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Primary School Science Problem-Solving Teaching: Teaching Misconceptions and Strategy Improvement

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Current Problem-Solving teaching in primary school science suffers from some misconceptions, such as "insufficient cultivation of problem awareness, lacking drive", "insufficient deliberation in problem setting, lacking design", "insufficient emphasis on the solving process, lacking effectiveness", and "insufficient evaluation of solving results, lacking feedback". To address these, this paper explores the "Four Emphases and Four Transformations" strategy for Problem-Solving teaching: First, emphasize connecting with life phenomena, transforming subject knowledge into practice; second, emphasize flexibly using questioning forms, rationalizing difficulty settings; third, emphasize providing differentiated guidance, autonomizing the solving process; fourth, emphasize monitoring the learning process, routinizing reflection and evaluation.

Keywords: problem-solving, primary school science, four emphases and four transformations

In May 2023, the Ministry of Education and 17 other departments jointly issued the "Opinions on Strengthening Science Education in Primary and Secondary Schools in the New Era", explicitly stating that through three to five years of effort, various measures for adding science education value within the context of the "double reduction" policy in education should be fully implemented. The "Opinions" point out the need to enhance students' Problem-Solving abilities. Problem-Solving ability is one of the key competencies for 21st-century talents and an important dimension for developing students' scientific thinking and improving inquiry and practical abilities in China's "Compulsory Education Science Curriculum Standards (2022 Edition)". Previous research on scientific Problem-Solving ability has mostly discussed its importance and underlying mechanisms from a theoretical perspective, with relatively few studies applying theory to teaching practice. This study clarifies the concept of Problem-Solving, and proposes cultivation suggestions based on the current state of primary school science teaching.

Conceptual Clarification of Problem-Solving

When exploring the original meaning of Problem-Solving, it can be broken down into two key stages: "what is a problem" and "how to solve it". Reviewing previous definitions of "problem", researchers generally agree on three important elements of a "problem"—"givens", "obstacles", and "goal". The process of how to proceed

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from the "givens", overcome the "obstacles", achieve the "goal" involves "a series of thinking activities and operational processes", which constitutes the "solving" itself. If the posing of a "problem" presents no obstacle whatsoever to the problem solver, then the prerequisite for the existence of this "problem" is not met. Combining the actual state of teaching practice, this study considers Problem-Solving in science teaching as a teaching activity that takes students' prior knowledge as the starting point, is triggered by certain obstacles, and has a clear goal as its purpose. This process focuses on students' cognitive development, the solving process, and the outcome.

Analysis of the Current State of Problem-Solving Teaching in Primary School Science

To propose targeted strategies for cultivating students' Problem-Solving ability, it is necessary to understand the current state of Problem-Solving teaching in science. Currently, the main shortcomings in Problem-Solving teaching are as follows.

Insufficient Cultivation of Problem Awareness, Lacking Drive

Disputes and the impulse to express arising from students' life experiences and practice constitute problem awareness. Problems raised in practice are a crucial component of learning. They define what students want to know and, to a considerable extent, determine what students will find. Numerous studies indicate that Chinese students generally lack curiosity, often taking things and phenomena in life for granted and rarely probing into the "why". As grade levels increase, students' "problem awareness" shows a declining trend. The lack of "problem awareness" leads to a lack of internal motivation in the learning process, making it difficult to cultivate a persistent spirit of "investigating things".

Insufficient Deliberation in Problem Setting, Lacking Design

Current "problem" setting in science teaching suffers from the following deficiencies. First, "problems" are detached from students' lives, lacking situational context. Many teachers directly copy questions from science textbooks when posing questions, lacking connection with reality, making it hard for students to develop interest in solving the "problems". The setting of "situations" is very important for developing Problem-Solving strategies, especially for lower-grade students.

Second, there is a lack of consideration for the difficulty level of "problems". Current problem setting is often too arbitrary, with many problems being either too easy or too difficult. Student-centered teachers should set "just-manageable difficulties"—challenging enough to maintain engagement, but not so difficult as to cause students to develop "fear of difficulty". When setting "problems", teachers must have a sufficient understanding of students' knowledge, skill levels, and interests to ensure their enthusiasm for exploring the "problems".

Third, there is a lack of understanding of problem structure, often presenting well-structured problems during subject teaching. Well-structured problems generally refer to those with clear, standardized givens, limited correct answers, and a complete set of solution methods or rules. Conversely, ill-structured problems are usually closely tied to specific contexts, have ambiguous givens, lack clear solution methods or rules, and often have open-ended answers. Well-structured problems often point to students' superficial learning, while ill-structured problems often point to deep learning. So-called Problem-Solving, in most cases, refers to solving real-life problems, which are ill-structured. The above phenomena are all due to teachers' lack of reflection on and theoretical consideration of "problems".

