



Strategies for Enhancing the Effectiveness of Elementary Science Classroom Teaching Based on Key Competencies

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Abstract: With the continuous development of quality education and the increasingly fierce competition for talents among countries, the cultivation of students' science and technology levels and key competencies serves as a daunting task for elementary and secondary school teachers. The current educational policy emphasizes that elementary teachers should pay due attention to the development of elementary students' key competencies, and improving the effectiveness of science classroom teaching is particularly significant. By elaborating on the concept of "key competencies" and by presenting the features of effective classroom teaching, this study reveals the profound and unique connotations of key competencies in the context of China's national conditions and the characteristics of the times. And this study points out some basic directions for the construction of elementary science classroom teaching as well. In addition, with the purpose of enhancing students' science and technology levels and cultivating their key competencies, this study proposes seven strategies that can effectively facilitate primary science classroom teaching, such as integrating multimedia tools to improve the effectiveness of science classroom teaching, highlighting the position of students and creating a good learning situation, and improving teachers' scientific competence and teaching abilities through multi-faceted learning and training. This study has a strong practical significance for pre-service and post-service elementary science teachers to design and implement more effective science classroom teaching.

Keywords: Elementary School Science, Effectiveness of Classroom Teaching, Key Competencies

1. Introduction

With the expanding emphasis on quality education, the cultivation of students' key competencies has attracted much attention. *The Science Curriculum Standards for Compulsory Education*, issued in 2022, pointed out the demands of the times to meet the fundamental task of fostering virtue through education and revealed the global trend of reform in science education [1]. The newly-issued curriculum standards also mentioned that the elementary school science curriculum should be designed and implemented based on the principles of developing the competencies of all students. Science teachers, as the navigators for elementary students to learn science and perceive its charm, should attempt to cultivate students' key competencies by improving the effectiveness of science classroom teaching, and providing

support for the growth of elementary students. This study aims to interpret the definitions and connotations of key competencies, and analyzes the directions of elementary science classroom teaching to establish a foundation for the effective implementation of key competencies in elementary science classroom teaching through multiple constructive strategies.

2. Connotations of "Key Competencies"

"Key competencies" is an emerging concept in education that has not yet been uniformly defined. International organizations, national and regional policy documents, and researchers use the concept of "key competencies" with some degree of ambiguity. In 2013, Organization for Economic Co-operation and Development (OECD) issued an official report, *Key Competencies for a Successful Life and a*

Well-Functioning Society, which leads the discussion of the skills and qualities that a person should possess to key competencies [2]. The report also constructed a framework of key competencies from the aspects of "people and tools", "people and oneself", and "people and society", corresponding to three types of key competencies, "ability to use tools interactively," "ability to interact in diverse social groups," and "ability to act autonomously" [3]. The report

highlighted that the determination of key competencies should not only be based on individual and societal needs but also on the nature of individual and societal goals. Subsequently, some countries began to carry out research and explorations on the content and index system of the competencies for future students. Table 1 presents the connotations of "key competencies" in different nations.

Table 1. Connotations of Key Competencies in Different Countries [4-6].

Nation or Organization	Connotation
United States-based Partnership for 21 st Century Skills	Three main areas: life and vocational skills, learning and innovation skills, and information, media, and technology skills, as well as four support systems: standards and assessment, curriculum and instruction, teacher professional development, and learning environments.
British Council of Department for Education and Skills	Communication, numeracy, the use of information technology, working with others, improve self-learning and self-doing, problem solving.
France	Utilization of scientific approaches, imagination and realization, mastering tools and methods, using professional language, using digital technologies, acting ethically and responsibly, be capable to locate in space and time.
Australia	Ability to create technology, especially information and communication technology; confident and optimistic attitude that permeates life, family, community and work; ability to solve problems and exchange information, plan and organize activities.
Germany	Professional, social, and autonomous competences, knowledge about work and across different career fields; ability to analyze relationships; conflict management, problem solving, mastery of foreign languages, media literacy, willingness and ability for lifetime learning; international cooperation, leadership skills, communication skills, responsibility, initiative, self-control, decision making; stress resistance, creativity, critical judgment, creativity, critical judgment, ability to act independently, and ability to make decisions etc.

