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COMMENTARY

Opportunities and Challenges in Digital Transformation of Education

Liaojian Qu

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"Technology can become the 'wings' that will allow the educational world to fly farther and faster than ever before – if we allow it."
–Jenny Arledge

THE WORLD is facing a fast and radical change due to the expedited development of digital technologies. Advances in digital technology are constantly driving the digital transformation of society as a whole. The concept of "digital transformation" first emerged in 1968 and became distinctive in the research literature after the year of 2014 (Reis et al, 2018). In its broad sense, digital transformation refers to the process that new digital technologies are integrated into all sectors of human activity, fundamentally changing all aspects of human life. This leads to a world that is increasingly experienced with, through, and by information technology (Stolterman & Fors, 2004).

The focus and aims of digital transformation vary in distinct sectors. In the sphere of education, digital transformation is the incorporation of digital technologies into educational organizations' management and operations to elicit changes and innovations in educational paradigms, teaching approaches, organizational structures, and more. It contributes to building a more open, adaptive, and resilient education ecosystem that support equity of quality education and lifelong learning (Zhu & Hu, 2022).

Digital education has the potential to make changes to the traditional education paradigm using its inherent advantages. First, it renders tailored teaching and student-centered instruction possible by allowing teachers and students more freedom in information acquisition and selection. Second, digital education promotes the development of students' digital competencies, which are essential for their survival in the digital era. Third, the deployment of digital technology and the consequential diverse teaching and learning modes are favorable for fostering students' interest and autonomy in learning (Lu, 2022).

Furthermore, digital education promotes the equity of education by making the educational system and resources more open and public, thus equalizing educational op portunities; it helps mitigate regional disparities in education by facilitating the exchange and sharing of information and resources between nations and regions (Yang, 2022). Additionally, digital education can generate a more learning-friendly environment by making education resources more accessible. That helps increase the efficacy and efficiency of education (Xu et al., 2023).

Despite the said opportunities, digital education brings forth a variety of challenges. For instance, the application of digital technology in education is typically founded on the collection of massive amounts of educational data. Data security and privacy of key stakeholders are vulnerable due to insufficient regulations in this regard. A widely accepted advantage of digital technology is its capacity to provide individualized education. However, the use of big data to profile students and determine their preferences may lead to biased information intake - in other words, the information cocoons. It is true that educational AI has broadened the routes to knowledge acquisition. Nevertheless, its reliance on intelligent machines, which are not yet generally affordable, may result in a new form of educational inequality. As emerging technology, intelligent technology is constantly evolving, which means its applications in education may be susceptible to a variety of vulnerabilities (Dong & Yang, 2023).

For the Chinese government, digital transformation of education has been high on the agenda. The 2024 World Digital Education Conference was co-hosted by the Ministry of Education of China, the Chinese National Commission for UNESCO, and the Shanghai Municipal People's Government on January 30-31 in Shanghai. *Digital Transformation of Education in China: A Review against the Backdrop of the 2024 World Digital Education Conference* in this issue is review of China's explorations and experiments in digital transformation in education (Ding & Wu, 2024). *Ethical Challenges of Educational Artificial Intelligence and Coping Measures: A Discussion in the Context of the 2024 World Digital Education Conference* expounds on the ethical risks in adopting AI technology in education and proposes pathways to establishing a framework of ethics of educational AI (Chen, 2024). It is hoped that the two articles can spark more discussions on rational application of AI in education to support sustaining development of digital education.

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COMMENTARY

Formative Assessment: A Significant Facilitator of Student Learning

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"Education is the most powerful weapon that we can use to change the world."
–Nelson Mandela

IN RECENT decades, formative assessment has garnered substantial interest of teachers and educational researchers. Definitions of formative assessment vary in the literature. Relatively well-accepted among them is the one that describe it as the process of seeking and interpreting evidence for learners and their teachers to determine where the learners are in their learning, where they need to go and how best to get there (Antoniou & James, 2014). As opposed to summative assessment, formative evaluation gives comprehensive evaluation and feedback throughout the learning process of students, with the purpose of assisting students in identifying learning gaps, modifying learning methods, and enhancing learning outcomes. Common forms of formative assessment include quizzes, observation records, face-to-face conversations, questionnaires, feedback, student self-assessment, etc. It is meant to evaluate not only students' academic performance but also their progress in learning attitudes, learning strategies, emotional skills, and other aspects (Wu, 2023).

For students, formative assessment allows them the opportunities for a better understanding of their learning status. Through timely, specific feedback, students can identify both their merits and shortcomings, reflect on and adjust their learning methods, and thus, formulate learning plans that better suit their needs (Cao, 2024). Moreover, formative assessment can significantly increase students' engagement in schoolwork, as it is typically embedded in every process of study, so supporting student active learning. Also, formative assessment can effectively stimulate learning motivations in students. The display of their progressive advancement in learning has the potential to enhance their senses of satisfaction and confidence, which in turn piques stronger interest in learning in them (Yang, 2023). In addition, self-assessment and inter-peer assessment entailed in formative assessment are beneficial for fostering students' reflective and critical thinking abilities.

For teachers, formative assessment is a valuable instrument for optimizing instructional outcomes. With formative assessment, teachers can flexibly use various devices to obtain information about students' learning progress, which helps optimize instructional objectives and improve teaching efficacy. Through predictive assessment, teachers understand students' prior knowledge and skills on a certain subject and develop teaching plans suitable for their current learning circumstances (Chen, 2023). In the process of instruction, they can engineer effective classroom discussions and Q & A activities to elicit evidence of student understanding; provide feedback that moves learners forward; and administer phased evaluation using assignments and quizzes to determine the ensuing teaching content. In this process, teachers modify their instruction and activities according to the assessment information, and students are activated to be the owners of their own learning (Chen, 2023). As a result, formative assessment is distinguished by its effects in boosting teaching outcomes.

Examination of Effects of Embedding Formative Assessment in Inquiry-Based Teaching on Conceptual Learning in this issue of the journal is an investigation of the impact of formative assessment on students' understanding of physics concepts in inquiry-based learning. The mixed method experimental research design was adopted to include both qualitative and quantitative data in the study. The results of quantitative analysis showed that the experimental group who were taught with the method of formative assessment-embedded inquiry-based teaching performed better in conceptual learning than the control group. The results of qualitative analysis supported the said finding and shed light on how the integration of formative assessment with inquiry-based learning enhanced students' grasp of concepts (Koksalan & Ogan-Bekiroglu, 2024). The article provides a deep insight into the role of formative assessment in implementing inquiry-based learning, a student-centered instructional strategy, in the classroom.

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ORIGINAL ARTICLE

Examination of Effects of Embedding Formative Assessment in Inquiry-Based Teaching on Conceptual Learning

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Abstract: *Scaffolding in learning and teacher guidance during inquiry can be attained by formative assessment, which needs to be built into every stage of inquiry. Investigation of the effects of embedded formative assessment in inquiry-based learning on students' conceptual understanding was the aim of this study. Mixed method experimental research design including quantitative and qualitative data collection methods was used for this study. The participants were 41 students, who were in tenth grade of a suburban public high school. The study reached the following conclusions. First, formative assessment combined with inquiry-based teaching serves as a catalyst for students' conceptual learning and elevates effects of inquiry. Second, eliciting evidence of learning and feedback may be the primary stages of formative assessment in accelerating student learning and supporting student knowledge development. This study suggests that assessment should be done when teaching continuous and teachers need to adopt formative assessment while performing inquiry-based teaching.*

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Introduction

FRAMEWORK for PISA science assessment focuses on scientific competencies that include identifying scientific questions, explaining phenomena scientifically, and using scientific evidence (OECD, 2007). Scientific competencies are influenced by scientific knowledge composing of knowledge about science and knowledge of science (OECD, 2007). Knowledge about science contains scientific inquiry and scientific explanations and both inquiry and explanations are the means of science (how scientists get data) and the goals of science (how scientists use data) as the basis for explanations of phenomena (Bybee, 2008). Knowledge of science is comprised of learning of scientific concepts and this learning is seen as a form of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982). According to Hewson (1992), learning a new conception means that the student understands it, accepts it, and sees that it is useful. If the new conception conflicts with an existing conception, it cannot be accepted until the student has reason to be dissatisfied with it (Hewson, 1992).

Formative assessment is the process of gathering evidence of student learning, providing feedback to students, and adjusting instructional and learning strategies that enhance achievement (McMillian, 2021). Three forms of formal formative assessment are particularly effective for helping students learn: purposeful questioning, teacher feedback, and self-assessment (Russell & Airasian, 2012). Feedback is the information given to students about how to improve their work or deepen their understanding (Russell & Airasian, 2012). Student self-assessment is a process in which students monitor and evaluate their learning and performance (McMillian, 2021). Therefore, by identifying misconceptions, providing feedback, and encouraging self-assessment, formative assessment can trigger a cognitive conflict and help students develop a deeper understanding of concepts.

Due to abstractness and unfamiliarity of science concepts, conceptual learning seems to be quite complex for most of the students (Scott, Asoko & Leach, 2007). Inquiry-based teaching (IBT), which is an instructional strategy, supports students to behave like scientists to construct knowledge (Keselman, 2003). IBT engages students in investigations to build mental frameworks and to explain their experiences (Haury, 1993) because it is assumed that science learning is about understanding and applying scientific concepts and methods instead of memorization of scientific facts (Bell, Urhahne, Schanze & Ploetzner, 2010). When students learn science in the inquiry context, they "develop epistemological understandings about nature of science and scientific knowledge, as well as relevant inquiry skills such as identifying problems, generating research questions, and designing and conducting investigations" (Abd-El-Khalick et al., 2004, p. 398), These knowledge and skills are aligned with scientific competencies in the framework that PISA determines.

Research shows that inquiry-based learning has positive contributions on cognitive knowledge of students (Alouf & Bentley, 2003; Chen & Chen, 2012; Derting & Ebert-May, 2010; Gibson & Chase, 2002; Hung, 2010; Johnson & Cuevas, 2016; Laipply, 2004; Rahmat & Chanunan, 2018; Taylor & Bilbrey, 2012). However, Minner, Levy and Century (2010) synthesized findings of 138 studies and stated that the outcomes of inquiry-based teaching have not always been positive in terms of student science conceptual learning. Since research reveals some mixed results for inquiry-based programs, instructional support would be helpful to eliminate these controversial issues. In opposite to what critics of inquiry have argued, conceptual frameworks try to increase the range of instructional supports to develop deeper understanding (Scott, Smith, Chu & Friesen, 2018). As a result, there needs to be scaffolding in learning during inquiry and this support can be attained by formative assessment. According to Chappuis et al. (2014), formative assessment includes formal and informal practices that teachers and students use to gather evidence to enhance learning. The process of formative assessment is iterative and consists of collecting, inferring and acting (Ruiz-Primo & Furtak, 2007); hence, it can support learning by developing strategies (Clark, 2012). Since teachers' role is to initialize, coach and help the inquiry process, one approach to such guiding to the students in their inquiry learning is formative assessment (Grob et al., 2021).

Inquiry cycle generally starts with the curiosity phase and then followed by the focus, explore, identification, gather, creation, sharing, and evaluation phases (NRC, 2000). In this process, assessment occurs at the end. Research shows that formative assessment affects students' science learning positively (Decristan et al., 2015; Ruiz-Primo & Furtak, 2007; Smith & Gorard, 2005; William, Lee, Harrison, Black, 2004; Yin et al., 2008). Introducing scientific inquiry and formative assessment both requires a considerable change in pedagogy (Rönnebeck et al., 2018). Formative assessment approach to teaching and learning fits well with an inquiry-based approach where the teacher's role is more about mediating the learning rather than directing the students along a specific route (Harrison et al., 2018). Students often need help in inquiry process and formative assessment helps students express their opinions and test them meticulously (Harlen, 2006). Therefore, examination of the effects of embedded formative assessment in inquiry-based learning on students' conceptual learning was the purpose of this study.

Literature Review and Research Aim

Research deals with formative assessment integrated in inquiry has been focused more on teacher practices (Bernard et al., 2019; Correia & Harrison, 2020; Grob et al., 2017; Ruiz-Primo & Furtak, 2007) and its effects on students (Bulunuz, 2017; Kusairi et al., 2021; Psycharis, 2016; Srisawasdi & Panjaburee; 2015; Yue Yin et al., 2008). Regarding these studies, researchers come to an agreement that constant assessment of students' conceptions, which is formative assessment, is essential to stimulate teaching and learning during inquiry. Even though, there is a link between students' level of performance and teachers' assessment practices, the integration of assessment and inquiry is a challenging duty and creates significant instructional challenges to teachers.

Hence, some researchers examined the impacts of formative assessment in the context of inquiry-based science education on students' outcomes. For instance, Yin et al. (2008) examined using formative assessment to promote conceptual change within a science unit taught with inquiry. They showed that the formative assessment did not have a significant influence on students' motivation, achievement, and conceptual change. Seven years later Srisawasdi and Panjaburee (2015) reached the opposite result. They examined the effects of formative assessment in simulation-based inquiry learning and conducted their study with high school students in a science course. Srisawasdi and Panjaburee found that the achievement of the experimental group in which the formative assessment was integrated with inquiry significantly differed from the control group. That is, formative assessment was a facilitator for students' conceptual learning. Additionally, Psycharis (2016) explored how scientific ability rubrics used in formative assessment process improved students' engagement during IBT and concluded that self-assessment helped them probe related questions and apply features of inquiry. Bulunuz (2017) preferred using formative assessment in inquiry-based physics courses in their studies. He discovered an increase in the level of conceptual explanation students made about the relevant concept. Finally, Kusairi et al. (2021) aimed to investigate students' struggles in understanding the physics concepts after they were taught by inquiry combined with formative assessment. Their results indicated enhancement in students' learning.

Although the value of assessing students' performance while they are engaging with inquiry activities has been understood for the last couple of years, evaluating and understanding the impact of the intervention have rarely been explored comprehensively in educational research. Besides, experimental studies mainly compared the instruction where formative assessment was implemented in inquiry-based learning with traditional or curriculum-based instruction. In order to investigate the difference formative assessment made in inquiry, both experimental and control groups should follow inquiry-based instruction. These previous works did not compare the value added by aspects of formative assessment within the context of inquiry-based learning. Based on these arguments, the research question of this study was framed as follows: Does embedding formative assessment in IBT affect students' conceptual understanding of physics? How?

