From "Invisible" to "Visible": A Practical Exploration of Digital and Intelligent Technologies in Enhancing Primary Science Experiment Teaching—Taking the Lesson "Where Did the Water Go?" from the Third Grade, First Semester Science Textbook as an Example

Zhu Xiaoqiang, Zhang Jianqing

Southwest University Affiliated Primary School, Chongqing 400700, China.

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Abstract: In elementary science experiments, numerous microscopic, transient, long-term, or abstract "invisible" processes pose cognitive barriers to students´ construction of scientific concepts. Based on the first lesson of Unit 2 "Water" in the third-grade Science textbook (Volume 1), "Where Did the Water Go?", this paper investigates the teaching difficulty of "the invisibility of water evaporation". In line with the educational philosophy of digital and intelligent empowerment and incorporating the latest research in primary science education, a three-dimensional teaching strategy of "visualization presentation - process tracking - evidence-based verification" is proposed. High-speed micro-level video recording, digital sensors, interactive simulation animations and intelligent assessment systems are used to integrate digital-intelligent technologies and make the abstract process of evaporation visible, observable and verifiable for students, thus helping them move away from the idea of "disappearance" to an accurate understanding of "evaporation". Finally, practical reflections on the deep integration of digital-intelligent technologies and science experiments are provided to offer actionable innovative teaching ideas for classroom teachers.

Keywords: Digital and intelligent empowerment; elementary science; water evaporation; experimental teaching

0. Introduction

According to the "Compulsory Education Science Curriculum Standards (2022 Edition)", science education aims to develop the four main abilities of students: scientific concepts, scientific thinking, inquiry-based practice and attitudes/responsibility, and promotes the teaching methods[1] of "learning by doing" and "understanding through exploration"; however, many essential steps in elementary science experiments, such as water evaporation, force transmission and celestial motion, are not visible to the naked eye. The above "unseen" processes are at the core of the creation of scientific ideas.

Recently, with the continuous progress of policies such as the "Education Informatisation 2.0 Action Plan" and the "Action Plan for Deepening Reform of Basic Education Curriculum and Teaching", digital and intelligent technologies are significantly altering the educational environment. Creation of digital-intelligent experimental spaces can overcome the old restrictions of time and place in education and promote more genuine learning[2]. Students can use digital-intelligent teaching tools to move from the lively macro world to the mysterious and wonderful micro world[3].

Using "Where Does Water Go?" as an illustration, this paper investigates how digital and intelligent technologies can turn the "invisible" process of water evaporation into "visible" learning materials to help students build scientific concepts and offer a practical path for the digital-intelligent transformation of primary science experiment teaching.

1. The Myth of the "Invisible": Teaching Dilemmas in "Where Did the Water Go?"

"Where Did the Water Go?" is the first lesson of Unit 2, "Water", in the third-grade science book. The Basic scientific idea is that "water evaporates into water vapour and enters the air"; in a textbook example, students are asked to wipe the blackboard with water, write the character for "water" on the board using water, and then observe that the water gradually disappears; thus, they are prompted to ask, "Where did the water go?", which is actually a problem of high-level thinking.

1.1 Students´ hypotheses are difficult to verify

Students present different reasons for the "disappearing water marks" in the lesson "Where Did the Water Go?", and all of them show various previous knowledge. The three kinds of hypotheses for them are generally as follows: firstly, the "absorption theory", that students believe the water is absorbed by the blackboard or chalk; secondly, the "flowing away theory", which proposes that the water has flowed to the floor or other unseen places; and thirdly, the "vanishing theory", according to which students think the water has completely disappeared. The above are based on the students´ daily lives and show their fundamental knowledge of evaporation. As the water vapour generated by evaporation is invisible, there is a natural problem of observation for the experimental results. Therefore, teachers have difficulty leading students in observation, reasoning and experiments to refute wrong ideas and thus build a scientific explanation of evaporation.

1.2 The evaporation process is invisible

Evaporation is a typical "invisible process"; that is, it is dynamic and cannot be directly observed with the naked eye, and as water vapour is colourless and intangible, there is a natural obstacle to students´ learning of scientific concepts. Third-graders are in a period of transition in their cognitive development; they are moving [4] from concrete, image-based thinking to early abstract logical reasoning and thus find it difficult to grasp and accept objective realities that are "invisible". In traditional teaching, teachers frequently use verbal descriptions or static illustrations, which are inadequate for supporting the students´ cognitive jump from concrete objects to abstract ideas. Some schools also do not have adequate science equipment and are missing visual aids or experimental materials for the simulation of evaporation; thus, students´ comprehension of this idea is hindered. Therefore, how to use modern educational technology or hands-on, life-related experiments to make the "invisible" process of evaporation "perceptible" is a key focus of instructional design.