In China, the concept of "key competencies" was first introduced in an official document, *Opinions on Comprehensively Deepening Curriculum Reform to Implement the Fundamental Task of Establishing Virtuous People*, in 2014 by the Ministry of Education. The document indicates the need for research on the development of students' competencies at each school level for lifelong and social development [7]. Additionally, another document, *Developing the Key Competencies of Chinese Students*, stipulates that elementary and middle school students should possess essential qualities and competencies to adapt to the changing demands of society. These competencies include social participation, independent development, and cultural accomplishment, which are comprised of six aspects [8]. In 2016, the General Office of the State Council released *The Implementation Plan of the National Action Plan for the Quality of Science (2016-2020)*, which emphasizes the need to improve the science curriculum system in elementary and middle schools based on the framework of key competencies for student development, to update the content of science and technology education in elementary and middle schools, and to strengthen the guidance for inquiry-based learning [9]. In order to accurately understand and implement national strategies and educational guidelines, it is necessary to build and develop a sound elementary school science curriculum system and explore the development path of key competencies in the science curriculum based on the national conditions and the characteristics of the times, the laws of student growth and the needs of society for talents, and the specific requirements for students into practical science classroom teaching [10].

3. Overview of Effective Classroom Teaching

Effective classroom teaching is a concept proposed under the background of the new curriculum reform, which aims to improve student learning effectiveness per unit of time in the classroom, help students complete their learning tasks more efficiently, and ultimately maximize the benefits of classroom teaching [11]. Achieving effective classroom teaching requires not only teachers to demonstrate adept teaching skills and schools to build modern teaching systems, but also requires active participation of students in learning activities, promoting classroom progress with teachers, and improving the quality and effectiveness of teaching. Effective classroom teaching should be a shared goal across all disciplines, including elementary school science. In pursuing this goal, teachers should prioritize scientific teaching, abandon the sense of exam-oriented education and the mode of problematic tactics, and focus on cultivating students' competencies beyond subject expertise. The key to promoting an effective classroom teaching of science in elementary schools is to cultivate elementary students' key competencies.

Teachers attend to students' intellectual growth and emotional gains in effective classroom teaching. The purpose of effective classroom teaching is to develop students' learning abilities and lifelong sustainable development competencies. Teachers who use effective classroom teaching advocate appreciation education and do not use test scores to qualify students' strengths and weaknesses [12]. Instead, effective classroom teaching requires teachers to be

proficient in identifying students' strengths and encouraging them to leverage their strengths, leading to students' confidence and success.

4. Basic Directions of Elementary Science Classroom Teaching Based on Key Competencies

Elementary school science teachers should follow some essential requirements for constructing effective science classrooms that are suitable for developing students' key competencies. They need to provide students with affluent science learning resources, create an excellent teaching and learning environment, and lay a solid foundation for the cultivation of students' key competencies.

4.1. Authenticity Should Be Ensured in Elementary School Science Classroom Teaching

The essence of science is to maintain authenticity, and elementary school science classroom teaching based on key competencies should take authenticity as a prerequisite [13]. For instance, the goals of science experiments in elementary schools are to describe and analyze things and phenomena, and use data to give feedback on realistic and clear results, to maintain the truth-seeking attitude of elementary students. For instance, in conducting science experiments, students should have a good knowledge of the experimental instruments, such as alcohol lamps, thermometers, microscopes, and scales, and learn to use the instruments in the experiments to maintain the scientific and comprehensive nature of the results. Learning in a truth-seeking and realistic manner in the elementary school science classroom can have a positive effect on enhancing elementary school students' science key competencies.

4.2. Imagination and Creativity Should Be Emphasized in Elementary School Science Classroom Teaching

Elementary science teachers should attach more importance to the development of the imagination and creativity of students, grasp the essentials of key competencies in science, and equip students with the basic abilities of model construction, scientific reasoning, scientific argumentation, and questioning and innovation in the scientific thinking and innovation dimensions. The production of scientific knowledge itself is the product of human reasoning, belief, and creation. For example, after introducing the content of "Journey to the Moon", a science teacher can lead students to imagine the situation of traveling in space, and observe the surface of the moon to arouse students' imagination and creativity, and guide students to build the "International Space Station".

4.3. Social Nature Should Be Highlighted in Elementary School Science Classroom Teaching

The science classroom itself has a social feature, and

elementary science teachers should explore the social nature so that the students can recognize the presence of scientific knowledge and grow as they engage in the process of science knowledge building. Inquiry and communication elements in science classroom teaching, such as questions, evidence, explanation, and communication, can help demonstrate the social nature of the science classroom. For example, in the science lesson "Recognizing Common Rocks", a teacher can show the images of common rocks in daily life, present the posture, characteristics, and colors of the rocks, and ask the students to collect rocks outside at the end of the class. It is necessary for elementary students to enhance their key competencies by linking their science knowledge to the social scenes and by learning to explain and analyze scientific phenomena. Nowadays, elementary school science classroom teaching emphasizes the all-round growth of students and the enhancement of comprehensive competencies rather than a single-liner transmission and assessment of science knowledge. Therefore, science teachers should make great efforts in cultivating students' interests and curiosity in science learning, improving interaction and communication with students, and providing more opportunities to explore the mysteries of science and nature.