Methodology

Research Design

Mixed method experimental research design including both qualitative and quantitative data collection methods was applied for this study (Cresswell & Clark, 2018). There were two groups in the research. One group named FAinIBT (Formative Assessment in IBT) participated in the physics course in which formative assessment was embedded in inquiry-based teaching while the other group named IBT (inquiry-based teaching) involved in the physics course where only inquiry-based teaching was implemented.

Participants and Settings

The participants were 41 tenth grade students studying in a suburban public high school. There were three tenth grade classes (Class A, Class B, and Class C) taught by the same physics teacher in the school. Among these three classes, Class B was selected as the FAinIBT group and Class A was selected as the IBT group by drawing lots. The number of the students in Class B was 20 while the population of the students in Class A was 21. There were also 20 students in Class C that was not selected for the study. The participants constituted of 29 female and 12 male students and their average age was 16. Anonymity was ensured by using numbers like S1 or S2 as participant identifiers.

Instructional Context

The participants were taking the physics class two hours a week when this research was conducted. The subject was geometrical optics and the instruction lasted five weeks. Students' difficulties in understanding of light, vision, and image formation have been mentioned in various researches (Chu, Treagust & Chandrasegaran, 2009; Galili & Hazan, 2000). Geometrical optics chapter included the following concepts: plane mirror, shadow, optical instruments, refraction, color, eye, lenses, and vision. The students in both groups engaged in guided inquiry to conduct research and experiments by providing them with guidance and intervention throughout the process to encourage in-depth learning (Kuhlthau, 2010). The teacher taught the same concepts and brought the same problems up in both groups. Lesson plans were prepared and experiments were conducted based on each week's learning objectives by using physical materials and simulations. Eight phases in guided inquiry design were followed in both groups to actively engage students, encourage them to ask significant questions, and provide them understanding of the content (Kuhlthau et al., 2015). The phases are as follows: Open, immerse, explore, identify, gather, create, share, and evaluate. Worksheets were constructed by taking the learning objectives of the national physics curriculum account and they were distributed to the both groups. The only difference between the groups was integration of formative assessment. Because knowledge of science was measured and compared between two groups, formative assessment was based on the students' understanding of concepts.

Each lesson in both groups started with questioning. For example, in the first week, the concepts of shadow and plane mirror were discussed and the lesson started with questions that led students to do inquiry. Videos about shadow were watched and then possible reasons underlying the situations in the videos were questioned. In this phase, the students were drawn to the open phase to arouse curiosity. The students discussed whether they came across the similar situations in their everyday lives and expressed the situation they found most interesting. When the teacher observed that everyone was curious and excited about the subject, she let them move to the next stage. During the immerse phase, they were encouraged to reveal their prior knowledge and explain the relevance of this information to the situations discussed in the classroom. In order to dip into the subject and explore, each student was asked to give a daily life example in the explore phase. In this phase, interesting ideas were presented and discussed. During the identify phase, the students worked in small groups and selected a research question. In the gather phase, the students gathered information from various sources and tested their hypothesis. During the create phase, a main result was obtained and then a common decision was reached. After that, the students shared their knowledge and compared their results with others. In the final stage, which was evaluated, the teacher evaluated the whole process.

Meantime, formative assessment cycle was embedded in the FAinIBT group. This cycle includes the following steps: eliciting evidence of learning, interpreting the evidence, identifying gap, feedback, planning learning, scaffolding new learning, and closing gap (Heritage, 2007). This cycle is also based on the common process for formative assessment whose core components are collecting data about student learning in real time, analyzing data in real time and after the lesson, and responding to student data immediately and in future lessons. Both formal and informal formative assessment practices were performed during every phase of the inquiry process in the FAinIBT group and feedback was provided to the students as both verbal and written via questioning and worksheets. For example, during the identify phase, the teacher visited the groups and checked whether the research question was proper or not. She gave feedback to the groups about their research questions by asking them how and why they chose that particular research question. During the immerse phase, the students' prior knowledge was taken into account to make instructional adjustments. In the explore phase, if there were examples that might irrelevant with the subject, the teacher provided feedback to the students for giving relevant examples. The teacher used formative assessment in the gather phase by questioning whether the students collected the right information on the subject and how deep they could proceed. For example, she asked "In which situations does the refraction occur? And what did you achieve as a result of your research?" In this way, the teacher captured the evidence of student learning and used that evidence to find the learning gap, and the students had the opportunity to understand the content and figured out the missing points. During the create phase, the teacher checked the results.

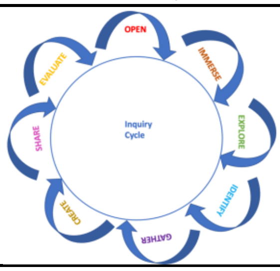
Questions were asked in both groups in order to encourage inquiry, reinforce important points, keep students' attention, and promote deeper processing of information. However, asking any type of question did not mean that the teacher was doing formative assessment. The questions that the teacher asked in the FAinIBT group served diagnostic purposes to allow the students to evaluate and compare their thinking with that of their peers to support formative assessment (Russell & Airasian, 2012). This type of questions was not used in the IBT group. **Table 1** illustrates models representing the instructional context employed in the IBT and FAinIBT groups and summary of the content week by week.

An example page for the teacher's feedback is provided in **Appendix A**. This feedback was given to the student, who was in the FAinIBT group, by writing on his worksheet distributed in the second week. The subject was refraction of light and the students filled out this worksheet during the gather stage of inquiry before doing experiments. The question was "when you make a hole on the plastic bottle filled with water and squeeze the bottle little to let the water flow, what would happen if we hold the laser towards the hole?" The student made the right prediction and wrote that "If the laser beam was sent with the right angle, it would follow the way of the water". Although his answer was correct, it was neither explanatory nor detailed. Therefore, the teacher appreciated his drawing in her feedback and asked that "What is the right angle? Why should the beam follow the way of water?" and added that "Please provide examples that we can observe the same phenomena". The self-assessment rating form that the students in the FAinIBT group used in the fifth week is shown in **Appendix B**.

Researchers' Roles

One of the researchers of this study was the physics teacher of the classes. While she was teaching, she guided and helped students throughout the in-

Table 1. Summary of the Instructional Context.

	IBT Group	FAinIBT Group
Model for the Instructional Context		
Weeks & Content	Instructional Context	Instructional Context
Week 1 Shadow and Plane Mirror	Watching videos about shadow shows. Asking questions and ensuring that prior knowledge is remembered. Achieving learning objectives by doing hands on activities with light sources, mirrors, and screens. Starting elimination of misconceptions through the activities.	Watching videos about shadow shows. Asking questions and ensuring that prior knowledge is remembered. Achieving learning objectives by doing hands on activities with light sources, mirrors, and screens. Starting elimination of misconceptions through the activities. Asking students if they could achieve the learning objectives and what they would like to learn more. Giving written feedback to their answers in the worksheets.
Week 2 Refraction	Asking daily life questions through images and making connections between phenomena (such as rainbow) and concepts. Ensuring the discovery of concepts through observations and simulation activities. Reinforcing the learning with a demonstration experiment with predict-observe-explain strategy. Sharing ideas by working with groups.	Asking daily life questions through images and making connections between phenomena (such as rainbow) and concepts. Ensuring the discovery of concepts through observations and simulation activities. Reinforcing the learning with a demonstration experiment with predict-observe-explain strategy. Sharing ideas by working with groups. Enabling students to conduct self-assessment and asking them how they could have learned better. Giving oral and written feedback.
Week 3 Lenses	Starting the lesson with discussion of wildfires in summer times. Investigation of working principles of microscopes and telescopes and presentation of the results. Exploring concepts such as focal length through simulation activities. Creating concept maps to provide the continuation of the inquiry.	Starting the lesson with discussion of wildfires in summer times. Investigation of working principles of microscopes and telescopes and presentation of the results. Exploring concepts such as focal length through simulation activities. Creating concept maps to provide the continuation of the inquiry. Enabling peer questions and providing feedback through discussions. Strengthen the outcome by requesting to think twice without giving the correct answer.
Week 4 Eye and Optical Instruments	Asking questions about eye defects and remedies. Construction of research questions and determination of image formation of lenses by watching videos and working with simulations. Discovering variety of lenses by doing hands on experiments.	Asking questions about eye defects and remedies. Construction of research questions and determination of image formation of lenses by watching videos and working with simulations. Discovering variety of lenses by doing hands on experiments. Asking further questions to the students according to their questions and answers and providing feedback.
Week 5 Color	Excitement of curiosity and enabling involvement by providing three dimensional visuals with the help of glasses. Raising questions about holograms. Doing experiments with prisms and color filters. Testing hypothesis and gathering information about the nature of color (whether it is a frequency or wavelength).	Excitement of curiosity and enabling involvement by providing three dimensional visuals with the help of glasses. Raising questions about holograms. Doing experiments with prisms and color filters. Testing hypothesis and gathering information about the nature of color (whether it is a frequency or wavelength). Asking students what they learned and how they learned and giving oral and written feedback. Students performed self-assessment.

quiry process. The following precautions were taken to prevent any bias: Instructional sequences for IBT and FAinIBT groups were prepared by two researchers together. The teacher kept anecdotes and took field notes in each lesson for both groups and discussed them with the other researcher. Moreover, inter-rater reliability was determined.

Even though having the same teacher in both groups might be a limitation due to the possible bias, this situation provided some advantages such as controlling cognitive abilities, motivation, and managing class time in both groups.

Measurement

Quantitative Data

Light and Optics Conceptual Evaluation (LOCE) test developed by Thornton and Sokoloff (1997) was applied as pre- and post-test before and after the inquiry based teaching in both groups to compare the students' conceptual understanding and find an answer for the first part of the research question. The LOCE test was chosen to use because it has high reliability and is suitable for high school students. Its adaptation study for the nation was done by (Demirci & Ahcı, 2016). A total number of questions in the test is 51 in which 50 of them are multiple choice questions whereas one of them is an open ended question. Difficulty levels of the items are between 13.9% and 76.2%. Due to the fact that, some of the questions were related to the concepts that were not covered during the inquiry-based teaching, they eliminated from the test and 37 multiple-choice questions comprised of the concepts taught were used for this study. These concepts were as follows: Image, plane mirror, focal length, refraction, vision, lenses, color, and shadow. An explanation section was added to the bottom of the all questions and the teacher requested the students to explain their reasoning behind their choices.

Qualitative Data

The students in the FAinIBT group kept reflective journals every week as a part of formative assessment. They expressed their feelings and thoughts, discussed their learning positions (which ways they chose and used), and explained the causes and consequences of situations they saw as a contribution to the process or understood their shortcomings (Hiemstra, 2001). Reflective journals helped the students do reflection and self-assessment. Therefore, these journals were also used to understand how formative assessment in inquiry-based teaching affected the students' learning. The reflective journals included the students' responses to the prompts such as what I learned, how I learned, what the purpose of the lesson was, what the most important factors were that allowed me to learn about the topic, and in what way the lesson was useful or useless for me.

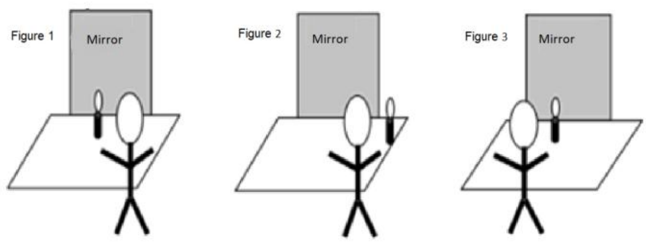
Analysis

Quantitative Data Analysis

The quantitative side of the study was conducted with 41 students studying in two groups. The students' responses to the LOCE before and after the instruction were analyzed by utilizing a scoring rubric developed based on Hogan and Fisherkeller (1996)'s coding scheme. This scheme was used in other research (Eksin & Ogan-Bekiroglu, 2013) because it enables comprehensive coding for student understanding. The coding scheme and corresponding scores are given in **Table 2**. The rubric was generated specifically for the content of each question. The overall maximum score the students could get from the LOCE was 222 while the overall minimum score was 0.
The fourth question in the LOCE and the scoring rubric for this question are shown below as an example:

Questions 1-5 refer to the three figures below of a candle on a table in front of a plane (flat) mirror.

Question 4: In Figure 3, the candle is moved back to its original location, and the person moves to the left to the new position shown. Compared to Figure 1, the location of the image of the candle is now:



A. *To the left of where it was in Figure 1;*
B. *To the right of where it was in Figure 1;*
C. *In the same location as in Figure 1;*
D. *There is no image of the candle;*
E. *Not enough information is given.*

Compatible Elaborate (6 points): C is correct. The position of the image of the object does not change according to the position of the observer in the plane mirror. If the location of the candle does not change, the location of its image will not change according to the position of the observer.

Compatible Sketchy (5 points): C is correct. Since the location of the candle remains the same, the image is also in the same place.

Table 2. Coding Scheme.

Student Response	Coding	Assigned Score
Correct choice with detailed scientific explanation.	Compatible Elaborate	6
Correct choice with superficial or inadequate scientific explanation.	Compatible Sketchy	5
Correct choice with non-scientific explanation.	Compatible/Incompatible	4
Incorrect choice with shallow explanation including inconsistent scientific knowledge.	Incompatible Sketchy	3
Incorrect choice with detailed explanation including unrelated concepts.	Incompatible Elaborate	2
A choice whether it was correct or not without any explanation.	No Evidence	1
No choice.	No Response	0

Compatible/Incompatible (4 points): C is correct. As the viewer maintains his distance from the mirror, the location of the image does not change.

Incompatible Sketchy (3 points): A is correct. The position and appearance of the candle does not change, but because the viewer changes his position, it becomes more to the left.

Incompatible Elaborate (2 points): B is correct. The image is further to the right, the viewer has moved to the left side of the mirror and the image of the candle has shifted to the right as the candle will be in line with the person.

No Evidence (1 point): Any option is marked, but the description part is left blank.

No response (0 point): The answer and explanation part is left completely blank.

The Shapiro-Wilk test was applied for normality analysis. The significance values of pre-LOCE test ($p = 0.19$) and post-LOCE test ($p = 0.50$) for the IBT group, and pre-LOCE test ($p = 0.83$) and post-LOCE test ($p = 0.53$) for the FAinIBT group were greater than 0.05. Skewness and kurtosis values also showed that the data were normally distributed; thus, paired and independent sample t-tests were performed within and between the groups. Cohen (1988)'s effect size was calculated for the t-tests to measure the magnitude of the pre-post changes for the IBT and FAinIBT groups.