Insufficient Emphasis on the Solving Process, Lacking Effectiveness

In terms of understanding the solving process, simple “imitative operation” is mistaken for Problem-Solving. Many teachers in class replace the process of student discussion and thinking—experimental procedure demonstration—rethinking and transferring of problems with direct demonstration of experimental steps. Superficially, the classroom atmosphere of “practical inquiry” is lively and enthusiastic, seemingly fitting the Problem-Solving classroom paradigm. But in reality, this type of scientific practice is another form of “direct instruction”—replacing “verbal explanation” with “behavioral demonstration”, narrowing Problem-Solving down to “imitative operation”. Problem-Solving teaching has fallen into the formalistic misconception of operating according to a fixed procedure.

Insufficient Evaluation of Solving Results, Lacking Feedback

Current inquiry activities in science classrooms often take “drawing a conclusion” or “solving the problem” as the final step and ultimate goal of teaching, lacking reflection and evaluation on the solving process. Reflection and evaluation of Problem-Solving include: identifying what the obtained result is; comparing whether the experimentally obtained result is consistent with the hypothesized result; proving that the obtained result indeed comes from the control of experimental variables; explaining what conclusion is drawn from analyzing the result; testing whether the conclusion one draws can be reached again using a different method, etc. Research shows that reflective evaluation ability has become one of the weakest abilities in students’ Problem-Solving process.

The purpose of evaluation is to improve teaching. In the age of artificial intelligence, a teaching approach oriented towards “results”, aimed at “practicality”, and dominated by summative evaluation can only present the outcomes of students’ Problem-Solving, cannot reveal the thinking process behind students’ Problem-Solving, and also cannot provide “feedback” to inform teaching.

Strategies for Improving Problem-Solving Teaching in Primary School Science

Based on the misconceptions of Problem-Solving, the concept of Problem-Solving, and combined with students’ developmental characteristics and research findings from the learning sciences, the following countermeasures are proposed to carry out Problem-Solving teaching more effectively in primary school science.

Emphasize Connecting With Life Phenomena, Transforming Subject Knowledge Into Practice

One characteristic of the science subject is its close connection with life phenomena. Teachers should better guide students to establish connections between scientific knowledge, phenomena, and life, encourage students to independently discover “things” in life, and transform them into investigable scientific research questions. The discovery here refers more to digging deeper into problems vertically, rather than expanding horizontally to more new problems. For example, a student discovers that their mother adds a lot of salt when thawing pork. When the student asks the teacher about this, the teacher does not directly explain the principle but guides the student to transform it into a scientific inquiry question “Can salt accelerate the thawing of pork?” and encourages them to design a controlled experiment for independent investigation to seek an explanation. Another example: After learning the knowledge point “Vitamin C can decolorize iodine solution”, the teacher uses the key problem of detecting Vitamin C content in drinks like “Water Soluble C100”, “Pulpy Orange”, and “Mizone” with iodine solution to carry out science inquiry activities based on Problem-Solving. This form of applying scientific knowledge to solve practical problems in life greatly stimulates students’ enthusiasm for Problem-Solving.

Emphasize Flexibly Using Questioning Forms, Rationalizing Difficulty Settings

According to the conceptual definition of “problem”, if only the “goal” of the “problem” is considered, without considering the students’ “givens”, the path for “solving” will be lost or interrupted. And if there is no “obstacle” in the “problem” setting, it cannot be called a “problem” either. Effective questions are the starting point of thinking. Student-centered teaching requires teachers to use students’ knowledge before entering the learning environment as the starting point for instructional design and strategy implementation.

When setting problems, the following four methods can be used to improve the effectiveness of questions: First, avoid treating clearly defined concepts or definitions as “problems”. In teaching practice, try to avoid posing questions far below students’ cognitive level. Problem-Solving unfolds on the basis of certain cognitive components; in other words, cognitive operations are the most basic components of Problem-Solving. Without the participation of cognitive components, mere purposeful operational sequences, such as dressing, brushing teeth, tying a tie, etc., cannot be called Problem-Solving. Posing questions below students’ current cognitive level may create a lively teaching atmosphere but is not conducive to the development of students’ higher-order thinking skills.

Second, contextualize problems. When posing questions, teachers should build a bridge between students’ real-life experiences and new knowledge, making it easier for students to access prior understanding and begin challenging the construction of subject knowledge in new areas. By creating real-life situations, the distance between the problem and students is shortened. For example, using “In which fields are magnifying glasses used?” as a question is relatively abstract and lacks connection with students’ life experiences. The teacher can phrase this question as “Where have you seen a magnifying glass?”, guiding students to recall specific life situations and stimulating effective thinking. Another example: In the fourth-grade lesson “How Is It Connected Inside?”, most students are unfamiliar with circuit mystery boxes. Directly showing the mystery box leaves students feeling at a loss. Teachers can create a situation like this: “The school is having circuit maintenance these two days. The electrician uncle found that some wires in the junction box are broken, some are not, but they can find where inside is disconnected and where is connected without disassembling the junction box. What method do you think they might have used?” This guides students to think about how parents handle such situations in life, helping students understand the function of the mystery box.

