered that regional online collaborative lesson preparation was favorable for heightening teachers' knowledge repertoire and that research and training activities organized by the grassroots community of digital education were effective in improving teachers' ability to apply IT in instruction.

Furthermore, online teacher community-based teaching research emphasized systematic design and management of the research process. Li (2012) proposed that OTR should include six elements: research platforms, information search tools, educational and teaching issues that promote teacher knowledge development, thematic discussions and resource investigation, online activities based on personal reflection and collaborative communication, and research outcome demonstration and evaluation; and that performance-based evaluation devices should be adopted to assess the specific output of the teaching research community. Regarding interaction media in teaching research, however, domestic video technology at that time was insufficiently advanced to support the quantitative analysis of classroom teaching; there were still practical complications in exporting data for teaching research evaluation and providing tailored teaching research support, such as intelligent video push services, due to the limitations of the earlier Internet technologies (Huang et al., 2014).

Intelligent Technology-Supported Teaching Research under the Initiative of "Internet plus Education"

Amid the rapid popularization of mobile terminals, such as smart phones and tablets, as well as the improvement of network bandwidth, intelligent technology gave new impetus to OTR development in the mid-2010s under the strategy of "Internet plus education." The technological convergence of the cloud, Internet, and terminals gave rise to innovative teaching research methods, significantly boosting the circulation efficiency of intellectual resources generated by experts, educational research staff, and leading teachers and thus increasing the sharing of teaching research space, resources, and outcomes. For example, intelligent video recording and broadcast technology has extraordinary capabilities for reproduction and cross-spatial sharing of scenarios and the capacity to capture multiple facets of classroom teaching, enabling teachers to research more diverse classroom practices (Hu & Xu, 2020). Also, intelligent technology-powered teaching research places a high value on the participants' experience, emphasizing individualized research services. The big data analytics-supported OTR library, for instance, can intelligently recommend research themes, reports, and other research-supportive services, facilitating data-driven teaching research (Li et al., 2018).

Factors Driving OTR Development in China

The digital transformation of education poses more demanding requirements for the teacher's competence in digital instruction, teaching research, and curriculum reform. In this context, teaching research is accorded with more explicit purposes: to serve education and teaching by guiding curriculum reform and improving the quality of teaching; to serve teacher professional development by aiding them in upgrading teaching methods and enhancing instructional competence; to serve student holistic development by delving into issues relevant to their learning and growth; and to serve educational decision-making by strengthening studies of basic education theories, policies, and practices (Zheng & He, 2022). In the digital era, there is a growing trend towards increasing OTR duties or online-offline blended research duties while decreasing purely face-to-face teaching research activities (Lyu, 2023). China's OTR development has been strongly driven by national policies, technical support, and application-focused research programs.

Ongoing Policy Direction

The Chinese government has released a series of papers to support the development of OTR. 2010's "The Outline of the National Medium- and Long-range Educational Reform and Development Plan (2010–2020)" emphasizes the necessity of strengthening the construction of an online teaching resource framework and promoting the sharing of high-quality educational resources (Ministry of Education of China, 2010). 2017's "The 13th Five-Year Plan for National Education Development" underlines the exploration and popularization of innovative teaching research by teachers under the strategy of "Internet plus Education" (State Council of China, 2017). In "The Action Plan for Digital Education 2.0," the MoE proposed the service model of "Digital Platform plus Education" to integrate all types of public education resources, platforms, and systems at all levels (Ministry of Education of China, 2018a). Subsequently, more relevant papers were issued, including "The Notice on Trial Actions for AI-supported Teacher Professional Development" (Ministry of Education of China, 2018b), "Opinions on Implementing the High-quality Teacher Cultivation Plan 2.0" (Ministry of Education of China, 2018c), "Opinions on Implementing the Program 2.0 for Enhancing the IT Application Capacities of National Primary and Secondary Teachers" (Ministry of Education of China, 2019), and "Guiding Opinions on Advancing the Strategy of 'Internet plus Education'" (Ministry of Education of China, 2021a), all of which advocate leveraging the new-generation Internet and AI technologies to advance digital and intelligent educational and teaching research.