Internal consistency was calculated by performing the Kuder Richardson formula 20. The value of reliability coefficient was 0.73 for the pre-test presenting that it had adequate internal consistency. On the other hand, the post-test had excellent internal consistency with reliability coefficient of 0.92. In order to assess the reliability of scoring, both researchers independently scored the students' pre- and post LOCE tests by using the coding scheme. After two researchers compared their scoring and computed the agreement for each test, they reached 92% agreement for the pre-test and the reliability measured by Cohen's κ was found as 0.76. Agreement percentage for the post-test was 95% and Cohen's κ was 0.82. Since Kappa values over 0.75 seem excellent (Fleiss, 1981), the students' scoring for their conceptual knowledge had high reliability. The researchers re-scored the responses and finalized scoring scheme.

Qualitative Data Analysis

Data obtained from the reflective journals were analyzed by using content analysis to determine the student' level of cognitive progress in conceptual learning and the role of formative assessment in this progress. These journals were read and summarized from a general point of view. Open coding was employed and codes were created by marking categories and meaningful sentences in the students' expressions in the journals. A code cloud was created and the codes were examined in terms of the relationship with each other. Categories covered the codes, but also the codes came together to create the categories. For example, one student wrote that "*I learned by doing experiment, watching videos, and researching and discussing the subject*". The underlined words attracted attention and this expression was considered appropriate to be included under the learning by applied methods (MA) code. Inter-coder agreement was calculated on random samples of approximately 30% of the journals by conducting the analyses separately. Percentages of agreement were 91% and Cohen's κ was 0.71.

Results

In accordance with the independent sample t-test results between the groups' pre-test scores, the IBT group's mean score obtained from the LOCE test ($\overline{X}_{\text{preIBT}}$ = 48.23) was close to the FAinIBT group's mean score obtained from the LOCE test ($\overline{X}_{\text{preFAinIBT}}$ = 45.60). As it can be seen in **Table 3**, there was no significant difference between the mean scores of the IBT and FAinIBT groups ($t_{(39)} = 0.729$, $p > 0.05$).

Paired sample t-test results indicated significant increases from pre-tests to post-tests within the groups' LOCE test scores. With regard to **Table 4,** there was a significant difference between the IBT group's mean value of pre-test and post-test ($t_{(20)} = -11.65$, $p < 0.001$). In other words, the mean score of the IBT group's post-test ($\overline{X}_{\text{postIBT}}$ = 89.52) was higher than the mean score of the IBT group's pre-test ($\overline{X}_{\text{preIBT}}$ = 48.23). Cohen's d value (d = 3.03) pointed out medium effect size.

Table 3. Independent Sample t-Test Results.

Groups	n	x̄	SD	Min. Score	Max. Score	df	t	p
IBT (Pre-Test)	21	48.23	15.79	27	85	39	0.729	0.473
FAinIBT (Pre-Test)	20	45.60	4.94	36	56			

Table 4. Paired Sample t-Test Results within the IBT Group.

Group	n	x̄	SD	df	t	p	Cohen's d
IBT (Pre-Test)	21	48.23	15.79	20	-11.65	0.000	3.03
IBT (Post-Test)	21	89.52	10.95				

Table 5. Paired Sample t-Test Results within the FAinIBT Group.

Group	n	x̄	SD	df	t	p	Cohen's d
FAinIBT (Pre-Test)	20	45.60	4.94	19	-15.42	0.000	4.17
FAinIBT (Post-Test)	20	104.15	19.19				

Table 6. Independent Sample t-Test Results Between the Groups' Post-Test Scores.

Groups	n	x̄	SD	Min. Score	Max. Score	df	t	p
IBT (Post-Test)	21	89.52	10.95	73	118	39	-2.97	0.006
FAinIBT (Post-Test)	20	104.15	19.19	72	143			

According to **Table 5**, there was also a significant difference between the mean values of pre- and post-tests of the FAinIBT ($t_{(19)}$=-15.42, p<.001). The FAinIBT group's post-test mean score ($\overline{X}_{postFAinIBT}$=104.15) was higher than the FAinIBT group's pre-test mean score ($\overline{X}_{preFAinIBT}$=45.60). Cohen's d value (d=4.17) indicated medium effect size.

Independent sample t-test results between the groups' post-test scores shown in **Table 6** presents that there was a significant difference between the mean scores of the IBT and FAinIBT groups ($t_{(39)}$ = -2.97, p < 0.05). The

Table 7. Mean Differences in the Groups Based on the Concepts between Pre- and Post-Tests.

Concepts	Mean Difference in IBT Group	Mean Difference in FAinIBT Group
Plane Mirror	8.14	11.15
Focal Length	8.23	9.50
Refraction	7.28	12.55
Defects of Vision	3.04	4.90
Image Properties for Lenses	3.76	3.45
Image Formation by Lenses	5.66	9.35
Shadow	3.80	6.05

Table 8. Categories, Codes, and Their Frequency Values.

Categories	Codes	Frequency
Ways of Learning	Method Applied	18
	Involving with the Process	15
Teaching Strategies	Teacher Guidance	15
	No Need to Memorize	9
	Adapting to Daily Life	12
Contributions of the inquiry	Permanent Learning	15
	Increased Inquiry Skills	12
	Learning to Learn from Feedback	18

FAinIBT group's mean score ($\overline{X}_{postFAinIBT}$ = 104.15) was quite higher than the IBT group's mean score ($\overline{X}_{postIBT}$ = 89.52).

The increase found in the participants' mean scores of the LOCE test from pre-test to post-test was analyzed based on the concepts in both groups. Findings presented in **Table 7** indicate that all the mean differences are significant ($p < 0.001$). Comparison of mean differences in two groups shows that the maximum increases occurred for the concept of refraction ($\overline{X}_{post-pre}$ = 12.55), plain mirror ($\overline{X}_{post-pre}$= 11.15), and focal length ($\overline{X}_{post-pre}$= 9.50) respectively in the FAinIBT group.

Categories and the codes with their frequency values derived from the students' reflective journals are presented in **Table 8**. Three categories and 8 codes were generated from the students' reflective journals. The categories were "ways of learning", "teaching strategies", and "contributions of the inquiry" (see **Table 8**). The code cloud displayed in **Figure 1** points out that Learning to Learn from Feedback (LLF) code and Method Applied (MA) code had the highest frequency and the most common ones. Teacher Guid-

Figure 1. Code Cloud.

ance (TG), Involving with the Process (IP), and Permanent Learning (PL) codes had the second highest frequency.

Some students' quotes about the LLF codes are as follows:

"My teacher's feedbacks reinforced my learning not only in the class but also at home and helped me to explore the joy in optics" (S6).
"My teacher's advices and feedbacks helped me realize my misconceptions and acquire the correct knowledge" (S1).
"My understanding was enhanced by my teacher's questions and feedback"(S3).
"Thanks to the questions asked by our teacher; we also understood how we should move forward in this process" (S2).
"The feedback that our teacher gave us helped me understand the parts that I was struggled with" (S5).
Examples from the students' excerpts related with the MA code are given below:
"I learned by doing experiments, watching videos, and discussing our findings from the investigations" (S6).
"Using simulations helped me understand the concepts because I made my own inferences" (S4).
Some students' statements emphasized the TG code:
"Our teacher guided us very well. When we asked a question, she asked about other examples and more questions, and allowed us to find ways to learn" (S4).
"It was great that our teacher encouraged us to answer questions and try new things" (S9).

Discussion

Assessment of inquiry has been an issue and formative assessment is a one promising practice to assess students' learning in their work (Nieminen, Häkkiöniemi & Viiri, 2021). Consequently, impacts of formative assessment integrated with inquiry on the students' knowledge of light and optics concepts were examined by collecting quantitative and qualitative data in this research. Various forms of formative assessment were used with inquiry approach in the FAinIBT group while the IBT group followed inquiry based instruction. Both groups were similar in terms of their knowledge of geometric optics concepts before the instruction.

The improvement in the students' learning in the IBT group after the instruction expresses that inquiry-based teaching created a positive effect in the students' conceptual learning of light and optics. This finding appeared also in previous research (Alouf & Bentley, 2003; Chen & Chen, 2012; Derting & Ebert-May, 2010; Hung, 2010; Johnson & Cuevas, 2016; Minner et al., 2010; Rahmat & Chanunan, 2018; Taylor & Bilbrey, 2012). Similarly, the students' in the FAinIBT group increased their knowledge, which means that embedded formative assessment in inquiry-based teaching supported the students' understanding of light and optics concepts. Comparison of two groups' results show that the students who were taught by inquiry and assessed formatively learned geometric optics concepts better than the students who were involved with inquiry based teaching but not assessed during the instruction. Other researchers also revealed parallel results (Bulunuz, 2017; Kusairi et al., 2021; Psycharis, 2016; Srisawasdi & Panjaburee, 2015). However, the findings divulged by Yin et al. (2008) contrast with the results of this study.

When students' learning was assessed concept by concept, the findings indicated that the students might expand their understanding according to the way that they demonstrated their learning achievements. Both oral and written feedbacks were given to the students while they were learning these concepts. However, eliciting evidence of learning stage of formative assessment was implemented slight differently. In the second week of the instruction, the content was refraction and the students performed self-assessment. The students learned plane mirror in the first week of the instruction and they were asked if they could achieve the learning objectives and what they would like to learn more. In the third week, the students produced and asked questions to each other while they were studying lenses and the related concepts. That is, the way of bringing out evidence of learning might affect student knowledge. Moreover, self-assessment which is a critical component of formative assessment might facilitate student learning more than the other facets of formative assessment. More specific research needs to be done on this issue.

It is very valuable to interpret the results of qualitative analyses, which supported the quantitative results; to understand how embedded formative assessment in inquiry triggered conceptual understanding. It seemed that the feedback given as oral and written was an important part of formative assessment cycle because it contributed to the students' learning most. Since telling students their score or proficiency category is not the type of feedback endorsed by the formative assessment literature (Shepard, 2008), feedback used in this study allowed the students to close the difference between what they learned and what they were supposed to learn. The way teachers use feedback contributes to the building of a learning environment that promote students' self-regulation (Correia & Harrison, 2020) because "feedback allows learners to review each set task, enabling further development of learning skills" (Higgins et al. as cited in Dorić, Lambić & Jovanović, 2021, p. 1438). The results are in agreement with the finding of Ruiz-Primo and Furtak (2007) who discovered that the teacher frequently applying components of formative assessment by eliciting questions and recognizing student's responses had students with higher performance. Teacher guidance in this study was another factor in the development of the students' learning. The study done by Aditomo and Klieme (2020) has analogous result that inquiry was positively related with learning outcomes when it incorporated teacher conceptual guidance, and negatively when it did not.

Formative assessment, especially teachers' feedback and students' self-assessment, provides instructional modifications, increases student motivation and enables students to maintain high engagement and achievement (Beesley et al., 2018; Cauley & McMillan, 2010; Fuller, 2017; Kerekovic, 2021; Leenknecht et al., 2021). This might be the case in this study because Koksalan and Ogan-Bekiroglu (2019) also discovered formative assessment in inquiry had a positive effect on the students' attitudes towards physics course. More research needs to be done to evaluate how formative assessment triggers student motivation, engagement, and learning.

Conclusion, Suggestion and Implication

Formative assessment has critical role in implementation of successful student-centered inquiry pedagogy in the classroom (Correia & Harrison, 2020). The following conclusions are drawn from the results of this study. First, formative assessment combined with inquiry-based teaching serves as a catalyst for students' conceptual learning and elevates effects of inquiry. Second, eliciting evidence of learning and feedback may be the most important steps of formative assessment in accelerating student learning and facilitating student knowledge development.

Black and Wiliam (2009) suggest classroom questioning, feedback and self-assessment as the activities to enact formative assessment. These activities were embedded in inquiry process in this study and shown as fruitful strategies in conceptual learning.

Often the term assessment for learning is used rather than formative assessment (McMillan, 2021). Assessment as learning is a particular case of assessment for learning and underscores that students should be valued participants in their own learning, able to identify their own learning gaps via constructive feedback and solve their learning needs via self-assessment (Earl & Giles, 2011). Accordingly, it can be suggested that self-assessment strategies can help the practice of assessment moves from assessment for learning to assessment as learning in inquiry-based teaching.

This study has several implications. Using formative assessment processes during instruction and implementation of formative assessment in inquiry to improve student learning are addressed in the current study. The conclusions suggest that assessment should be done when teaching continuous and teachers need to adopt formative assessment during inquiry-based teaching. Since formative assessment can provide multiple opportunities and multiple contexts for teachers to expose students' concepts (Furtak & Ruiz-Primo, 2008), "scientific inquiry learning may thus be better achieved by explaining to teachers about implementing formative assessment, so that their instruction may focus on to meet student learning goals" (Ruiz-Primo & Furtak, 2007, p. 79).

Although formative assessment has valuable contribution to learning, there are some issues such as teachers' ineffective training and their limited assessment ability problematize utilizing formative assessment (Chen, Q., Zhang, J. & Li, L. 2021). Moreover, even well-educated and experienced teachers had difficulties while integrating formative assessment in inquiry-based learning because making the assessment formative was an approach outside of the order they were used to (Bernard, et al., 2019). Consequently, in-service and pre-service teacher education programs can be designed to encourage teachers in this integration. Future studies would be conducted with an independent teacher or multiple teachers to examine the ability of the teacher to implement the formative assessment in inquiry process and investigate the interactions between teacher and students more closely. This research contributes to the assessment in science education literature by presenting how formative assessment practices applied in inquiry improve conceptual learning.