5. Strategies for Enhancing the Effectiveness of Elementary Science Classroom Teaching

To cultivate students' key competencies, the focus of elementary science classroom teaching should be designed and implemented toward the growth and experience of the students, the exploration and analysis of scientific mysteries, and the perception of the unique charm of the science discipline. To better improve the effectiveness of elementary science classroom teaching, strategies for improving the effectiveness of the science classroom in elementary schools are proposed to reshape the elementary science classrooms, so as to provide a solid guarantee for strengthening students' key competencies.

5.1. Integrating Multimedia Tools to Improve the Effectiveness of Science Classroom Teaching

Elementary science teachers should be receptive to the development of modern educational technologies. Cultivating students' scientific thinking habits in the learning and exploration of elementary science learning can help facilitate the cultivation of scientific competency in the process of developing problems or scientific awareness [14]. To promote effective science classroom teaching, teachers can frequently introduce topics of interest to students in practical teaching so that students can actively participate in the learning activities and stimulate their learning motivation. For instance, when learning the content of "The Life Cycle of Silkworms", a science teacher can first ask students to collect materials regarding silkworm rearing and encourage students

to experience the fun of rearing silkworms to stimulate their interest in learning, then the teacher can choose to use multimedia tools to present additional images and information about silkworm molting, and show pictures of other animal larvae, allowing students to intuitively feel the miracle and greatness of life. These practices can make the content of the lesson more exciting and inspire students' imagination and creativity.

5.2. Highlighting the Principal Position of Students and Creating a Good Learning Situation

To promote active and creative learning, it is important for teachers to position themselves as facilitators and organizers of students' learning. This includes guiding students to explore and discover, and giving them opportunities to express their individual and collective ideas [14]. To develop elementary students' key competencies in science classroom teaching, teachers are required to do their best to mobilize students' learning enthusiasm and initiative by reducing instructing and analysis, generating more questions and prompts, changing traditional and outdated teaching concepts, creating a good teaching and learning environment, giving students with more time and space for thinking, and providing more opportunities for expressing individual and collective ideas. Students can acquire more scientific knowledge and improve their thinking and inquiry skills. For example, when teaching the content of "The Properties of Magnets", a teacher can give students enough time and space to explore and engage them in hands-on science activities. Such an arrangement could encourage students to learn more actively and to have a greater willingness to explore scientific knowledge. At the same time, this process can help develop students' hands-on skills and improve their spirit of pursuing truth. This method of inquiry learning can at the same time mobilize students' learning potential, develop their key competencies, as well as increase their participation in science learning, which is conducive to achieving the construction of an effective elementary school science classroom.

5.3. Stimulating Students' Learning Motivation and Their Interest in Learning Science

Interest is the best teacher. Most elementary students are curious about the world, but their curiosity tends to stay at the level of fun and novelty. Motivating students to learn science involves expanding the scope of scientific phenomena exploration and research. Teachers can achieve this by designing guiding questions and providing opportunities for independent inquiry and collaboration. For example, when teaching the unit "Common Characteristics of Plants," a teacher can invite the students to grow two kinds of plants, observe and record their growth, and bring them to school after a month. When students bring out plants such as cacti, sunflowers, aloes, and hanging baskets, the teacher can lead them to observe and analyze the common features of the plants. The teacher should design some guiding questions,

such as: "Do cacti and sunflowers need to be watered at the same time? What conditions do cacti and aloes need in common to grow?" Then the teacher can guide students to seek answers to their questions through independent inquiry and collaboration. This approach can fully motivate students, arouse their interest in learning, and mobilize their motivation for science learning.

5.4. Improving Teachers' Scientific Competence and Teaching Abilities Through Multi-Faceted Learning and Training

To construct an effective science classroom, the training of pre-service and new science teachers should be emphasized, and teachers can improve their teaching skills and abilities through multi-faceted learning and training. In order to improve the scientific competencies of elementary science teachers, schools should strengthen the training of professional knowledge and skills, and it is suggested to enroll college graduates with science and engineering-based majors to join the teams of elementary school science teachers. The content of the elementary science courses includes areas such as the living world, the material world, and the earth and universe, and involves knowledge from multiple disciplines such as biology, chemistry, physics, and geography, to comprehensively improve the scientific knowledge and skills of elementary science teachers, schools should organize tests and assessments for pre-service and new in-service science teachers and promote their scientific competencies through training and other means. Meanwhile, elementary school science teachers also need to know how to utilize modern educational technologies and methods flexibly, and enhance their abilities in producing courseware and presenting teaching materials. Through continuous learning, discussion, collaboration, and communication, teachers can learn key abilities and skills for science teaching and be capable to achieve a high level of disciplinary integration.