Additionally, local governments in China have launched specific policies to support regional OTR development in response to the central government's "Guiding Opinions on Implementing the 'Internet Plus' Initiative" (State Council of China, 2015). The Education Department of Ningxia Hui Autonomous Region, for example, initiated its collaboration with Central China Normal University in 2020 to conduct online evaluations and ratings of IT literacy among primary and secondary teachers within the provincial region in an effort to boost their digital literacy and IT application abilities through evaluation and incentives. "The Report on the Development of IT Literacy among Primary and Secondary Teachers in Ningxia" was produced as an outcome of the partnership. In the meantime, Ningxia's Artificial Intelligence Education Research Institute, with 10 county-level AI education research and training centers for teachers from five municipal regions, was established. A framework of multi-level research and training programs under the online-offline blended pattern was developed to enhance teachers' digital competence and promote the digital transformation of education in Ningxia (Li & Rao, 2023).

Robust Technical Backing

As a result of the persistent national construction of "Three Links and Two Platforms" (namely, the school link to a broadband-based network, the class link to excellent teaching content, the individual link to the online learning space, the national public educational resource, and the educational administration platforms), online platforms, such as the national smart education platforms, can provide increasingly advanced education and teaching research avenues and resources for teachers throughout the country (Wang, 2015). The "Smart Primary and Secondary Education of China" platform, for instance, devises channels for thematic education, curricular instruction, after-school services, teacher research and training, home education, and practical experiences in educational reform. Among them, the teacher research and training channel includes columns of teacher learning resources, teacher ethical education, exemplary courses, thematic research and training, academic lectures, and mentoring of anchor teachers. The Service Center for Vocational Specialties and Courses on the "Smart Vocational Education of China" platform launched a wealth of high-quality specialty resource banks, online excellent courses, and open video courses; columns such as the "teaching resource center," "virtual simulation training center," and "teacher service center" were in development (Wang, 2022).

In the meantime, under the state's policies like "The Developmental Strategy for National Informatization" (State Council of China, 2016) and "IT Development in the 14th Five-Year National Plan (Central Cyberspace Affairs Commission, 2021), new-generation information technologies, such as big data, cloud computing, AI, virtual reality, and 5G communications, have undergone robust development, popularization, and application in China. Such dynamics continue to provide powerful support for OTR development.

Application-Driven Research Programs

As digital technologies advance, diverse OTR practices have emerged, such as live streaming-based teaching research, collaborative distance teaching research, learning analytics-based teaching research, etc. (Zheng & He). For example, in 2010, an educational technology association was formed in Guangzhou City for primary and secondary teachers, which later sponsored plural educational technology application research and training programs. Also, member schools of the association carry out collaborative OTR activities like “lesson honing through different approaches,” giving teachers the opportunity to discuss their differential teaching methods, techniques, and ideas, as well as sharing experiences and learning from each other's strengths, in order to continuously improve their teaching research abilities and promote common growth in them (Zhao et al., 2010).

In addition to the proliferation of local OTR practices, the central education authorities have been actively promoting the creation of OTR agencies. In July 2021, the MoE’s Higher Education Department issued the “Notice on Conducting Pilot Projects for Building Virtual Teaching Research Offices,” proposing to launch trial projects for exploring the standards, construction paths, and operation patterns of new-generation teaching research organizations in the intelligent era (Ministry of Education of China, 2021b). In February 2022, the MoE announced the first list of 439 trial projects of virtual teaching research offices in universities, setting forth objectives, duties, quality monitoring, facilities, and technical criteria for these online offices. It also provided the “virtual teaching research office platform” and “virtual teaching research information platform” for institutions involved in the program (Ministry of Education of China, 2022a). In the same year, the MoE released the second list of virtual teaching research offices in trial, suggesting that the virtual teaching research office’s WeChat official account and “College Smart Teaching Research Platform” be used to communicate the practical experiences and research outcomes of online teaching research actors (Ministry of Education of China, 2022b).