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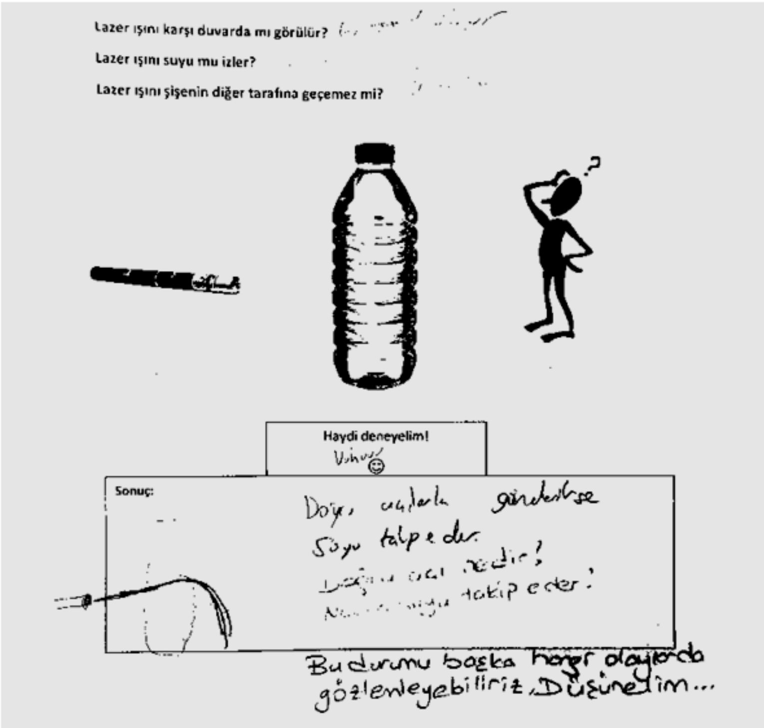
APPENDIX A

An example page for the teacher's feedback from the second week's worksheet.



APPENDIX B

Table B1. Self-Assessment Rating Form Used in the Fifth Week.

Content	Got It	Got Most of It - Just Some Fine - Tuning Needed	Got Some of It - Further Work Needed	Don't Get It at All - Help, Please
How rainbows are formed.				
How objects are seen with colors.				
How LCD TVs work.				
How holograms occur.				

ORIGINAL ARTICLE

Developing an Achievement Test on the Subject of 'Circulatory System' for Sixth Graders¶

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***Abstract**: This study aims to develop a test to measure sixth grade students' success in 'Circulatory System'. For this purpose, a draft test containing 22 questions was prepared by the researchers. And then, the draft test was submitted to expert opinion and examined in terms of language and content. Following expert opinions, the 22 multiple-choice questions were administered to 128 seventh graders attended to two different secondary schools. Item analysis was performed in the data and thus, two questions were removed from the draft test. According to the findings, the overall item difficulty value of the 20-question final test was calculated as 0.654, and the item discrimination value was calculated as 0.54. KR-20 reliability coefficient of the test was 0.71. Seven of the questions are at the remembering level. Additionally, there were eight questions at the understanding level and five questions at the analysis level according to Bloom' revised taxonomy.*

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Keywords: *Achievement, Circulatory System, Test Development, Sixth Graders*

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***Conflict of Interests**: None*

¶: This article was produced from the master's thesis of the first author. The authors have no competing interests to declare that are relevant to the content of this article. All authors have participated in the research and in the article preparation. All authors have approved the final article.

***Ethics Approval**: All procedures performed in the study were in accordance with the ethical standards of Atatürk University. Ethic approvals were obtained with the decision (reference no: E-56785782-050.02.04-2300297174) of the Social and Human Sciences Ethics Committee.*

Introduction

TODAY, the aim of education is to raise individuals who are enterprising, self-expressive, productive, problem-solving, open to new ideas, and able to think critically. In this perspective, the way to teach students information and today's technology depends on the education and training programs provided in schools (Buyruk, 2018; Tutkun & Aksoyalp, 2010). A correct understanding of the outcomes that are intended to be given to students occurs during the teaching process. The extent to which the teaching goals have been achieved, that is, how successful the teaching process is, is understood through measurement and evaluation (Açıkgöz & Karslı, 2015; Yıldız et al., 2019). In other words, the students' achievement and permanent behaviours are evaluated through measurement and evaluation process (Üçüncü & Sakiz, 2020).

Measurement is the symbol equivalent of certain features that we need in every aspect of our lives. In order to evaluate education, learners must be measured based on a criterion. We can get the answer to how much the achievements determined in education have been achieved by measuring. The quality of the measurement tool depends on its validity and reliability (Öztemel, 2018). Due to the need to create a qualified measurement tool, the "measurement and evaluation" course has begun to be taught as a compulsory course in teacher training faculties in our country (Özkan, 2006).

One of the most important issues in performing measurement and evaluation precisely and accurately is the selection of measurement tools. This is also valid for science education. If the academic achievements of students are to be measured in education, one of the measurement tools that should be used is achievement tests (Kargın & Gül, 2021). Achievement tests are instruments developed to measure the knowledge and skills gained by the student through a certain learning process. The essays, quizzes, open-book tests, true-false tests, multiple choice tests, homework and projects are used to measure and evaluate student success (Ayvacı & Durmuş, 2016). The most preferred among these measurement tools are multiple choice tests. These tests are often used in transition to a higher education institution in our country (Temizkan & Sallabaş, 2015). In multiple choice tests, the number of options can generally vary between three and five, depending on the student's level. Only one of these options is correct, and the others contain incorrect answers (Kargın & Gül, 2021). These tests are very reliable and can be easily applied in a short time, so they are also very useful for teachers. For this reason, it is frequently preferred in measurement and evaluation processes. In addition, since its scoring is objective, it provides an advantage in terms of providing reliable results (Ayvacı & Durmuş, 2016; Çardak & Selvi, 2018; Singh & Rosengrant, 2003; Timur et al., 2019). Of course, multiple choice tests have some disadvantages as well as these advantages (Temizkan & Sallabaş, 2015). These features are shown in **Figure 1**.

One of the most important features that distinguishes multiple choice tests from other testing techniques is that they provide a lot of data for statistical studies. One of the positive features of multiple choice questions in education is that they can be applied to all age groups, from primary school level to higher education level. It can be said that its reliability is high because the results obtained by different raters are close to each other (Akbulut & Çepni, 2013). Multiple choice tests, which are difficult to prepare but easy to score, are prepared to suit the age of the student. In our country, the number of options for multiple choice tests is preferred as three for primary schools, four for secondary schools, five for high schools and higher education. Since it is possible to ask questions about each learning outcome in these exams, content validity can also be ensured. However, it is difficult to write questions about higher-level cognitive skills. Written items can generally measure lower-level cognitive features such as knowledge, comprehension and application level (Küçükahmet, 2002).

There are researches on developing achievement tests in different subjects of chemistry, physics and biology in science courses in our country (Bolat & Karamustafaoğlu, 2019; Demir et al., 2016; İlhan & Hoşgören, 2017; Keçeci et al., 2019; Kenan & Özmen, 2014; Nacaroğlu et al., 2020; Saraç, 2018; Şener & Taş, 2017; Yalinkilic & Gul, 2023). However, regarding biology, only an achievement test developed by Gülbahar (2023) was found on the circulatory system in the science curriculum updated in 2018 in Turkey. When the development process of this test is examined, the distribution of the questions to the learning outcomes is not specified, and on the other hand, their place in the renewed Bloom Taxonomy has not been examined.

Researchers state that when evaluating student performance in the teaching process, instruments that measure students' understanding and comprehension levels should be used rather than instruments that direct students to memorize. At this point, the renewed Bloom Taxonomy appears as a classification in which different thinking stages are listed (Gündüz, 2009). Taxonomy is an approach that allows classifying the learning outcomes expected to be achieved by students as a result of an education (Bümen, 2006). Therefore, it can be said that there is a need to develop a new achievement test on the sixth grade Circulatory System, which is compatible with the achievements of the 2018 science course curriculum (Ministry of National Education [MoNE], 2018) and takes into account the Revised Bloom Taxonomy. Therefore, in this research, Circulator System Achievement Test (CSAT) was developed by considering the MoNE (2018) sixth grade Science Course Curriculum.

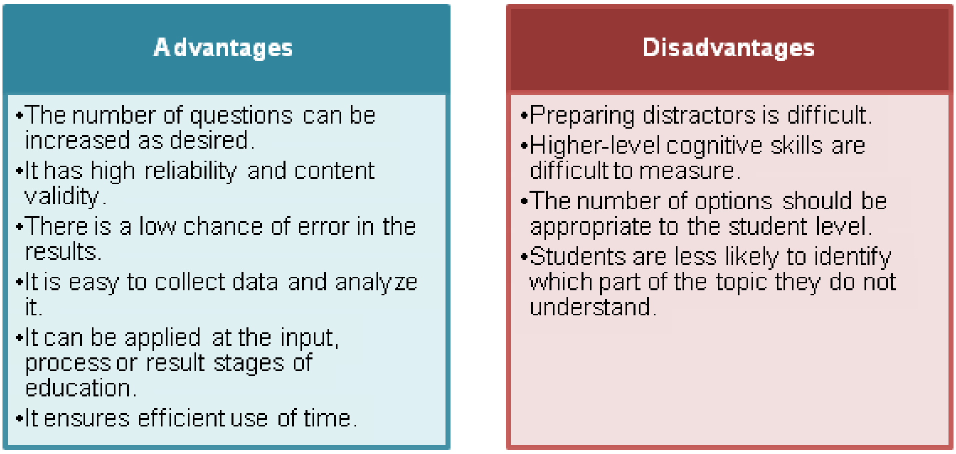

Figure 1. Advantages and Disadvantages of Multiple Choice Tests.

Purpose of the Research

This study aims to develop an achievement test on 'Circulatory System' in the sixth grade science course curriculum. For this aim, answers were sought to the following research questions.

1. *Is the CSAT developed to determine the students' achievement levels on the Circulatory System valid?*
2. *Is the CSAT developed to determine the students' achievement levels on the Circulatory System reliable?*

Method

This study was conducted with the survey method. The sample group research consisted of 128 (65 females, 63 males) 7th grade students from two primary schools randomly selected in a city in the east Turkey. 87 of the students (41 females, 46 males) participated in the study from the first school and 41 (24 females, 17 male) from the second school. According to this, 50.1% of the students are female and 49.2% male in total.

Development Process of Circulatory System Achievement Test (CSAT)

The development process of the CSAT was continued by considering the stages of the test development predicted in many studies in the literature. The stages of the test development followed in this research are similar to the stages used in the studies of Haladyna (1997) and Kızkapan and Bektaş (2018) was done in a similar way. Accordingly, the stages followed and the procedures performed in the test development process are presented below:

Determining the Purpose and Scope of the Test

The purpose of the CSAT to be developed in the research is to determine the student success level for the 'Circulatory System' subject in the sixth grade 'Systems in Our Body' unit. According to the Science Course Curriculum, there are five learning outcomes for the subject of 'Circulatory System' (MoNE, 2018). These:

(1) F.6.2.3.1. Explains the functions of the structures and organs that make up the circulatory system using models.
(2) F.6.2.3.2. Examines the pulmonary and systemic circulation on a diagram and explains their functions.
(3) F.6.2.3.3. Defines the structure and functions of blood.
(4) F.6.2.3.4. It refers to blood exchange between blood groups.
(5) F.6.2.3.5. Evaluates the importance of blood donation for society.

In addition to the above learning outcomes, some basic topics and concepts that are expected to be taught about the 'Circulatory System' subject are also included in the sixth grade curriculum (structures and organs that make up the circulatory system, structure and function of the heart, blood vessels, pulmonary and systemic circulation, blood groups, blood donation, circulatory system). Therefore, CSAT was developed by considering the learning outcomes and concepts included in the curriculum.

Literature Review and Determining Test Questions

After determining the scope of the test by examining the 6th Grade Science Curriculum (MoNE, 2018), a comprehensive literature review was conducted by the researchers. In this process, first of all, the achievement tests developed for 6th Graders on the Circulatory System were examined. As a result of the investigations, achievement tests developed by different researchers were found. For example, expert opinion was sought for the validity of the test developed by Çakmak et al. (2012). Its reliability was determined with data collected from 42 students and the Cronbach Alpha internal consistency coefficient was calculated as 0.79. The pilot application of the circulatory system achievement test developed by Özay Köse and Yıldırım (2020) was conducted with a total of 50 students in the 2017-2018 academic year. After item analysis, a test consisting of 25 questions was developed.

However, the reliability coefficient was not mentioned in the study. Achievement test prepared by Yalçınkaya (2018) was prepared according to the Ministry of Education (2005) Science and Technology Course Curriculum. Validity and reliability studies were provided with expert opinion and data collected from 38 students. As a result of item analysis, an achievement test consisting of 19 multiple-choice questions was developed. Cronbach Alpha reliability coefficient was found to be 0.71. An achievement test was developed by Gülbahar (2023) for the new curriculum updated in 2018. However, when the development process of this test is examined, the distribution of the questions to the learning outcomes is not specified, and on the other hand, their place in the renewed Bloom Taxonomy has not been examined.

As a result, when the achievement tests developed for 6th graders on the Circulatory System are examined, it is seen that some of them did not contain item analysis, a pilot study was conducted with a small number of samples, only expert opinion was consulted for validity, the tests were prepared according to the pre-2018 curriculum, the distribution of the questions according to Bloom's taxonomy was not examined, or the questions in the test were at the lower levels of the cognitive domain. For this reason, it was decided to develop a new achievement test in the study. Thus, different questions were prepared from these studies. In the process of preparing questions, relevant resources (textbooks, different resources in internet, etc.) were examined and a total of 22 multiple choice questions were prepared for the Circulatory System topic.

Preparing the Draft CSAT and Asking for Expert Opinion

As stated before in the research, 22 multiple-choice questions, each with four options, were prepared after reviewing the relevant literature. In the literature, checking content validity is one of the must-do practices regarding the test development process (Tunç & Kılınç Alpat, 2015). Because to what extent the questions in the measurement tool represent the scope of the subject is an issue that must be taken into consideration. One of the frequently used methods for the content validity is to obtain expert opinion (Çalık & Ayas, 2003; Treagust, 1988). For this purpose, the draft form of CSAT, which includes 22 multiple-choice questions, was presented to the opinion of a total of six experts, including five academicians and one science teacher. After being examined by experts in terms of features in terms of language, scope, appearance, content, etc., the test was given its final form.

In the research, in addition to expert opinion, to ensure the content validity of the test, a specification table was prepared according to the Bloom's Revised Taxonomy and the questions were analysed by the same experts. Thus, it was determined which level of the cognitive domain the 22 questions in the test fell into in Bloom's Taxonomy (**Table 1**).

When **Table 1** is examined, seven out of 22 questions are at the remembering level, eight at the understanding level, one at the application level and six at the analysing level.