1.3 Difficulty in Constructing Abstract Concepts

Although it is only presented in a simple way that "water evaporates into water vapour and enters the air", the scientific idea of evaporation actually includes several abstract concepts, such as changes in the state of matter and movement of tiny particles. Although the students have had many sensory experiences of "water disappearing" in their daily lives, they lack the basic knowledge of water vapour as a type of matter. The Problem of teaching is that although students can memorize the word "evaporation", they are unable to understand the actual scientific concept; sometimes they even mistake "water vapour" for "hot air" or "white mist". Thus, their conceptual development is shallow and only at the level of linguistic surface understanding, lacking a deeper comprehension of the fundamental properties of matter. Therefore, the teaching should include gradually organised investigative activities to lead students from descriptive observation to an essential understanding and thus promote the genuine construction and internalization of scientific ideas.

2. The Value and Significance of Digital Intelligence in Enhancing Primary School Science Classroom Teaching

Deep integration of digital and intelligent technologies in the teaching of primary school science

experiments is revolutionising the problems of teaching "invisible" knowledge. Using the case of "Where did the water go?", the values and importance of digital and intelligent technologies in improving science experiment teaching are mainly shown in the following three ways:

2.1 Overcoming sensory deficiencies to obtain the cognitive construction of scientific ideas

The Main advantage of digital and intelligent technologies is that they can change abstract, microscopic and invisible scientific processes into intuitive and visual learning materials, thus helping students make a cognitive jump from daily life to scientific concepts. "Curriculum Standards for Science in Compulsory Education (2022 Edition)" aim to foster students´ scientific understanding; however, many of the critical transformation processes in traditional teaching cannot be directly observed by one´s eyes. With the help of high-speed micro-level video recording and interactive simulation animations, students can clearly observe the dynamic process of a water droplet gradually shrinking, as well as a microscopic simulation showing blue spheres – representing water molecules – "jumping" out from the water surface and dispersing into the air. The above visualisation has solved the main problem of "evaporation being unseen" and also given concrete support for the abstract idea that "water changes into water vapour and goes into the air"; research shows that digital and intelligent technologies can break down abstract scientific principles into concrete investigation tasks and thus promote students´ scientific thinking and habits. During the class "Where Did the Water Go?", students observe colour changes in cobalt chloride test paper and analyse real-time data from humidity sensors to gradually build the scientific idea that "water has not disappeared but has turned into water vapour in the air"; thus, they have achieved a cognitive shift from the misconception of "disappearance" to the concept of "evaporation".

2.2 Reconstructing Teaching Models to Foster in-depth inquiry and practice

Digital and intelligent technologies have greatly changed the old way of teaching science experiments and promoted a change from "one-way instruction" to "multi-dimensional interaction"; in the lesson "Where Did the Water Go?", humidity sensors collect data in real-time and generate dynamic line graphs to show students the connection between the disappearance of water marks and increasing humidity. Analysis of comparative experiments aids in the initial learning of environmental effects on evaporation for students. The above "process-tracking" method turns the hidden process of evaporation into measurable and observable data, enables experimental evidence to validate the phenomenon of evaporation, thus strengthening the scientific integrity of research activities and promoting students´ understanding of evidence-based reasoning. Integration of teaching modes for virtual and hands-on experiments has been employed to maintain the practicality of physical manipulation and utilise the benefits of virtual simulations; thus, students can now carry out independent investigations in a secure and regulated environment.

2.3 Improve the chain of evidence and promote evidence-based scientific thinking

Digital and intelligent technologies can also offer evidence-based support for experimental research and help students develop an empirical mind and scientific thinking based on evidence. Cobalt chloride test paper can be used in a new way to make invisible water vapor visible in this lesson. Time-lapse photography with a smart imaging system can be used to obtain high-resolution images of the colour changes during evaporation for better demonstration of the process. Students can further compare data from humidity sensors, and upon observing that "humidity changes more rapidly in ventilated conditions but dissipates easily; conversely, it rises steadily in enclosed environments", they learn about evaporation and also start to understand the idea of controlled variables. Based on the above investigation and digital/intelligent evidence, a foundation has been established for the development of students´ scientific thinking.

3. From "Invisible" to "Visible": Breakthrough Strategies Empowered by Digital and Intelligent Technologies

Digital and intelligent technologies can provide more precise experimental data and also extend the forms and methods of experimental teaching to promote all-around development of students [5]. In response to the teaching requirements of the lesson "Where Did the Water Go?", this paper proposes a three-dimensional teaching strategy based on "visualization presentation-process tracking-evidence-based verification", and the following is the specific implementation path:

3.1 Visual Representation: Making the Evaporation Process Visible

To solve the problem of "invisibility of the evaporation process", digital and intelligent technologies can be employed to visualise the microscopic evaporation process and help students gain an initial understanding that "water is continuously turned into water vapour".

3.1.1 High-speed imaging technology

High-speed cameras can be employed by teachers to capture the gradual reduction of water droplets due to continuous heating and then display this video on a large screen. Although the individual water molecules are transparent, the gradual changes at the edge of the droplets can be enlarged and shown to clearly observe the dynamic process of evaporation for students. The above experiment has successfully refuted the idea that "the water flowed away" or "the water disappeared", thus helping students to learn that evaporation is an ongoing, dynamic process.