Issues with OTR among Chinese Teachers

Inadequate Recognition of OTR among Teachers

The majority of schools have not developed a proper understanding of the value of OTR, placing insufficient weight on ORT activities. That results in the low efficacy of ORT in many schools. Teachers tend to view OTR as a minor supplement to conventional teaching research, an opportunity to upload and download digital materials, rather than a practice in which they should harness the advantages of educational technology to innovate teaching paradigms and increase instructional outcomes (Chen, 2021). They seldom infuse the perspective of professional development into OTR activities.

Most OTR organizers have limited experience in OTR management and are incapable of formulating scientific OTR plans and corresponding implementation procedures, which compromises OTR's effectiveness as well as restricting OTR participation among ordinary teachers (Cheng, 2022).

More Focus on "Quantity" than "Quality" in OTR

Issues of superficial exploitation of OTR platforms are pervasive. First, the communication between OTR participants is mostly a simple transmission of information, lacking substantive interaction, which results in a lack of complete research processes or in-depth research findings. Second, many schools save the effort to develop their own OTR platform; instead, they choose to copy those of others. This simplistic emulation may lead to their inability to conduct statistical processing of data. Third, most OTR follows a rigid form, which is insufficiently relevant to questions encountered in actual teaching situations. Issues like these bring about the low effectiveness of OTR practice, hindering the achievement of its expected outcomes (Li, 2022).

Unbalanced Equipment in OTR Facilities

With the national "Three Links and Two Platforms" and other basic educational technology in place, the majority of schools in China have developed rudimental conditions for digital education. Nevertheless, the disparities in educational infrastructure between urban and rural schools have hindered OTR's popularization. In some rural schools, teachers have difficulty accessing basic facilities necessitated by OTR activities, such as high-performance computers and Internet connectivity. For schools in remote rural and ethnic minority areas, factors such as less developed infrastructure, outdated facilities, and frequent network disconnection discourage their teachers from engaging in OTR, who would choose to stay with face-to-face teaching research instead (Zhai, 2023). Regarding the soft environment, a portion of schools have not developed stable OTR platforms, leaving a gap between their nominal functions and teachers' actual needs. Furthermore, most of them do not have specialized staff for network maintenance and platform management, which negatively affects the implementation of OTR (Wei, 2023).

A Lack of Mature Evaluation Mechanisms for OTR

Teachers' engagement in and devotion to OTR, to a certain extent, is contingent on relevant evaluation and incentive mechanisms. A proper evaluation framework can assess the effects of OTR work while also providing evidence for necessary adjustments to OTR implementation (Li, 2022). Nonetheless, the majority of schools focus on immediate teaching outcomes rather than the process of teaching research in their teacher evaluation. Fewer schools have OTR-specific evaluation mechanisms for measuring teachers' participation and achievements in OTR. In this situation, teachers cannot obtain feedback on and recognition of their OTR work. Over time, they may lose motivation for enhancing their OTR engagement (He & Zheng, 2023).

Conclusion

In the context of the digital transformation of education, OTR plays a significant role in advancing teaching research and teacher professional development. The popularization of OTR brings new opportunities as well as challenges to instructors' teaching research work. Schools must leverage all reachable digital resources to create an autonomy-supportive, highly efficient research environment to facilitate teachers' engagement in OTR practice. Teachers at all education levels should use their initiative to integrate cutting-edge technologies into teaching research to continuously heighten their professional competence and upgrade the quality of education.

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REVIEW

Professional Educational Researchers in China’s Five-Level Education and Teaching Research System: Their Promotive Roles in Chinese Basic Education Development

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***Abstract**: Professional Educational Researchers (PER) are a crucial component of China’s Five-Level Education and Teaching Research System (ETRS), which has been of fundamental importance to Chinese basic education development. PERs play a significant role in directing teachers’ professional development, advancing basic education curriculum reform, and supporting educational decision-making. This article explains the concept of the PER in the context of the ETRS, describes the professional criteria for being a PER, and expounds on their significance for basic education advancement.*