Findings

During the scope validity studies of the research, the draft CSAT was finalized in line with expert opinions. Then, the item analysis and reliability analysis phase was started. According to Bryman and Cramer (2001), the number of samples should be at least five times the number of items in the scale. Therefore, in this research, the draft test was administered to 128 students during one class hour. Afterwards, item analysis was performed on the data obtained from the students. At the stage of item analysis, values of item difficulty-item discrimination were calculated (**Table 2**).

According to Rao et al. (2016) and Deborah et al. (2021), questions with $pj > 70\%$ are classified as 'easy', questions with $0.30 < pj < 0.70$ are classified as medium difficulty, and questions with $pj < 0.30$ are classified as 'difficult' in multiple choice tests. On the other hand, questions with $rj \leq 0.30$ are weakly discriminative; questions with $0.30 < rj \leq 0.39$ are classified as good level discrimination, and $rj > 39\%$ are classified as excellent level of discrimination. When the item analysis results in **Table 2** are examined, the item difficulty index of one question (Q-8) fell into the difficult category. The item difficulty index value of the nine questions was evaluated in the very easy category. All other questions are of medium difficulty. When the item discrimination of the questions was examined, the item discrimination index value of two questions (Q-8, Q-18) fell into the weak category. However, four questions are at a good level of discrimination, and all of the remaining questions are at an excellent level of discrimination. In light of these findings, it was decided to remove two questions (Q-8, Q-18). The average item difficulty index for the remaining 20 questions was calculated as 0.65, and the average item discrimination was calculated as 0.54. The KR-20 reliability coefficient of 20-question CSAT is 0.71. When the analysis results are evaluated, it can be said that CSAT is a reliable test with medium difficulty and excellent discrimination. After the item analysis was completed, the 20 questions left in the test were renumbered and the test was given its final form. The distribution of the questions in the final CSAT according to the Revised Bloom taxonomy is shown in **Table 3**.

When **Table 3** is examined, seven out of 20 questions are at the remembering level, eight at the understanding level and five at the analysing level.

Table 1. Specification Table for the Questions in the Draft CSAT.

Learning Outcomes	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
Learning Outcome 1	Q-1, Q-2, Q-4	Q-3, Q-6, Q-9, Q-10	-	Q-8	-	-
Learning Outcome 2	-	Q-5, Q-6, Q-7, Q-9, Q-10	-	Q-8	-	-
Learning Outcome 3	Q-11, Q-15	-	-	Q-12, Q-13, Q-14	-	-
Learning Outcome 4	Q-16	Q-19	Q-18	Q-17, Q-21	-	-
Learning Outcome 5	Q-20	Q-19, Q-22	-	Q-21	-	-

Table 2. Item Analysis Results of CSAT.

Items	pj	rj	Items	pj	rjx
Q-1	0.81	0.66	Q-12	0.59	0.51
Q-2	0.69	0.58	Q-13	0.70	0.56
Q-3	0.80	0.65	Q-14	0.79	0.63
Q-4	0.58	0.51	Q-15	0.58	0.46
Q-5	0.78	0.63	Q-16	0.41	0.36
Q-6	0.83	0.66	Q-17	0.39	0.36
Q-7	0.72	0.59	Q-18	0.44	**0.29**
Q-8	**0.23**	**0.12**	Q-19	0.55	0.51
Q-9	0.77	0.62	Q-20	0.34	0.35
Q-10	0.89	0.68	Q-21	0.54	0.59
Q-11	0.80	0.64	Q-22	0.47	0.34
Overall test				0.65	0.54

Table 3. Specification Table for the Questions in the Twenty-Question Final CSAT.

Learning outcomes	Questions*	Bloom's Taxonomy
Learning Outcome 1	Q-1 Q-2 Q-3 Q-4 Q-6 Q-8 Q-9	Remembering Remembering Understanding Remembering Understanding Understanding Understanding
Learning Outcome 2	Q-5 Q-6 Q-7 Q-8 Q-9	Understanding Understanding Understanding Understanding Understanding
Learning Outcome 3	Q-10 Q-11 Q-12 Q-13 Q-14	Remembering Analyzing Analyzing Analyzing Remembering
Learning Outcome 4	Q-15 Q-16 Q-17 Q-19	Remembering Analyzing Understanding Analyzing
Learning Outcome 5	Q-17 Q-18 Q-19 Q-20	Understanding Remembering Analyzing Understanding
* Some questions meet more than one learning outcome		

Discussion and Conclusion

As stated before, the MoNE makes changes in the curriculum in certain periods in line with the needs of the education process. Therefore, measurement and evaluation tools applied in schools need to be updated in accordance with new curriculum. This study aims at developing a CSAT for the 6th graders.

Achievement tests are one of the most frequently preferred tools to measure students' achievement levels in any subject. In this regard, it is important that achievement tests are valid in terms of scope and structure (Üçüncü & Sakız, 2020). In this research, it can be said that a consistent test with high content validity was developed as a result of the improvements made in line with item analyses and expert opinions. It is highly likely that carrying out the test development process correctly by following the stages of the test development prescribed in the literature will cause this result. As a matter of fact, the stages followed in the literature are similar to this study (Haladyna, 1997; İlhan, 2020; Kargın & Gül, 2021). The stages of the test in the literature are similar to this study (Açıkgöz & Karslı, 2015; Bolat & Karamustafaoğlu, 2019; Haladyna, 1997; Kargın & Gül, 2021; Kızkapan & Bekaş, 2018). For example; Eren et al. (2020) developed a test on 'elements and compounds' in the 7th grade secondary school science courses by following similar steps to this research. As a result of reliability and validity analysis, they developed a 27-item test for the subject 'elements and compounds'. Çardak and Selvi (2019) performed a similar study for the 'teaching principles and methods' course. It was carried out by following a 10-stage process, including the determining the purpose of developing the achievement test, determining the objectives and behaviours of the course, creating the specification table, writing multiple choice test items for critical behaviours, presenting the specification table and test items to expert opinion, obtaining student opinions for the first test draft, developing the draft test, the application (first trial application), item analysis with the data obtained from the trial application, and calculation of the statistics of the second trial application and the final test. After the validity and reliability analysis, it was concluded that this multiple-choice test can be used in scientific studies and courses related to 'Teaching Principles and Methods' course subjects. As a result, it can be said that this research overlaps with some studies in the literature in terms of test development steps (Yalinkilic & Gul, 2023). However, since the questions in this research were examined by a small number of experts, this can be considered a limitation for the study. Because Akbulut and Çepni (2013) and Üçüncü and Sakız (2020) suggested that in order to ensure content validity, it should be determined whether the harmony between expert opinions is valid or not.

Considering the stages of the test development in the research, firstly a literature review was conducted. Thus, 22 questions, each with four options, were prepared in line with the learning outcomes in the Science Course Curriculum. After expert opinions, the questions were placed in the specification table. In the literature, while preparing the draft test, it is recommended to write three items for each outcome in the specification table (Atılgan, 2013; Yalinkilic & Gul, 2023). In this study, an attempt was made to increase the content validity CSAT by paying attention to this criterion. After content validity studies, the draft test containing 22 questions was administered to 128 students for item analysis. At stage of item analysis, item difficulty-item discrimination indexes were calculated and the test was reduced to 20 questions. The average item difficulty of the CSAT was 0.65, and the average item discrimination was 0.54. It can be said that these results show that the test is of medium difficulty and perfectly discriminatory (Assimi et al., 2022). In addition to this positive result, although multiple choice tests have many advantages such as application and scoring (Ayvacı & Durmuş, 2016), they also have disadvantages such as finding the correct answer randomly. In order to minimize this disadvantage, it is recommended that open-ended questions be included in achievement tests in addition to multiple-choice questions (Saylan-Kırmızıgül, & Kaya, 2019). Therefore, the fact that there are only multiple choice questions in the achievement test developed in this study is a limitation for this study. However, the multiple choice questions in the test can be of great benefit to teachers in terms of saving time, ease of scoring, objectivity and preparation for exams that measure achievement. On the other hand, although multiple choice questions are not fully effective in determining misconceptions, the answers given can identify deficiencies or distortions in the subject (İdin & Aydoğdu, 2016; Özkan & Eryılmaz Muştu, 2018; Şen & Eryılmaz, 2011).

Bloom taxonomy is frequently used in test development processes in the field of education. This situation is explained by the advantage of the cognitive domain classification in Bloom's taxonomy in ensuring that the purposes of the items are clear and observable (Ayvacı & Türkdoğan, 2009). Supporting this situation, Özkan and Yadigaroğlu (2020) stated that when developing a test, it is necessary to prepare the questions by taking the renewed Bloom Taxonomy into consideration. Thus, the questions can be classified more clearly and in more detail.

The findings of the research showed that seven out of 20 questions in the CSAT are at the remembering level, eight at the understanding level and five at the analysis level. One of the two questions eliminated as a result of item analysis is at the analysis stage (Q-8) and the other is at the application stage (Q-18). These questions may have been found difficult by most students because they were in high knowledge level of Bloom's taxonomy. As a matter of fact, item difficulty and discrimination values show that these questions are outside the desired limits. In addition to the item analysis findings, the KR-20 reliability coefficient of the CSAT was 0.71. This value shows that the test is a reliable test.

The findings of the research also showed that all of the questions in the final CSAT cover all the learning outcomes in the curriculum and are distributed evenly among the learning outcomes. Accordingly, it can be said that the content validity of the achievement test is high. In addition, it can be predicted that the test will provide detailed information about the students' learning levels and give accurate results about the general concepts of the subject.

It is envisaged that this test, whose reliability and validity has been verified, can be used by educators as a measurement tool in measurement and evaluation studies on the subject of 'Circulatory System'. In addition, this test can be used by science education researchers in experimental studies as a data collection tool to compare the achievements of student groups.

As a result, taking into account the findings and limitations of the study, the following suggestions are offered for future research:

- As it is known, multiple choice tests are not sufficient to measure high-level knowledge of the cognitive domain in Bloom's taxonomy. As a matter of fact, in this research, questions for the create level were not prepared in the draft test. Since high-level information is mostly tested with open-ended questions, different types of questions such as open-ended questions can be prepared in addition to multiple choice questions in similar achievement tests in the future.
- Research suggests that two- or three-stage tests measure knowledge better. Therefore, two or three-stage multiple choice tests can be developed in future research.
- In future research, new achievement tests can be developed by using larger samples and applications in schools at different levels.

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REVIEW

The Ethical Challenges of Educational Artificial Intelligence and Coping Measures: A Discussion in the Context of the 2024 World Digital Education Conference

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Abstract*: Artificial intelligence (AI), as the core technology of the fourth industrial revolution, has been widely deployed in many areas, bringing tremendous changes to human society. At the same time, AI has also instigated a variety of ethical issues regarding basic human rights, social order, private safety, and more. In order to maintain a balance between technological development and the ethics of AI, governments of various countries and international organizations are working to develop AI regulations and ethical norms. A forum themed "Artificial Intelligence and Digital Ethics" was held as a side event during the 2024 World Digital Education Conference (WDEC), showcasing the Chinese government's adherence to the ethical notion of "human-centered AI" and the principle of "digital for good" in using AI in digital education. The forum emphasized the importance of establishing the ethics of educational AI for circumventing relevant ethical risks and creating healthy environments for the digital transformation of education. Based on the forum's theme, this article seeks to set forth the necessity of formulating a code of ethical norms for educational AI and to explore pathways to building an ethical framework in this regard in order to provide insights into the rational application of AI in education and promote the sustainable development of digital education.*

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Introduction

ARTIFICIAL INTELLIGENCE (AI), a central technology in the fourth industrial revolution, is widely used in numerous facets of human life and brings ongoing transformative changes to society (Feng, 2022). The widespread application of AI and its deep integration into fields like education, health care, finance, communication, and media have substantially increased society's productivity and economic outcomes. Viewing AI as the focus of international competition, major countries around the world have formulated their own strategy for the development of AI to enhance their national competitiveness (Chen & Zhu, 2024).

However, AI-induced ethical risks related to issues such as basic human rights and social order have the potential to bring about immense threats to society (Feng & Zang, 2024). AI ethics, as a component of technological ethics, is currently high on the agenda of science and technology development governance in many countries. In January 2020, the US federal government released the "Regulation Guidelines for Artificial Intelligence Applications" to guide the federal government's regulatory and non-regulatory measures for AI development and application (Zhu et al., 2023). The European Union initiated its effort to build a regulatory framework for the application of AI technology in 2016. In 2018, it created the High-Level Expert Group on Artificial Intelligence to accelerate the establishment of a unified legal regulatory framework for AI. In June 2023, the European Parliament enacted the draft compromise amendment of the Artificial Intelligence Act, marking the EU's leading position in AI regulation in the world. (Ning et al., 2023). UNESCO's "Recommendation on the Ethics of Artificial Intelligence," released in 2021, is the first international paper to regulate AI ethics globally. It affirms that AI ethics should prioritize the protection of human rights, freedoms, and dignity as a core value (Zhu & Hu, 2022).

AI is an important driving force for educational development. The majority of countries in the world place a high premium on the application of AI in education. The US's report titled "Preparing for the Future of Artificial Intelligence" emphasizes that AI development has increased the social demand for high-level talents, and intelligent applications have become a key focus of the strategy of strengthening educational foundations (Executive Office of the President, National Science and Technology Council Committee on Technology, 2016). The report "Growing the Artificial Intelligence Industry in the UK" calls for an expansion of the AI-specialized talent pool as a national strategy (Hall & Pesenti, 2017). In Germany's "High-Tech Strategy 2025 Progress Report," AI technology is described as a "future weapon" for heightening national competitiveness and educational innovation (Federal Ministry of Education and Research, 2019). According to UNESCO's *Rethinking Education: Towards a "Global Common Good,"* *crucial* to the sustainable and healthy development of educational AI are creating intelligent learning settings and personalized learning paradigms, improving evaluation systems, and providing scientific education management and services (UNESCO, 2017).

Educational AI has also garnered wide attention in China. In January 2024, the Ministry of Education of China, the Chinese National Commission for UNESCO, and the Shanghai Municipal People's Government jointly organized the 2024 World Digital Education Conference (WDEC) with the theme of "Digital Education: Application, Sharing, and Innovation." Its six forums focus on the topics of the improvement of teacher digital literacy and competence; the building of digital education and a learning society; the evaluation of global trends and indices in digital education development; artificial intelligence and digital ethics; the challenges and opportunities of digital transformation for basic education; and the digitalization of education governance and digital education governance, respectively (Ministry of Education, 2024a). Outstanding among them is the forum on "artificial intelligence and digital ethics." Based on the forum's theme, this article explains the necessity of formulating a code of ethical norms for educational AI and discusses the pathways to building a framework of ethics in this regard in order to provide insights into the rational application of AI in education and promote the sustainable development of digital education.