3.1.2 Interactive Simulation Animation

Generative AI technology can be employed to create interactive simulation animations for the above lesson. Blue small spheres are used to show water molecules in the animation; colourless, transparent spheres are for water vapour in the air. Evaporation is taking place; the blue spheres are moving more rapidly, "leaping" above the water´s surface, and have turned into colourless spheres dispersed in the air. Teachers can also create evaporation animations in various situations as required; for instance, under sunlight, increasing the temperature of water droplets causes the blue spheres to move faster and more of them to "jump" out of the liquid, thus helping students intuitively learn about the effect of temperature on the speed of evaporation.

3.2 Process Tracking: Making Evaporation Data "Speak"

Although visualisation can aid in the sensory learning of evaporation, to gain an in-depth understanding of the evaporation process, one needs to turn the "invisible" process into quantifiable data and have the data speak for itself.

3.2.1 Humidity sensor real-time monitoring

Prior to class, before class, teachers can place temperature and humidity sensors in different parts of the classroom, such as above the blackboard, to collect real-time air humidity data and display dynamic line graphs. Students have noticed that as the water marks fade, the changes in the humidity curve are also being observed. As the water marks decrease, they will observe a considerable increase in humidity near the blackboard and only slight changes in the humidity of other parts of the classroom. The above data show that water has not been lost; it has only turned into water vapour in the atmosphere. Observation further shows that the humidity near the blackboard is gradually dropping over time and is now close to that of other areas in the classroom. It also helps the students learn that water vapour is constantly in motion in the air.

3.2.2 Data analysis of the comparative experiment

To investigate other factors of evaporation further, teachers can design a comparison experiment with humidity sensors: one group in a well-ventilated area and the other in a sealed container. Humidity sensors of both environments are used to measure changes in humidity and transmit

the data to a computer for comparison. Ventilated group has a quicker rise in humidity but is more easily distributed; the sealed group has continuous humidity accumulation. Data analysis has shown that although there is evaporation, the effect of various environmental factors on this process is still unknown.

3.3 Evidence-based Verification: Making Water Vapor Visible

Visualisation and process tracking show that there is evaporation from various angles; however, for third-graders, the most direct evidence is to make the invisible water vapour visible.

3.3.1 Cobalt chloride paper color test

Cobalt chloride test paper changes colour in the presence of water; it is blue when dry and turns pink or purplish-red upon contact with moisture. Teachers can put the test papers in various places on the blackboard: directly at the watermark, near the watermark, and far from it. Students will observe that the paper at the water mark gradually changes colour from the bottom and becomes progressively darker; the paper near the water mark also shows a colour change, but more slowly; and the paper far from the water mark has little to no colour change. Visible colour change of the cobalt chloride paper shows that water is evaporating and thus produces water vapour in the air.

After carrying out the experiment of water evaporation from a blackboard, students can conduct further studies of evaporation on various surfaces, such as glass slides, leaves and stones. A high-tech experiment has shown that the speed of colour change for indicator paper is different on different surfaces; it is fastest on glass, moderate on leaves, and slowest on stone. The above variations in colour change may lead the students to think: is the future of water affected by the surface properties of objects? Some surfaces are loosely structured and porous, thus easily absorbing water; others have very little absorption capacity and allow water to evaporate directly into the air.

3.3.2 Auxiliary observation with intelligent imaging system

A digital microscope can be used to record and compress the time-course of colour changes in cobalt chloride paper via time-lapse photography for an entire transformation. Students can clearly see on-screen that the blue area of the cobalt chloride paper is gradually being "invaded" by pink; thus, it is very engaging and helps them better learn about evaporation.

4. Reflection and Summary

In the future, with the development of generative artificial intelligence and virtual reality, etc., among other new-age digital and intelligent technologies, elementary science experiment teaching will be significantly changed. According to the "Outline for Building a Strong Education Nation (2024-2035)", we need to find effective ways to use digital tools for personalised teaching and innovative teaching to create more opportunities for the all-round development of students. No matter how teaching develops, the basic aim of integrating digital and intelligent technologies in elementary science education is to help students better understand, love and apply for science. By all-encompassing application of the above-mentioned technologies, the lesson "Where Did the Water Go?" has successfully turned the "invisible" process of evaporation into a "visible" investigation for students. Technology has evolved from being a simple aid to now serving as a cognitive framework to help students overcome sensory deficiencies and construct scientific ideas through microscopic animations, data plots, colour-changing reactions and time-lapse photography, etc. The above method provides an extensible system for primary school science education and also shows that education can make the complex world understandable; thus, digital and intelligent technologies are essential paths to achieve this aim.

About the author

Zhu Xiaoqiang (1989.12-), male, Han nationality, from Dianjiang, Chongqing, holds a master´s degree and is a primary and secondary school teacher at the first-level position. His research direction is subject teaching

Zhang Jianqing (year. month—), male, Han nationality, from Wenshan, Yunnan, holds a bachelor´s degree and is a secondary school teacher. His research direction is subject teaching

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