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DUE TO THE importance of educational research for a nation's education development, every major country in the world has its own educational research system pertinent to its special situations. Educational research workers in Germany place a chief focus on applied and experiential research (Liu, 2023). Their counterparts in the US put more value on theoretical research and development in education (Jiang, 2021). Those in the UK are more concerned about the practical application of educational theories (Wang, 2022). Typically, there are professional educational supervisors or instructional advisors deployed in a country's educational research system (Zeng et al., 2023). In China, the five-level education and teaching research system (ETRS) has been instrumental in advancing Chinese basic education. A group of specialized professionals employed by this system, known as "professional educational researchers" (PER), have made substantial contributions to its functioning (Tan, 2023). This article aims to explain the roles of PERs in the ETRS and their significance for promoting basic education development in China.

Who are the PERs in the Five-level ETRS?

China's ETRS consists of five levels of institutions: the central-, provincial-, municipal-, and county-level education and teaching research (ETR) institutions and school-based teaching research offices (Yang, 2023). PERs are professionals staffed by provincial-, municipal-, and county-level ETR institutions under the jurisdiction of the three levels of educational administrative departments, specializing in education science studies and teaching research at the basic education level (Li & Shen, 2011). PERs' work spans a wide range of responsibilities, including conducting instructional research, serving teacher professional development, integrating educational resources, providing educational counseling, and more.

PERs have close connections with basic education institutions and teachers, serving as a bridge between theoretical research and teaching practice and between educational administrative departments and frontline teachers (Lu & Wang, 2019). They provide interpretations of governmental education policies, assist teachers in reaching a right understanding of the national curriculum program and course standards, and initiate regional education and teaching reform (Liu, 2008). Also, PERs are responsible for monitoring the quality of education in their respective regions and formulating improvement strategies accordingly. In the meantime, they need to follow domestic and international ETR dynamics closely and translate existing research outcomes into teaching practice. In addition, they are accountable for organizing all kinds of ETR projects and activities to support younger teachers' professional growth (Ministry of Education of China, 2019).

Professional Criteria for Being a PER

Practical Expertise

Practical expertise of the PER includes practical knowledge and experiences, as well as concern with practical issues and awareness of innovation (Wang, 2021). Their practical knowledge, represented by their understanding of practical issues in education and proficiency in disciplinary instruction, is fundamental to their ETR work. It derives from their practice of teaching, as the majority of them had years of instructional experience before becoming professional researchers. As the reform in basic education intensifies, PERs' work demands more diverse practical experiences, including observations, analyses, and generalizations of frontline teachers' educational and instructional practices, alongside their own on-site experiments (Lu et al., 2018). Despite the fact that PERs do not need to deal with students directly on a daily basis, all ETR work is primarily aimed at boosting student development. Therefore, it is important for the PER to pay attention to actual teaching issues and base their research on concrete teaching situations. The practice-focused research paradigm enables the PER's work to suit the needs of teachers and be professionally supportive of their classroom instruction (Wang, 2021). Additionally, a PER must have the consciousness of reform and the practical ability to innovate pedagogical notions and methods to continuously enhance the quality of teaching (Shen, 2021).

Research Capacities

Research capacity is central to a PER's competence. A proficient PER must first be a good observer, sensitive to issues arising in education and teaching. Moreover, PERs must be academically competent in approaching research questions analytically, leveraging their prior educational experiences and disciplinary expertise (Wan & Zhu, 2024). Furthermore, they should have the ability to develop a proper research design and implement it in collaboration with teachers. Based on experimental findings, they need to conduct theoretical generalizations for extensive application of their research results (Fan, 2008).

Multi-Tasking Ability

Multi-tasking ability is a necessary qualification for PERs because they have multiple roles to play, plural responsibilities to fulfill, and an onerous workload to complete (Li & Shen, 2011). To the teacher's eye, PERs are curriculum and subject experts, acting as directors for their professional development; in the mind of educational administrators, they are disseminators of education policies, safeguarding the quality of basic education in their respective regions (Sun, 2022). According to the Ministry of Education's 2019 "Opinions on Strengthening and Improving Educational Research for the New Era's Basic Education," PERs in the new era should provide four categories of services: services for schools, teachers, students, and educational administrators (Ministry of Education of China, 2019). That means a PER's responsibilities include supporting the school's education and teaching, guiding teachers' professional growth, promoting student holistic development, and providing evidence for scientific educational decision-making. What's more, a PER's day-to-day work contents are of varied descriptions, including both professional research duties and miscellaneous administrative tasks (Tang & Tang, 2022). It requires comprehensive qualities and abilities to do their job well.