Ethical Challenges of AI in Education

AI is developing at an unprecedented pace because of the maturation of technologies such as cloud computing, big data, virtual reality, and deep learning. AI applications continue to integrate into all facets of society, causing profound changes in human production and life. The developmental trend of AI shows that its impact on education is increasingly intensifying (Li et al., 2018). According to Huai (2024), the Minister of Education of China, in today's world characterized by accelerating technological and industrial revolutions, digital technology has increasingly become a driving force that fundamentally changes and reshapes human society's thinking patterns, organizational structures, and operational modes on all fronts. Education faces both new challenges and opportunities. Every country is contemplating the epochal question of "where education is headed."

With its intelligent, automated, and high-precision data analysis and processing capabilities, educational AI can empower teaching and learning in many ways, such as simulating the roles of teachers, administrators, peers, partners, and competitors to promote communication and collaboration (VizcainoI, 2004); providing students with adaptive learning support services by assisting in building adaptive learning environments and analyzing and diagnosing the learning style and needs of students (Luckin, 2016); helping students formulate right answers to questions by utilizing natural language processing and deep learning technologies (Guo et al., 2019); identifying learners' emotional needs in the learning process and providing tailored emotional support by automatically recognizing their body movements and facial expressions using the affection detection technology (Saneiro et al., 2014); giving students feedback that suit their cognitive levels by automatically evaluating their learning outcomes (Perikos et al. 2017); supporting teachers in making teaching decisions and learners in making learning decisions through decision-making management technology (Luckin et al., 2016).

Despite its value in data integration and analytics, educational AI elicits a wide variety of ethical concerns, such as the challenge to the traditional role of teachers, deviation from student holistic development, academic misconduct due to technological abuse, and security infringement induced by data leakage. Therefore, it is imperative to thoroughly examine the ethical complexities arising in the design, development, and application of educational AI and to make careful considerations about what ethical principles should be followed to ensure a legitimate use of AI in education (Deng & Li, 2020).

Challenging Teachers' Role as Educators

AI has reformed the traditional education ecosystem, enabling AI-powered robots to now fulfill instructional duties that were previously exclusive to teachers. The history of AI application in education displays that AI's educational functions have undergone significant changes throughout various developmental stages. Older-generation intelligent instructional applications such as SOPHIE, MYCIN, and GUIDON played the roles of tutors, trainers, and evaluators in training and teaching, capable of making decisions and giving directions based on disciplinary knowledge and existing experience. New-generation AI applications, such as LearnSmart, Knewton Platform, Squirrel AI Adaptive Learning, AI Teaching Assistant Jill Watson, MIT's Tega Robot, Anki's Cozmo Robot, and robotic trainer Alpha 2, can play more sophisticated educational roles in intelligent tutoring, question paper setting, Q&A, evaluation, and other teaching tasks (Feng et al., 2020). Newly developed intelligent robots and intelligent search engines have become effective assistants and companions of students in their autonomous inquiry-based learning and cooperative learning, and some of them can even function as emotional support and digital entertainment (Wang, 2021). The trend toward AI outperforming human educators in certain instructional behaviors is growing.

Nevertheless, teachers' responsibilities go far beyond knowledge imparting; teaching entails more complex and higher-order duties, such as moral character and value education and social education (Hao, 2022). Concerns such as "whether educational AI is capable of making correct moral or value-related judgments," "whether it will entirely replace teachers," and "if it can assist students in developing social and emotional skills to prepare them for future social integration" remain unanswered. When AI assumes increased roles as educators, the traditional ethics of education will be put to the test.

Impeding Student Holistic Development

Tailored teaching, as opposed to mass teaching, is the notion of education that students should be taught with varied objectives and approaches according to their differential foundations, competences, interests, and personality traits. It is of vital significance for supporting students' holistic development and cultivating creative talents for the new era (Yan, 2021). However, in the context of AI applications in education, excessive personalized "push and customization" could potentially impede the comprehensive development of students.

In the process of educational innovation and reform, the educational community seeks to harness technological applications to realize tailored education. The implementation of student-personalized learning has become a key component of educational AI. Personalized learning applications, such as intelligent virtual assistants, mentor systems, and adaptive learning systems, are all developed based on the individual characteristics of learners' languages, learning styles, preferences, etc. (Yang et al., 2018). These applications, powered by big data analytics and recommendation algorithms, can help realize mass personalized learning by adjusting course difficulty according to students' learning abilities, adapting learning materials to suit each learner's progress in real-time, and providing tailored exercises at the appropriate time (Jin et al., 2017).

Nevertheless, AI-assisted tailored instruction does not necessarily contribute to holistic student development. Educational AI based on big data analytics can decompose human knowledge into computable digital symbols and effectively track and analyze students' learning behavior and process. Personalized recommendation algorithms can easily cause the "information cocoons" effect (Wang, 2023). Based on the algorithmic push, the content presented to students is what suits the students' interests or preferences as a result of the filtration and selection by technology. Over time, students' learning interests and attention may be constrained within a predetermined range, their knowledge horizons may be narrowed, the inclusiveness and diversity of learning content may be compromised, and their thinking may be manipulated by algorithms (Ma, 2022). Moreover, students' overreliance on recommendation algorithm-dominated information acquisition can easily lead to their behavioral and thinking inertia; their initiative in learning will be impaired by technology (Feng et al., 2020). All these factors are detrimental to students' all-round development.

In addition, educational AI based on machine learning and recommendation algorithms has the potential hazards of information discrimination and bias, which are often implicit or covert under the illusion of personalized learning (Hu, 2021). When technology becomes a new form of totalitarianism, humans either conform to the work procedures prescribed by technology or they become appendages to technological tools (Zhou, 2007). The plurality of ethical risks associated with AI applications in education is noteworthy.

Threatening Data Privacy

The right to privacy is crucial to the protection of human dignity, autonomy, and agency. Data privacy refers to individuals' claims that data about them generated in the processes of information collection, storage, use, and transmission should not be accessible to other individuals and organizations. Data privacy aims to prevent unauthorized abuse or public disclosure of personal information (Du, 2017). Amidst the rapid development of educational AI, privacy infringement and data leakage emerge, posing grave threats to the security of teachers' and students' personal information.

Environmental information can also be gathered and recorded in educational settings, in addition to personal features like the fingerprint, face, and voice being used in determining user identity. In Raja Yusof et al.'s (2017) study, a positioning system and a learning behavior visualization system that could monitor student classroom activities in real-time were developed and applied to 132 teachers and students. The temperature, humidity, and carbon dioxide concentration in the classroom may affect the learning efficacy of teachers and students, as well as their physical health. In response to this concern, Peng and Chen (2017) developed a real-time monitoring system for the classroom environment based on Bluetooth. In addition, intelligent sports devices such as the smart wristband and intelligent lung capacity assessment tool can be used to collect students' health data, and consequently, problems with physical fitness and sports ability in students may also be revealed (Yu, 2020). The proper use of the aforementioned information can support the enhancement of educational services; nevertheless, without adequate protection, the large amounts of personal information controlled by intelligent systems may risk leakage, and the exploitation of said information for certain illegal purposes can lead to privacy infringement.

Inciting Academic Misconduct

Academic misconduct is an attempt by a student to gain, or help others gain, an unfair academic advantage (University of Cambridge, 2019), including but not limited to plagiarism, cheating, collusion, and the use of unauthorized aids during a test or exam. When misused, AI technology can facilitate academic misconduct.

AI technologies, such as ChatGPT, can be used to produce persuasive and logical texts in response to the user's requirements, making AI-generated paper, automatic plagiarism, and the fabrication of data possible (Luo & Ma, 2023). In the meantime, students' overreliance on AI technology and undiscriminated acceptance of its offerings may lead to cognitive laziness and thus deteriorate their academic competence. Even worse, the prevalence of using mobile devices as cheating tools has grown. In Ikanth's and Asmatulu's (2014) study, 70% of the student participants admitted to using various high-tech devices in examinations, group assignments, reports, and paper writing. To better serve their educational purposes, the developers of educational AI applications must consider how to avoid ethical risks in their products.

Pathways to the Establishment of Ethics in Educational AI

All stakeholders in education are subject to the ethical hazards of AI technologies, which could be latent, chronic, and irreversible. To ensure effective governance of AI applications in education and prevent technological abuse, it is imperative to establish ethical norms that inform the development and use of educational AI (Feng et al., 2020).

Jie Chen, Vice Minister of Education of China and Director of the National Committee of UNESCO, emphasized at the 2024 WDEC that the expedited advancement of digital technology has brought forth unprecedented challenges and opportunities for global education, profoundly changing educational ideas, models, and paradigms. The Chinese government places great stress on the governance of digital education, adhering to the principle of maintaining balances between AI development and security and between AI innovation and moral considerations. The establishment of the digital education expert council committee and AI ethics committee and the formulation of regulation frameworks for educational AI are underway to meet the challenges of AI applications in education (China Youth Daily, 2024).

In the process of integrating AI in education, it is important to clarify the moral limitations of AI applications in regular instruction, scientific research, and social services, as well as formulate industry standards, governance regulations, and ethical norms for educational AI in order for AI to contribute to a safe, efficient, and sustainable development of education (People.cn, 2024b). Imperative among various pathways to the establishment of the ethics of educational AI are ascertaining their goals and principles, strengthening the governance of educational AI, and enhancing the AI literacy of teachers and students.

Ascertaining Educational AI Ethics Goals and Principles

Goals of Ethics in Educational AI

The explicit goals of educational AI ethics provide directions for the effort in this regard. Establishing the ethics of educational AI is aimed at safeguarding human rights and educational equity, supporting sustainable development of education, cultivating responsible users of technology, and promoting the coordinated development of technological innovation and ethics for a healthy, orderly, and sustainable development of educational AI.

Safeguard Human Rights and Educational Equity: To ensure that the application of AI technology in education does not infringe on human rights to privacy, personal data security, and equitable education; to ensure that all students have equal access to the educational resources and opportunities brought about by AI technology (Xiao, 2023).

Support Sustainable Development: To align the advancement of educational AI with the goals of sustainable development in society as a whole; to contribute to the equity of quality education and promote lifelong learning (Tao, 2023).

Coordinate the Development of Technological Innovation and Ethics: To encourage innovation in educational AI within the framework of AI ethics; to promote parallel advancements of technology and ethics to drive the ongoing progress of education (Deng, 2024).

Cultivate Responsible Users of Technology: To educate teachers and students to become responsible users of technology; to affirm the ethical principles and norms in the use of AI technology to prevent abuse and misuse of technology (Wu et al., 2024).

Principles for the Ethics of Educational AI

To guide the ethical use of social networking sites, Parrish (2010) developed a model of ethical principles named PAPA, which stands for information privacy, accuracy, property, and accessibility. Using this model as a framework of reference, Du et al. (2019) put forward ethical principles of educational AI, highlighting responsibility and accountability, privacy protection, impartiality, transparency, non-maleficence, precaution, and reliability of systems in the adoption of AI in education.

Responsibility and Accountability: AI actors, especially developers and deployers of educational intelligent systems, must fulfill their responsibilities and obligations under specific laws and regulations.

Privacy Protection: Individuals in the educational community should be able to access, manage, and control personal data processed by intelligent machines to prevent unauthorized sharing of user information with other individuals or businesses.

Impartiality: Training algorithms with inaccurate or biased data produces biased outcomes, leading to algorithmic discrimination. AI should avoid making decisions that are systematically unfair to certain groups of people in the realm of education.

Transparency: Factors that influence the decisions made by algorithms should be visible, or transparent, to stakeholders in education who use and regulate the systems that employ those algorithms.

Non-maleficence: This principle emphasizes that algorithms should "do no harm," which entails not infringing the privacy of teachers and students and avoiding misuse of AI technologies in other ways. There must be mechanisms in place to prevent harm from the unforeseen behavior of machines.

Precaution: There should be systems to oversee the behavior of machines and corresponding warning devices, which enable users of AI technology to react promptly when machines engage in behaviors that harm humans.

Reliability of Systems: This principle concerns algorithmic systems' stability and consistency. AI systems should have reliable features such as safe operation and the capability of avoiding being maliciously manipulated.

Enhancing Ethical Issue Governance with Educational AI

Human-machine collaboration is becoming increasingly popular in educational settings. It brings about new challenges for the educational community, both technologically and ethically, requiring AI governance based on specialized legislation, regulations, and policies, which is the precondition for deep, orderly, and healthy integration of AI in education (Xia et al., 2023). Ethics connect moral norms and the law, and the ethics of educational AI need to be institutionalized by a series of conventions, policies, and rules (Xu, 2023). **Table 1** exhibits global efforts to address ethical issues in the development and application of AI technology.

Table 1. Papers on AI Ethics Issued by Major Countries and International Organizations.

Names	Years	Issuers
Recommendation on the Ethics of Artificial Intelligence (UNESCO, 2021)	2021	The United Nations
Responsible AI: A Global Policy Framework (ITechLaw, 2021)	2021	ITechLaw
The Roman Call for AI Ethics (RenAIssance Foundation, 2020)	2020	Italy
Principled Artificial Intelligence: Mapping Consensus in Ethical and Rights-based Approaches to Principles for AI (Berkman Klein Center for Internet & Society, 2020)	2020	Berkman Klein Center of Harvard University
AI Principles: Recommendations on the Ethical Use of Artificial Intelligence by the Department of Defense (Defense Innovation Board, 2019)	2019	The U. S.
Principles for the Governance of New-Generation AI: Developing Responsible AI (Fu & Cai, 2019)	2019	China
Recommendation of the Council on Artificial Intelligence (OECD, 2019)	2019	OECD
Communication: Building Trust in Human Centric Artificial Intelligence (European Commission, 2019)	2019	European Commission
Artificial Intelligence: Australia's Ethics Framework (Australian Government, 2019).	2019	Australia
IEEE AI Ethics and Governance Standards (IEEE, 2019)	2019	IEEE SA
AAAI Code of Professional Ethics and Conduct (Association for the Advancement of Artificial Intelligence, 2019).	2019	AAAI
Social Principles of Human-Centric AI (Cabinet Secretariate of Japan, 2019)	2019	Japan

These official papers include a wide range of ethical principles for AI, such as agency and supervision, privacy and security, social and environmental well-being, and responsibility and accountability. Each paper has its own focus. Among them, UNESCO's "Recommendation on the Ethics of Artificial Intelligence" puts forth the most principles, including sustainability, fairness and non-discrimination, transparency and explainability, awareness and literacy, etc. The OECD's "Recommendation of the Council on Artificial Intelligence" highlights as principles for responsible stewardship of trustworthy AI: inclusive growth, sustainable development, and well-being; human-centered values and fairness; transparency and explainability; robustness, security, and safety; and accountability (OECD, 2019).