Third, use drawings or actions to supplement verbal expression of problems. For example, in the third-grade lesson “Motion of Objects on an Inclined Plane”, the teacher asks: “A small ball and a cube are on the same inclined plane. Can you describe how the two objects will move?” Due to limited expressive ability of lower-grade students, they find it difficult to accurately describe the answer. In practice, the teacher can add after this question: “You can use gestures to express the motion of the objects”. With such problem setting, students more easily use gestures to substitute for verbal expression of the two motion states, “sliding” and “rolling”.

Fourth, deconstruct high-difficulty problems in the form of a “problem chain”. For example, in the sixth-grade lesson “Solar Eclipse”, “How is a solar eclipse formed?” is a teaching difficulty point. The teacher can start with the first question: “During a solar eclipse, what is the arrangement of the Sun, Earth, and Moon?” and proceed to the second question “What happens when sunlight hits the Earth?” and several other questions to gradually set up a “problem chain”, guiding students to think about the dynamic process of a solar eclipse, using progressive questions to inspire students to autonomously construct knowledge.

Emphasize Providing Differentiated Guidance, Autonomizing the Solving Process

Teachers should guide students to learn the basic steps and methods of Problem-Solving, and provide different methods and frameworks for different problems, allowing students to acquire the basic methods and abilities for Problem-Solving during the learning process. This "guidance" must necessarily involve students' thinking, because directly informing the result or an imitative process does not include students' cognitive process. In practice, simply having students imitate experimental operations, assuming they will learn effectively this way, is a misunderstanding. In practice, teachers should focus on the quality of students' Problem-Solving, not just the appearance of conforming to the Problem-Solving paradigm. Therefore, there are corresponding teaching strategies for Problem-Solving of different difficulty levels. For relatively simple experimental operations, pre-activity checklists can be used to encourage students to practice with reference, gradually clarifying steps through trial and error. For medium-difficulty experiments, encourage students to first attempt autonomous Problem-Solving in group form. Group discussions allow members to learn from each other, reach a consensus, and then proceed with experimental operation. Alternatively, after a whole-class discussion, one student can demonstrate on stage, guiding other students to point out what was done correctly and incorrectly in the demonstration, using key operational points to remind students to discover independently and refine practical key points.

For problems with high difficulty that require teacher assistance, teachers can provide guidance on key tools, key lines of thinking, etc. For example, in the fifth-grade lesson "Heat Transfer in Metals", students have difficulty finding a suitable Problem-Solving tool—thermochromic ink. If the teacher directly tells them, students passively accept it without triggering independent thinking. At this stage, materials can be presented while guiding with "This material is called thermochromic ink. Can you guess its use?" Combining the problem and the material name, students make educated guesses, eliminating the "tool obstacle" in the Problem-Solving process, directly reaching the Problem-Solving goal. Another example: In the sixth-grade lesson "Changes Between Baking Soda and Vinegar", for the difficult problem "Is the white precipitate after the reaction still baking soda?", most students lack a solution approach. The teacher can use the question "Recall the characteristics of baking soda. What can it react with?" as a key hint, building a bridge for students to cross the "thinking obstacle".

Emphasize Monitoring the Learning Process, Routinizing Reflection and Evaluation

According to the connotation of Problem-Solving, Problem-Solving does not emphasize whether students solve problems independently; on the contrary, it does not exclude students achieving goals through external guidance or teamwork. Mastering knowledge itself and obtaining learning outcomes are not the only purposes of Problem-Solving, or even the main purposes. Experiencing an effective learning process and thinking development process, as well as cultivating students' ability to monitor their own learning during the Problem-Solving process, is more important. Therefore, teachers should guide students to value reflection on Problem-Solving, including reflection during the process and upon completion.

Reflection during the process refers to students' self-monitoring and adjustment abilities, which requires the use of "metacognitive" teaching strategies in the Problem-Solving process. Metacognitive theory emphasizes reflection and revision during cognitive activities. Metacognitive ability can help students control and revise their own learning behavior by defining learning goals and monitoring the learning process. Students need the ability to understand what stage their learning is at and know whether learning is sufficient. Teachers can co-design self-assessment forms with students for adjusting the progress of Problem-Solving. These forms are not about the right or wrong of specific Problem-Solving; their purpose is to guide students to self-check during the solving process, constantly reflect on their methods and hypotheses, revise their conclusions based on experimental results and new information, and become aware of which methods are currently effective and which aspects are inadequate. These strategies enable students to more flexibly adjust Problem-Solving methods, and understand what help is needed to better adapt to the complexity and changes of the problem.

Reflection upon completion is divided into “positive reflection” and “negative reflection”. “Positive reflection” refers to the gains from experiencing the Problem-Solving process, such as gains in scientific concepts, scientific thinking, inquiry practice, and attitudes and responsibilities. “Negative reflection” refers to reflection on the shortcomings in the Problem-Solving process. “Negative reflection” guides students to reexamine the behavioral path of Problem-Solving, accumulate experience through review, and improve Problem-Solving skills. In the teaching process, teachers can use questions like “What have you gained from experiencing this Problem-Solving process?” and “If you were to conduct the experiment again, how would you improve to make yourself more efficient and accurate? Why?” as prompts after each Problem-Solving activity, guiding students to reflect on the Problem-Solving process and enhance their Problem-Solving ability.

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