Mentoring Capability

The PER is typically seen as the "teacher of teachers." As mentioned earlier in this article, most of the PERs were anchor teachers in their respective disciplines, which place them in an advantageous position in directing research and training among ordinary teachers (Zhang, 2014). Moreover, PERs have the responsibility to guide the basic education curriculum reform. The curriculum and teaching modifications are a chief part of their work. PERs need to continuously study cutting-edge instructional notions and methods and guide teachers to apply them to classroom practices (Mou, 2022). In recent decades, Chinese basic education curricula have undergone three major rounds of reform, from "double foundations-focused" teaching to "three objectives-oriented" curricula and "key competences-centered" education. Each of them posed new requirements on PERs' directive ability in curriculum reform (Xu, 2022).

Promotive Roles of PERs in Basic Education Development in China

The five-level ETRS is a distinctively Chinese educational research system that has been instrumental in China's basic education development. PERs in this system have played critical roles in teacher professional growth, curricular development, the monitoring of the quality of regional education, and the transmission of education policies (Pan, 2019).

Advancing Curriculum and Teaching Development

Curriculum and teaching studies are a core area of educational research, focusing on theoretical and practical questions associated with school curricula and instruction. Included in this area are studies of teaching objectives, contents, models, and assessment, as well as solutions to specific challenges emerging in the teaching process (Zeng, 2014). Curriculum and teaching research are central parts of PERs' work.

Improving the Quality of Curriculum Design

Curriculum design is a creative endeavor concerning the systematic organization of knowledge delivery, seeking to give students a structured learning experience (Liang & Zhang, 2023). PERs are engaged in formulating and revising curricular schemes for schools in the region based on national education policies, curriculum programs, and course standards. For example, in designing the curricular scheme for secondary geography education, PERs need to consider that the courses under the scheme cover all necessary geographical knowledge at this level, and in the meantime, pay attention to the connection between content knowledge and students' life experiences to ensure the practical purpose of the curriculum (Fu, 2014). In the process of curriculum research, PERs develop teaching resources, such as teaching materials, learning protocols, and courseware, in collaboration with teachers to make sure that they suit the needs of students. In addition, PERs must stay current with disciplinary developments and revise course contents in a timely manner to guarantee that the curricular scheme is in sync with the advancement of information. For instance, in the context of environmental science becoming a mainstream discipline because of the exacerbating effects of global climate change, PERs need to follow the research advances in this field in order to incorporate relevant content into the curriculum (Li, 2018).

Innovating Teaching Strategies

Teaching strategies are methods that teachers use to deliver teaching materials in ways that keep students engaged and optimize instructional outcomes. They may adopt different teaching strategies according to expected teaching objectives, student cognitive levels, teaching settings, and classroom resources (Zhao, 2014). To realize successful implementation of prescribed curricula, PERs need to explore effective teaching strategies to support teachers' classroom organization. They must pay attention to the recent developments in pedagogical theories and practices and help teachers innovate their teaching strategies (Li, 2012). A core job responsibility of the PER is to provide directions and training to teachers on teaching strategies and techniques to heighten their instructional levels. For example, in training novice English teachers, they may demonstrate how to apply the immersive teaching method to create an authentic English context for students (Yu, 2013). In addition, PERs conduct supervision and evaluation of the classroom implementation of specific teaching strategies. Through regular lesson observations, examination of teaching protocols, and interviews with students, they check on teachers' execution of the teaching strategy in exploration and evaluate its effectiveness (Ling, 2019).