Amid the widespread use of AI in education, major countries and international organizations have actively advanced their governance of ethical issues associated with educational AI. For example, the Australian Government Department of Education sponsored research on AI and school education, which resulted in "*Artificial intelligence and emerging technologies (virtual, augmented, and mixed reality) in schools: A research report*" (Southgate et al., 2019). UNESCO released the reports "Beijing Consensus: Artificial Intelligence and Education" (Ministry of Education of China, 2019) and "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development" (UNESCO, 2019) as part of the outcomes of the

Table 2. Papers on AI Ethics Issued by the Chinese Government.

Names	Years	Key Points
The Strategy for the Development of New-Generation Artificial Intelligence (State Council of China, 2017)	2017	Increase financial and policy backing and formulate state-level overall plans for AI development.
The Three-Year Action Plan for Promoting the Development of New-Generation Artificial Intelligence Industry (2018-2020) (Ministry of Industry and Information Technology of China, 2017).	2017	Accelerate the development of AI industry; drive the deep integration of AI and the real economy.
Guidelines for the Construction of National New-Generation Artificial Intelligence Innovation and Development Pilot Zones (Ministry of Science and Technology of China, 2017).	2020	Support the construction of new-generation AI innovation and development pilot zones to address major issues in AI research and industry; build healthy ecology for better AI development
The 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and Long-Range Goals 2035 (State Council of China, 2021)	2021	Formulate strategic scientific plans and programs for fundamental, core areas associated with the national security and development; Initiate a number of forward-looking and strategic nation-level major scientific and technological projects in cutting-edge fields such as AI, quantum information, integrated circuits, life and health, neuroscience, biological breeding, aerospace technology, and deep ocean exploration, etc.
Opinions on Strengthening the Comprehensive Governance of Internet-based Information Service and Algorithms (State Council of China, 2021).	2021	Develop governance and supervision mechanisms for algorism security and advance algorism innovation for a trustworthy, high-quality, and orderly development of algorism, to support the construction of a nation with strong cyber power.
A Code of Ethics for New-Generation Artificial Intelligence (Ministry of Science and Technology of China, 2021).	2021	Set forth basic ethical norms for AI as well as rules for AI application regulation, research and development, supply, and use.
Regulations on the Management of Internet-based Information Service and Recommendation Algorithms (State Council of China, 2012).	2022	Regulate Internet-based information service and recommendation algorithms; safeguard national security and public interests; protect the rights of individuals and organizations to data safety to promote healthy development of information services.

International Conference on Artificial Intelligence and Education. The University of Buckingham's Institute for Ethical AI in Education released "The Ethical Framework for AI in Education" in 2021 (University of Buckingham, 2021). These papers set forth both overarching goals and concrete content on the ethics of educational AI.

China has the advantages of economies of scale, colossal volumes of data, and complete infrastructure for developing its Internet-based industries. The Chinese government places high importance on the development of AI technology and has issued a series of policies to strengthen the governance of AI security (**Table 2**).

These papers mark the Chinese government's commitment to the governance of ethical issues with AI. Despite the fact that there is no specialized government paper on educational AI in China, the exploration of building an ethical framework for it is underway. The 2024 WDEC marks a starting point in this regard. In his keynote speech at the forum on "artificial intelligence and digital ethics," Vice Minister of Education Guangyan Wang reaffirmed the Chinese government's adherence to the ethical notion of "human-centric AI" and the principle of "digital for good" in harnessing AI in digital education and emphasized the importance of establishing the ethics of educational AI for circumventing relevant ethical risks and creating healthy environments for the digital transformation of education (People.cn, 2024a).

Enhancing AI Literacy in Teachers and Students

At the 2024 WDEC closing ceremony, the "Shanghai Call for Cooperation on Digital Education" was released as an outcome document. Under the heading of "cooperation on promoting teachers' capacity building," it is advocated to "popularize inclusive and effective digitalized pedagogies, develop smart teacher assistants, explore digitalized collaborative teaching and research and human-machine collaboration, support teachers in becoming knowledge producers, learning facilitators, and development mentors, and improve teachers' digital competency" (Ministry of Education of China, 2024b). The teacher still plays unique roles in student growth and development despite the growing trend of human-machine collaboration in digital education. AI cannot replace teachers, whereas digitally competent teachers may replace those who are digitally incompetent (Yu, 2020).

It is critical for teachers to develop rational attitudes toward the concern that AI technology may threaten their jobs. They can reap the benefits of AI and, in the meantime, navigate the ethical challenges of integrating AI into instruction. Intelligent machines may assist teachers by reducing the number of easy and repetitive tasks they had to complete by themselves in the past, allowing them to dedicate more time and effort to activities of greater instructional value. As a result, they can better meet students' needs for emotional communication, morality and character development, and mental health education (Zhang, 2023).

Effective human-machine collaboration depends on improving teachers' digital competence. Enhanced AI literacy is beneficial for the teacher to better harness the advantages of machines and their own merits. The "Digital Literacy of Teachers" released by the Ministry of Education in December 2022 proposes a framework for teacher digital literacy, which includes digital awareness, digital technology foundation and intelligence, digital application, digital social responsibility, and professional development (Ministry of Education of China, 2022). Meeting the aforementioned criteria necessitates relevant digital training. According to the 2022 Blue Book on Artificial Intelligence Education, the lack of systematic AI training for frontline primary and secondary teachers ranks as the second factor contributing to teachers' difficulty using AI applications in teaching. It also stresses the importance of increasing teachers' awareness of AI ethics in response to the ethical challenges of the adoption of AI technology in education and teaching (AAIED, 2023).

In the context of expedited knowledge updating in the AI era, students must have the ability to learn autonomously to keep up with the advancements of the time. Strengthening digital literacy can help them do so. Digital literacy entails not only basic IT knowledge but, more importantly, the competency to successfully process, analyze, and utilize information (Zhang & Fu, 2001). In the AI era, information has become the most important resource, and students with strong digital competence can be more efficient in finding valuable content in oceans of information to support their learning. Nevertheless, excessive dependence on technology may impair students' independent and critical thinking abilities; "information cocoons" as a consequence of intelligent recommendation impede their access to more comprehensive and diverse information (Zhang, 2023). Therefore, it is imperative to incorporate AI ethics education into student digital literacy training.

Conclusion

The use of AI in education has generated substantial benefits by increasing the breadth and depth of information flow, while at the same time, the ethical hazards associated with it have become a key concern of the educational community. Global efforts have been made to establish ethical norms for educational AI in a bid to safeguard the values of human rights and dignity. China is making its own contribution to the construction of the ethics of educational AI, which is evidenced by its hosting of the debate on this issue at the 2024 WDEC. The international education community aims to determine paths for advancing educational AI while upholding ethical and moral standards to benefit society as a whole.

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REVIEW

Digital Transformation of Education in China: A Review Against the Backdrop of the 2024 World Digital Education Conference

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Abstract: *The flourishing digital technologies are impacting intensively on all facets of education development. How to promote the digital transformation of education by leveraging emerging digital technologies has become a highly concerning topic among educational researchers throughout the world. The Chinese government organized the 2024 World Digital Education Conference in Shanghai on January 30-31 to advance the digital transformation in education. The conference summarized China's achievements in digital education and laid out a vision for building an international exchange and cooperation platform for global digital education development. This article is a review of China's explorations and experiments in the digital transformation of education.*

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TECHNOLOGY and education are two major driving forces for human society's advancement. Digital technology is catalyzing an intense educational transformation. Amid the new wave of technological and industrial revolutions, the digital transformation of education has become a global consensus. "Digital learning and transformation" were made one of the five thematic action tracks for the UN's Transforming Education Summit in 2022 (United Nations, 2022). Nations around the world have launched a variety of digital education development strategies to leverage digital technology to promote inclusive, equitable, and quality education.

The 2024 World Digital Education Conference (WDEC), co-hosted by the Ministry of Education of China, the Chinese National Commission for UNESCO, and the Shanghai Municipal People's Government, was held in Shanghai on January 30-31. With the overarching theme of "Digital Education: Application, Sharing, and Innovation," the conference focused conversations and exchanges on the following topics: the improvement of teacher digital literacy and competence; the building of digital education and a learning society; the evaluation of global trends and indices in digital education development; artificial intelligence and digital ethics; the challenges and opportunities of digital transformation for basic education; and the digitalization of education governance and digital education governance (Ministry of Education, 2024a). In his keynote speech at the conference, Minister of education Huai (2024) set forth China's national strategy for digital education, which includes transitioning from the "3C" philosophy of "Connection, Content, and Cooperation" to an "3I" approach of "Integration, Intelligence, and Internationalization"; prioritizing application-oriented services, expanding the sharing of quality resources, and promoting educational reform and innovation; and positioning Chinese digital education as a practical platform to implement the Global Development Initiative, the Global Security Initiative, and the Global Civilization Initiative, providing effective options for the development and transformation of global digital education.

The Digital Transformation Has Become an Inevitable Trend in Education Development.

China's societal development has entered a brand-new digital era, where the digital transformation of education is underway. In digital education, modern technologies, including computers, multimedia, big data, artificial intelligence (AI), and Internet-based communication, are comprehensively adopted to adapt education and instruction to the new requirements posed by the digital society (Liu & Liu, 2022). The processes of transforming educational paradigms, instructional methods, and management systems, as well as educational research patterns use educational technology (Chen & Liu, 2023). It is not simply about collecting data and upgrading systems and equipment, but more about the overall enhancement of the digital awareness and competencies of all stakeholders. Digital education is fundamentally and systematically transforming the established educational system (Li, 2024).

From the perspective of technological development, with their constantly amplifying power, emerging technologies such as 5th Generation communication, AI, big data, blockchain, and metaverse are bringing substantial impacts on people's learning methods and thinking patterns (Zhang, 2020). Driven by new technologies, digital education infrastructure has significantly improved, the foundation of AI computing power and data centers is strengthening, and the digital ecosystem for educational innovation is in formation, all of which provide strong support for the digital transformation of education. (Du, 2020)

From a social development standpoint, the need to increase people's capacities to adapt to digital life calls for digital education development. The demand for intelligent education that facilitates autonomous learning, individualized learning, and lifelong learning is growing. In the digital era, learners pursue more flexible and convenient learning styles and blended instruction models for a better learning experience (Wang, 2023). Furthermore, the new era necessitates the development of key competencies that are different from those in the past, such as diverse thinking and complex problem-solving, instigating the need for a new wave of educational transformation (Xia et al., 2023).

Within the educational system, the digital transformation of education supports the achievement of the goal of "quality, equitable, and highly efficient education" by upgrading teaching and learning modalities. The integration of digital technology into education not only generates new instructional models such as flipped classrooms and online and offline-blended teaching, but also breaks down the constraints of traditional schooling by changing the organizational formats of education (Zhu & Hu, 2022a). Additionally, practical issues that arose in the development of education, such as path dependence and the lack of prompt reactions to emergencies, also make it necessary to build a more robust, digitalized national education system (Zhou et al., 2020).

The Significance of Digital Transformation in Education

Promoting the Improvement of Teacher Professional Competence

For teachers, information technology (IT) serves not only as an aid in teaching but also as a vehicle for professional development. According to the" *Education Informatization 2.0 Action Plan*," building a teaching force that can adapt to technological advancement in the new era and utilize technology to enhance their educational and teaching abilities is a key component of digital education development (Ministry of Education of China, 2018). New-generation information technologies like AI offer teachers possibilities for long-range career development. The Ministry of Education of China (2022) issued the "Digital Literacy of Teachers" as a part of teacher professional criteria, which defines teacher digital literacy in five dimensions. This paper provides evaluation standards and training directives for teacher digital literacy, marking Chinese education's entry into a new stage in digital transformation.

With improved digital literacy, teachers can more easily adapt to the digital education settings, have a more reasonable use of digital tools and resources, and are more ready to update the notion and methods of education evaluation, achieving greater teaching outcomes (Zhang et al., 2023). Regarding individualized teaching, teachers with adequate digital literacy can make better use of digital resources to administer tailored instruction, such as by digitally diagnosing students' learning circumstances, adjusting teaching strategies in a timely manner, and utilizing online learning platforms to customize learning materials for each student (Zhang, R., 2023). Furthermore, digitally competent teachers have more choices in their teaching approaches. For example, they can create a hybrid classroom that integrates online and offline teaching, dismantling the restrictions of space and time in instruction and practicing a more learning-centered education; they can also utilize multimedia resources, virtual reality tools, online collaboration instruments, social media platforms, and other resources to create an intelligence-assisted learning scenario to foster students' ability to use technology to solve problems (Wu, 2018). Furthermore, the improvement in digital literacy helps the teacher implement more scientific student evaluation. First, by using digital technology, teachers can expand the evaluation scope to cover students' higher-order abilities such as innovation awareness, collaboration skills, and critical thinking ability (Dai, 2023). Second, they can use intelligent technology to successfully realize formative assessment and track students' learning progress and performance in real time so as to direct them to carry out more personalized and effective learning. Third, they can adopt big data-based learning analytics and human-machine collaboration to obtain precise evaluation results to support legitimate educational decision-making (Ma, 2019).

Optimizing Student Learning Outcomes

The primary goal of digital education is to develop students' key competences that are crucial for their lives in the information age, which includes core capabilities and essential qualities being progressively cultivated throughout various levels of education and aligned with the requirements of an informatized society (Zhu & Hu, 2022b). Digital tools and technologies in education can significantly boost student learning outcomes through intelligence-assisted study, personalized learning, and ubiquitous study.

Intelligence-Assisted Study: Openness is the most distinctive feature of digital education. Smooth information flow between schools, families, and society; data sharing; interconnectivity of knowledge; sharing of collective wisdom; and coordination between digital devices under the digital education paradigm all contribute to the more effective learning of students (Zeng & Zhou, 2022).