5.5. Encouraging Students to Engage in Cooperative Learning and Mobilize Their Initiatives

Cooperative learning mode is an effective approach for the enhancement of students' key competencies, and it is also an important way for students to master relevant knowledge and comprehensive abilities in science learning. In elementary science classroom teaching, teachers should notice the fact that the cooperative learning enables students to carry out full cooperation and communication around the key contents, which not only effectively activates teaching and learning in the classroom, but also promotes the overall qualities of the classroom teaching effects. For instance, when teaching the lesson "Comparing Different Soils", students can explore specific issues through collaborative learning, organize specific content on the basis of communication and discussion between group members in the process of exploration, and complete exploratory learning by summarizing. Implementing classroom teaching in this way can help improve the general classroom teaching atmosphere,

and facilitate students to approach the core knowledge in the process of cooperative learning based on phased cooperative goals and sustainable exploration and communication. The adoption of the cooperative learning approach in elementary school science classrooms can also effectively promote the cultivation and development of students' key competencies, which will be of great help to the future growth of all elementary students.

5.6. Optimizing the Introductory Session Before Class to Improve the Precision of Classroom Teaching

The introductory part is the key to improving classroom teaching effectiveness and the basis of the whole teaching activities [11]. Elementary science teachers should pay attention to the introductory session before class to guide students to study the learning content in advance and to pave the way for the formal lesson. Currently, the most common method of introduction is the provision of introductory questions. Before teaching a new lesson or unit, a science teacher can choose to assign several simple assignments based on the learning content and then guide students to preview the new lessons based on the questions, through which they can find the answers. The important thing for students is to construct a general understanding of new lessons by previewing, and making clear the modules or directions they do not understand, so that the teachers will have a focus when teaching and can realize the target-oriented teaching with half the effort. For example, before teaching the content of "Climate and Seasons", a science teacher can assign students a homework assignment. The main task is to find and collect leaves, flowers, and other carriers that correspond to the climate and seasons. By doing this, students can have a preliminary understanding of this section about the relationship between seasonal changes and climate change, understand the laws of the changing seasons, and feel the characteristics of climate change. In the formal class, the teacher can ask the students to show the information they have summarized. Then the teacher can guide the students to give feedback to the teacher on the knowledge points that they fail to understand during the preview process. The teacher should adjust the lesson plan according to the students' feedback in time to realize the teaching process of highlighting the key knowledge points and stepping up the difficult points. Therefore, it is not difficult to achieve the teaching objectives of the lesson. The introduction session is the beginning of a lesson, and teachers need to show students interesting teaching resources and ask inspiring questions, to further stimulate students' interest in learning science and improve their understanding of scientific knowledge.

5.7. Designing Meaningful Questions to Expand the Depth of Students' Learning

Designing meaningful questions in classroom teaching can not only improve the teaching and learning atmosphere but also help develop students' thinking abilities. Learning from

knowledge taught by science teachers without thinking, elementary students may understand some scientific concepts and natural phenomena but may stay at a relatively shallow level. Through setting and designing questions in the science lessons, teachers can guide students to a deeper understanding of knowledge and improve the effectiveness of science classroom teaching [15]. Therefore, teachers need to thoroughly analyze the important and difficult knowledge points and the thinking levels of students in the lesson preparation process. Then the teachers can design questions that are connected with the content and knowledge points to ensure that they are in line with elementary students' experiences and knowledge system, and help break through the key and difficult points. In the process of giving questions, the science teachers should first select and design questions that can promote thinking development or expand the depth of teaching according to students' physical and mental characteristics and the objectives of the science curriculum. At the same time, teachers should ask students more inspiring questions and guide students to give their own understanding from different perspectives. Thereafter, students are encouraged to share their opinions and insights among themselves to know and understand the knowledge more deeply. It is also necessary for elementary science teachers to guide students to find and raise questions in science classes and dare to question the authority of the textbooks or the teachers' opinions, which is helpful to develop critical thinking ability. In addition, teachers should allow sufficient time for students to think deeply and fully explore their thinking potential, taking into account the difficulty level of the questions.

6. Conclusion

The construction of effective classroom teaching in elementary school science cannot be achieved without the hard work of teachers. Firstly, elementary science teachers should implement the general requirements of the new curriculum standards for cultivating students' key competencies, highlight the principal position of students and create a good learning situation. Then, from the perspective of teacher competencies improvement, training, assessment, and other aspects, it is necessary to build a high-quality and dynamic team of elementary school science teachers. In addition, elementary science should try a variety of science teaching methods and use modern educational technologies to create more interesting, interactive, and effective science classrooms for students.

This study discusses connotations of key competencies and presents main features of effective classroom teaching. Seven constructive strategies that can effectively optimize science classroom teaching in elementary schools are proposed. This study has a good practical implication for science teachers engaged in teaching elementary science to design and implement classroom teaching based on key competencies.

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