Promoting Teacher Professional Development

Organizing High-quality Training Programs for In-service Teachers

Educational development necessitates systematic in-service teacher training to increase educators' teaching capacities and professional competences continuously and comprehensively. PERs work to develop a wide range of teacher training programs and events according to teachers' individual needs and the needs of disciplinary development. These training programs could take a variety of forms, including courses, lectures, seminars, and practical projects, among other activities, with the purpose of helping teachers raise their levels of education and teaching by upgrading educational ideas and taking in fresh teaching techniques and methods (Cheng, 2019). Also, PERs conduct follow-up evaluations on training participants to assess the effects of these training programs on their instruction. In Chen's and Deng's study, for instance, PERs developed a one-month training program named "Teaching Practice and Reflection" for novice secondary English teachers. The program entailed training on teaching protocol design, observations of leading teachers' lessons, reflections on their own teaching practices, and other processes. Following the training sessions, the PERs tracked and evaluated the novice teachers' performance through a questionnaire survey to measure the effectiveness of the training program (Chen & Deng, 2018).

Formulating Teacher Evaluation Frameworks

Teacher evaluation is an integral part of the educational system, meant to evaluate the outcomes of the educational behavior of the teacher and provide a framework of reference for future improvement (Ou, 2009). PERs are held responsible for formulating valid and reliable teacher evaluation frameworks based on scientific criteria. They typically develop an evaluation scale incorporating comprehensive indicators such as the teaching level, teaching research engagement, moral commitment, etc. In addition, they regularly gather comments on the teacher from their students, colleagues, and superiors. Teachers are given the evaluation results as feedback in order to form a right understanding of their strengths and weaknesses (Xu, 2012). As a result, PERs establish a multi-dimensional teacher evaluation framework that is impartial and objective, including measurements of the teacher's performance in instruction and teaching research as well as comments from chief stakeholders.

Developing Teacher Incentive Schemes

Teacher incentives are initiatives introduced to encourage teachers to improve the quality of their teaching, enhance their teaching qualifications, and retain the teaching profession (Zhang, 2022). PERs are delegated by the education department to develop teacher incentive schemes for schools under its jurisdiction. These incentive schemes, such as "excellent teacher selection" and "exemplary teaching paradigm award," are manipulated to support teacher job satisfaction and career development. Furthermore, PERs are responsible for providing high-performing teachers with more opportunities for professional development, such as participating in core research projects and academic exchanges, with a view to building the talent pool for regional education development. PERs also help local schools foster a positive campus culture to increase teachers' senses of belonging to the school and identification with their profession (Xu, 2023).

Developing and Popularizing Educational Resources

Selecting and Developing Optimal Teaching Materials

The adoption of the right teaching materials is crucial to the successful implementation of curricula. Teaching materials are an essential source of knowledge for students; high-quality instructional materials facilitate students' comprehension and mastery of knowledge, thus enhancing their learning outcomes (Li, 2021). PERs must pay substantial attention to the selection of textbooks and the development of necessary supplementary teaching materials to ensure the quality of student learning. First, they screen all sorts of textbooks published and select the right ones according to the national curriculum programs and course standards. Often, they need to work with teachers to develop supporting supplementary teaching materials, such as exercise books and instructional PPTs, based on the actual needs of classroom teaching (Yang, 2024). In Li's study of primary science education, for instance, PERs made every effort to ensure that the teaching materials included covered all necessary strands of scientific knowledge suitable for this educational level while also providing students with abundant experimental materials and teaching aids (Li, 2024). Also, PERs review the teaching materials from time to time and update them in a timely manner to keep them consistent with disciplinary development and educational reform (Li, 2024).

Promoting the Application of Educational Technology

The use of educational technology can significantly expand the range of educational devices and resources. In the context of the digital transformation of education, PERs have the responsibility to promote the exploitation of digital resources and encourage the application of educational technology by teachers (Zheng, 2024). To do so, they need to develop ample knowledge of state-of-the-art educational technology, such as online education platforms and intelligent instruction applications, and disseminate it among teachers. In the meantime, PERs organize the digital literacy training programs to help teachers cope with the challenges of educational technology. Additionally, they focus on searching for as well as developing digital teaching resources, such as instructional videos and online courses, to enrich teachers' instructional devices. In Shen's study of junior secondary English education, PERs introduced an intelligent speech recognition application to help students modify their pronunciation and improve their proficiency in spoken English. In this process, they maintained intimate communication with the instructors to discern the effects of this application and help them solve technical issues to ensure its smooth operation (Shen, 2012).