Personalized Leaning: In digital education, the use of AI, big data, and learning analytics makes personalized learning practical. Based on educational technology-supported analyses of student learning foundations, styles, and progression, as well as the learning challenges they face, personalized learning strategies can be formulated, and personalized learning materials and resources can be determined for each individual student (Qiao, 2024).

Ubiquitous Study: As a result of the improved digital infrastructure, popularized access to the Internet, cumulative digital resources, and increased smart learning platforms and terminals, mobile learning emerged as a new mode of study. It significantly expands student learning venues, allowing learning to occur at any time and in any place. It opens up new possibilities for students' convenient access to information and self-directed learning (Ren, 2015).

Diversifying educational scenarios

With the application of new technologies in education, such as AI and virtual reality (Li, 2023), novel education patterns emerge. The use of digital content, information technology, and intelligent equipment will result in more diverse learning scenarios. Outstanding future educational settings include the blending of physical and virtual environments, the provision of both formal and non-formal education opportunities, and the in-depth collaboration among education actors (Xing et al., 2022).

Hybrid of Reality and Virtuality: Educational AI is instigating the formation of a human-machine collaborative learning community, which distinguishes itself with a blend of virtuality and reality, enabling more open, autonomous, and immersive learning processes (Jiang et al., 2016).

*Combination of Formal and Non-formal Education Opportunitie*s: Digital education dismantles the temporal and special boundaries typical of traditional education, giving students more non-formal learning options to satisfy their individual needs. Free access to educational resources also assists them in restructuring fragmented learning materials from prescribed disciplines in formal schooling (Ye et al., 2016).

In-depth Collaborative Learning: In digital education, online platforms and intelligent devices help increase the frequency of teacher-student and inter-student interactions in resource sharing, conversation, and inquiry, as well as diversify the formats of collaborative learning, thus enhancing student communication and collaboration skills (Zhao et al., 2021).

Strategies for Advancing the Digital Transformation of Education

China, among many countries, advances digital transformation in education under the basic action framework of "policy support, resource backing, practical explorations, and technology-enabled evaluation" (Yang et al., 2023). Top-level policies provide directives for actions in the digital transformation of education. Resource backing entails the creation of digital education resources and infrastructure. Practical explorations of educational technologies emphasize the engagement of all digital education actors and the effectiveness of technological applications. Technology-enabled evaluation supports policy-making and practical adjustments by providing relevant data and evidence. There are intrinsically logical connections and interdependent relationships between these dimensions (Jing & Lyu, 2023).

Policy Support: Top-Level Strategic Planning

Policy support serves as the cornerstone of the digital transformation of education. The government has the responsibility to provide institutionalized guarantees by formulating strategic plans for digital education, developing norms and standards for educational technology, and establishing effective management and operation mechanisms (Sui, 2023).

In recent years, the Chinese government has strived to advance the strategic action for digital transformation in education and published a number of plans to propel digital education. 2010's "Strategy for National Medium- and Long-Term Education Reform and Development (2010–2020)" emphasizes that a high value must be placed on educational technology, which has a revolutionary impact on education development and should be harnessed to drive the realization of educational modernization (State Council of China, 2010). In 2012, the Ministry of Education issued the "Ten-Year

Development Plan for Education Informatization (2011-2020)" to set forth the goals and responsibilities of various educational sectors in developing digital education, including the building of digital campuses with necessary digital teaching resources, tools, and simulation laboratory software in all levels and types of schools, the initiation of the "Three Links and the Two Platforms" program, and more (Ministry of Education of China, 2012). To improve the IT application level of schools, enhance the digital literacy of teachers and students, and build a uniform "Internet plus education" platform, 2018's "Education Informatization 2.0 Action Plan" put forth the goal of realizing "three popularizations" by 2022: the popularization of teaching applications among teachers; the popularization of learning applications among all school-age students; and the popularization of digital campuses among all schools (Ministry of Education of China, 2018). In 2019, the State Council issued the paper "Modernization of Chinese Education 2035," reaffirming the strategic action of accelerating the digital transformation of education by building intelligent campuses, developing intelligent teaching, management, and service-integrated platforms to change the methods of education governance, and establishing a modern educational management and monitoring system to facilitate precision management and scientific decision-making (State Council of China, 2019). At the 2024 World Digital Education Conference, Yingli Li, Deputy Director of the Vocational Education and Adult Education Department of the Ministry of Education of China, delivered a speech on the theme of "the construction of digital technology-enabled learning society," in which he explained China's top-level efforts for building a learning society, including issuing the "Implementation Plan for the Construction of a Learning; publishing "Key Undertakings for Building a Learning Society"; and formulating specific measures for building learning cities and learning communities in the county regions as well as for the reform of further education for academic qualifications and the innovation of non-academic education (Ministry of Education of China, 2024b). All the said policies are aimed at clarifying strategic goals and phased pathways for the digital transformation of education, underscoring the important position of digital education in the national development strategy (Xue et al., 2023).

Resource Backing: Boosting Digital Education Resources

Digital education resources, which are guarantees of sustainable digital transformation in education, span all supportive conditions such as digital infrastructure, equipment, software tools, teaching and learning resources, and more. They play a central role in improving schools' digital and intelligent teaching, management, and service (Dai & Zhu, 2023).

In 2021, the Ministry of Education of China released "Guiding Opinions on Promoting the Construction of New-Generation Educational Infrastructure and Building a High-Quality Supportive System for Education." The paper put forward specific pathways to accelerating the construction of a new-generation educational infrastructure system that is structurally optimized, highly efficient, economically applicable, intelligent and green, and safe and reliable. It provides directions for building a world-class digital education base, which encompasses information networks, platform systems, digital content, smart campuses, and innovative applications. At present, the framework of new-generation educational infrastructure in China is taking shape and transitioning from an emphasis on "quantity" to a focus on "quality." A mature system of new-generation educational infrastructure will provide solid foundations for more equitable, inclusive, and high-quality digital education (Zheng & Zhou, 2021). Shanghai's practice is an exemplary experiment in building digital education infrastructure, according to the speech by Hao Wang, Deputy Director of the Education Commission of Shanghai, at the 2024 WDEC. The municipal government of Shanghai has worked to realize a universal upgrade of digital facilities in all primary and secondary schools in the city in the current wave of digital transformation in education. The program "Strengthening All Basic Education Schools" was launched to give special support to underprivileged schools to make up their gaps in digital infrastructure that is essential for their success in digital transformation (Ministry of Education of China, 2024b).

At the conference, Dawang Zhou, Director of the Department of Science, Technology, and Information Technology of the Ministry of Education of China, presented China's achievements in the construction of the National Smart Education Platform. The platform has been upgraded and iterated five times to date, now with the National Smart Reading Platform and three provincial-level smart education platforms from Guangxi, Yunnan, and Gansu provinces being incorporated. It developed and launched the "Intelligent Education" app. Its resource bank has gathered approximately 88,000 primary and secondary education resources, over 10,000 high-quality online vocational education courses, and roughly 27,000 high-quality MOOCs for higher education. It also provides special services such as "2023 Summer Educational Research and Training," "Network Security Education," and studying abroad. It has become more functional with the improved user registration process, unified search engine, and features of likes, favorites, and shares, and friendlier to special groups like the elderly. The National Smart Education Platform will continue to enhance its capacity to support personalized learning and lifelong learning for all by expanding the coverage of high-quality education resources (Ministry of Education of China, 2024b).

Based on prior achievements, Minister of Education Huai (2024) described China's prospective endeavors in the development of digital education resources by claiming that China would continue to converge and integrate domestic and overseas high-quality resources to expand the overall resource pool on the national smart education platform; focus on increasing resource supply through various means with an emphasis on courses in STEM education, information technology, arts education, and vocational skills; enrich resource formats by developing digital textbooks and extensively collecting teaching aids, lesson plans, courseware, teaching designs, virtual simulation experiment resources, etc.; innovate resource evaluation mechanisms using the massive and dynamic data aggregated by the National Education Big Data Center, to promote the full lifecycle management of resource development, storage, updating, and removal. In sum, China is committed to building its National Smart Education Platform into a system that expands horizontally and connects vertically, leveraging collective wisdom from across the country and around the world.

Trials of Applications: Optimizing Educational Technology Application

Application is the touchstone for the effectiveness of educational technology. To apply educational technology to digital education, China has invested heavily in the construction of pilot and demonstration projects under the initiative of "Internet plus Education" and in the innovation of application scenarios drawing on successful experiences at home and abroad (Dai, 2023). Important experiments include establishing mechanisms for cross-grade collaboration to ensure data consistency across all educational phases and settings; diversifying instructional patterns by driving the shift from traditional in-class teaching to mixed classroom learning that combines online and offline instruction and in-class and after-school activities; and developing dedicated platforms for the dissemination and promotion of high-quality teaching practices (Gao, F., 2021).

According to Huai (2024), China will conduct large-scale application demonstrations to amplify service efficiency in digital education. To achieve this, it will deepen ongoing digital education pilot programs to facilitate the nationwide application of the national platform, in an effort to expand the coverage of quality resources and transform pilots into exemplars. Schools will be encouraged to integrate platform resources and services into their educational practices to deepen their application. Furthermore, China will innovate policies and mechanisms to promote application, guided by the principle that "effective utilization is true proficiency, and indispensability is essential." Through thematic teacher training, model case selection, assessment incentives, and evaluation reforms, the usage of the smart platform will become a habit for both teachers and students.

Digital Empowerment: Enhancing Educational Actors' Digital Competency

The digital advancement has brought new requirements for education; improving digital literacy and competence of educational actors is an imperative in the new era. Teachers and students cannot harness complex technological systems and tools without proper digital literacy training, and consequently, the reform of teaching paradigms will be unattainable (Dong & Yang, 2023).

First, it is important to develop a thorough and workable mechanism for teacher digital literacy training. The Ministry of Education's "Digital Literacy of Teachers" can be used as a framework of reference in developing action plans and innovative training programs. It is advisable to experiment with the integration of pre-service and in-service digital literacy training for teachers. Also, schools in various regions should organize high-quality digital training sessions tailored to local conditions, along with engaging teachers in the national training programs during summer and winter breaks. Minister of Education Huai (2024) cited the practice of No. 3 Affiliated Primary School of the Chongzuo Normal University in Guangxi Zhuang Autonomous Region as an exemplar, where teachers utilize resources from esteemed educators in Beijing, Shanghai, and Tianjin for collaborative lesson preparation and online teaching research. This approach has accelerated their professional development and revitalized the distinctively Chinese teaching research system.

Second, fully leverage all digital resources to facilitate teachers' and students' digital growth. Working on smart campuses with high-performance facilities, omnipresent digital terminal networks, innovative classroom environments, and IoT intelligence, teachers and students can spontaneously accumulate digital literacy and skills (Li, 2015). The use of educational applications such as the National Smart Education Platform, "intelligent teaching assistants," and "AI teachers" should be encouraged among them to promote innovation in teaching methods, integrate digital technology into diverse areas including physical, aesthetic, and labor education, and transition from the single-subject-based use of technology to the interdisciplinary and multiple scenario-based application (Zhong et al., 2021). Huai (2024) visited an "Agricultural Microbiology" class assisted by the National Smart Education Platform at Ningxia University and found that teachers and students there "interacted frequently within the smart system, quickly and precisely addressing knowledge gaps and experimental doubts, and greatly enhancing the classroom experience."

Third, integrating technology into learning and teaching activities to innovate instructional patterns is an effective way to improve the digital literacy of teachers and students. Infusing digital literacy development into the curricular objectives, content, and structure is essential (Zhao & Lu, 2021). Huai (2024) called for promoting "intelligence-assisted learning" by developing intelligent learning companions and implementing intelligent tutoring systems, empowering each student to reach their full potential. Likewise, "intelligence-assisted teaching" should be popularized by means of developing intelligent teaching assistants in support of lesson preparation, workload reduction, and efficiency enhancement for teachers, thereby allowing them more energy for creative teaching activities.

Digital Evaluation: Strengthening Digital Education Monitoring and Assessment

Digital technology is transforming the educational evaluation system. The use of new technologies, such as big data and AI, in performance assessment can effectively solve issues with traditional evaluation methods, such as the lack of uniform standards. Through the convergence of broad-scale evaluation data and multimodal data analytics, a comprehensive evaluation system capable of real-time feedback can be established to trace the process of digital transformation in education over a longer period of time (Ji, 2023). Empowering educational decision-making by developing standardized, consistent evaluation indicators and powerful databases has become a globally recognized practice (Yu, 2022).

Despite certain progress in evaluation processes such as model construction, impartial data collection, and intelligent data processing, the digital evaluation of education in China is still in its infancy. However, the use of technology has not fundamentally eliminated the limitations inherent in the established educational evaluation system. Outstanding issues include the low-level coupling between evaluation and technology, insufficiently legitimate evaluation indicators, and one-sided evaluation methods (Jing & Lyu, 2023). Due to the vast territory of China, a "one-size-fits-all" evaluation model is not a reasonable approach. Inter-regional, urban-rural, and inter-school disparities must be considered in the evaluation of the digital transformation of education in China. In the meantime, it is necessary to examine the emotional factors in digital education evaluation from a humanistic perspective, continuously optimizing assessment methods to mitigate the negative emotional burdens on key stakeholders (Zhang, 2021).

Educational data is of strategic value for the digital transformation of education. To effectively collect and utilize educational data, it is necessary to improve the security measures of data safety, strengthen the regulatory capacity for the collection and use of data by teachers and students, and establish ethical norms for the application of AI in education. The Chinese government adheres to the principle of "digital for good," emphasizing the importance of research on AI and digital ethics, the scientific assessment of the impacts of intelligent technology on education, and the rational application of intelligent technology (Huai, 2024).

Conclusion

In the AI era, the digital transformation of education is an innovative and highly complex undertaking. It is a systematic and fundamental change in the domain of education, providing new opportunities for educational advancement. Globally, there is a growing consensus about the significance of digital education development; countries are advancing digital education more forcefully. The global exploration of digital transformation in education is becoming increasingly active. China is leveraging digital education to promote educational equity and quality, as well as to support the development of a learning society. The deep integration of digital technology and education is to be accelerated to comprehensively enhance students' learning, teachers' instruction, schools' management, and the nation's overall educational innovation. The digital transformation in education will substantially increase the nation's digital competency across the board, further modernize Chinese education, and contribute to its high-quality socioeconomic development.

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