Monitoring and Improving the Quality of Regional Education

Assessing the Quality of Education in the Region

Monitoring the quality of education concerns assessing periodically how well the educational system works and making improvements accordingly (Liu, 2021). It is a primary component of PERs' work. PERs need to develop a scientific and workable assessment indicator framework, which is used in the large-scale survey of education quality to determine the progress and challenges in regional schooling (Wu, 2017). A main feature of the assessment framework is to assess teachers' instructional quality, including teaching content, methods, attitudes, outcomes, and other dimensions. Based on the systematic assessment, they can clarify the existing level of instruction as well as spot issues and inadequacies (Jiang, 2021).

Analyzing Educational Data

PERs have the responsibility to gather and analyze educational data to support evidence-based decision-making in education (Shen, 2018). In conducting educational research, PERs pay a lot of attention to collecting all sorts of information and undertaking in-depth analysis using data analytic tools.

Based on the analysis results, they can identify the underlying regularities and development trends in education and write reports to present a relatively comprehensive picture of the issue in discussion. For instance, student academic results, a fundamental component of educational data, are regularly gathered by PERs, who will subsequently apply learning analytics to them and formulate the report on student academic quality in the region (Liu & Wu, 2019).

Instigating Reform and Innovation in Regional Education

Educational reform is a critical driving force for educational advancement, concerning changes in educational ideas, organization, contents, methods, and more. Education can better meet the needs of social and individual development by introducing reform and innovation (Wang, 2003). PERs need to keep a close eye on ongoing developments in domestic and global education and instigate reform and innovation in regional education. Often, PERs are deeply involved in the formulation of the regional plan for educational reform and are responsible for developing targeted strategies and implementing programs. They also encourage schools and teachers to innovate teaching practices by exploring new instructional methods and patterns. Furthermore, they try to generalize successful innovative experiences by propagating them in the regional community of education (Pang, 2019). In Song's study of the secondary education curriculum reform, PERs played an active role in propelling teachers to change their old notions of education and experiment with new teaching models. For example, they encouraged secondary physics teachers to adopt the experiential teaching model to increase students' hands-on experiences, which significantly enhanced the latter's grasp of knowledge of this subject. Successful cases arising in the experimentation of the said teaching model were widely spread in the region to promote the overall enhancement of physics education (Song, 2022).

Propagating Education Policies

Appropriate interpretation and thoughtful execution of education policies are of vital importance to education development, ensuring that it is on the right track. PERs have the duty to promptly transmit education policies to schools and teachers and provide them with implementation directions (Xia, 2020). To do so, they need to keep themselves informed of the publication of and changes in the central and regional governments' education policies and give reliable interpretations of them. Furthermore, they help schools develop concrete execution plans based on their specific situations and monitor the enacting process of these policies to make sure that they are seriously carried out with expected outcomes (Xia, 2020). For example, following the issuance of the "Double Reduction Policy" by the central government, PERs developed a series of measures to ease the academic burden of students, such as reducing the amount of homework, optimizing test and assessment methods, etc. In the process of advancing the new curriculum reform, PERs sponsored a variety of training activities to ensure that teachers had the right conception of the new curriculum standards and educational notions (Du, 2014).

Conclusion

The five-level ETRS is critical to China's endeavor to build a high-quality education system with distinctively Chinese characteristics. PERs have played an impactful role in the ETRS by advancing the quality of basic education, promoting teacher professional development, and driving instructional reform. They act as the bridge between educational theory and practice and the intermediate link between educational departments and frontline teachers. Amid the intensifying reform of education in China, it is imperative that PERs continue to enhance their professionalism to better serve the long-term development of Chinese basic education.

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