ISSN 2663-8169 Vol. 5, Issue 20: 168-173, DOI: 10.25236/IJNDE.2023.052030

Discussion on the Integrated Teaching Mode of Science and Education Based on PBL—"Take Solar Energy Desalination Xinjiang Salt-Alkali Water Treatment" as an Example

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Abstract: *Under the requirements of environmental protection and promoting sustainable development, solar energy, as a clean and mature technology in the field of chemistry, plays a significant role in the learning of university and high school chemistry. In Xinjiang, especially in the southern region, there is a large area of saline-alkali soil with various types, heavy salt accumulation, and complex formation, which seriously hinders the sustainable development of agriculture and animal husbandry and ecological environment protection, impeding local economic development. Based on the course "Fundamentals of Materials Engineering," and taking "Solar Energy Desalination for Saline-Alkali Water Treatment in Xinjiang" as a problem-oriented approach, this study adopts a student-centered and teacher-guided teaching model, incorporating a series of driving questions. This not only stimulates students' interest in learning and cultivates higher-order thinking skills but also integrates cutting-edge scientific research information into educational activities, facilitating the integration of "science and education."*

Keywords: *Problem-Based Learning (PBL) teaching model, Science and Education integration, Solar Energy Desalination, Saline-Alkali Water*

"Fundamentals of Materials Engineering" is a compulsory course for undergraduate and graduate students majoring in materials science and engineering. Its teaching characteristics include serving as a bridge from theory to engineering and from fundamentals to specialized knowledge. It has strong engineering and practical aspects, playing a crucial role in cultivating students' professional qualities and engineering abilities. However, during the teaching process, it was observed that students' enthusiasm for learning was low, their interest in the subject was diminished, and their focus was primarily on exam preparation. Nonetheless, this course possesses a strong professional and applied nature, and mastering it can lay a solid foundation for future studies. Therefore, this paper combines the Problem-Based Learning (PBL) teaching model with the "Science and Education" integration model, exploring a blended teaching approach that is conducive to improving students' learning efficiency based on the characteristics of the course and the students' learning patterns.

1. PBL Teaching Model

The PBL teaching model was first proposed by American neurologist Professor Barrows in the 20th century and has become a commonly used teaching model both domestically and internationally [1-2]. PBL stands for Problem-Based Learning, which is a learning approach based on problem scenarios, also known as problem-oriented teaching. The PBL teaching model fully embodies the student's position as the main participant in the teaching activities. It introduces the content to be learned through the design of problem scenarios, allowing students to actively discover, think, and solve problems, thereby gaining knowledge and completing teaching tasks [3-4]. During the problem-solving process, students typically communicate and collaborate in learning groups, which not only enhances students' awareness and abilities for independent thinking but also improves their communication and interpersonal skills, providing a developmental path and space for their physical and mental well-being and social integration.

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2. Science and Education Integration

Teaching Model the integration of science and education began at the University of Berlin in the early 19th century. Integrating scientific research into universities was an innovative practice that transformed classical universities into modern ones [5]. Subsequently, American universities learned from the German model and further institutionalized the integration of science and education. Johns Hopkins University established the world's first graduate school, becoming the pioneer of research universities [6]. "Science and Education Integration" refers to the deep integration of scientific research and higher education. Broadly speaking, it is the mutual promotion and coordinated development of scientific and technological undertakings and educational undertakings in national policies. From a narrow perspective, it is a new initiative of higher education institutions to organically integrate scientific research and teaching into talent cultivation [7-9].

In the course "Fundamentals of Materials Engineering," students not only learn theoretical knowledge but also need to enter the laboratory for experimental operations to acquire practical skills. When entering the laboratory for the first time, the teacher needs to explain the relevant details of the experimental operations, using existing projects as examples to help students better understand the significance of the discipline. This, to a certain extent, reflects the significance of "science and education integration." The combination of scientific research and teaching is an inevitable trend and a necessary choice to integrate talent cultivation resources and improve talent quality. Teaching provides a series of resources for scientific research, while scientific research offers a continuous supply of cases and practical application skills for teaching.

3. Integration of PBL and "Science and Education Integration"

Taking problem-oriented, putting forward driving problems, attaching importance to the combination of student-oriented teaching mode (PBL) and the teaching mode of "science and education integration", it can cultivate students' scientific research literacy and teamwork consciousness while teaching knowledge, and form a four-in-one comprehensive teaching model of "teaching- research-teacher-student". Teaching cannot be separated from teachers 'teaching and students' learning, and scientific research is also inseparable from teachers 'guidance and students' exploration. Therefore, teaching and scientific research have the same elements. The combination of the two can not only provide more practical cases for teaching, but also provide new ideas and context for scientific research.

At the same time, both teaching and scientific research should be proactive, that is, students should actively explore, discover, learn and summarize, rather than absorbing all the knowledge taught by teachers step by step. It is necessary to give full play to the dominant position of students in the classroom and scientific research and the guiding position of teachers in this process. When students begin to think, discover, cooperate and explore for these exquisitely designed questions, students' initiative will be fully reflected. By asking questions, teachers guide students to constantly learn knowledge and improve their ability, and finally make students form a sense of identity and pride in chemical and chemical subjects.

In many years of teaching practice, students generally find the course difficult, with engineering knowledge hard to comprehend. Teachers also feel that "Fundamentals of Materials Engineering" sets too many course goals, and general teaching methods are insufficient to enhance students' learning interests, resulting in less than ideal classroom teaching effects. The root cause of students' difficulty in learning and teachers' difficulty in teaching mainly lies in several aspects: limited class hours, numerous course goals, multiple learning objectives, extensive content, weak foundations, and insufficient practice. Moreover, this course has strong practicality in engineering and requires mutual support from multiple disciplines, with closely linked knowledge between disciplines, posing a considerable challenge for students who have received specialized teaching in multiple subjects. Due to the weak foundation in integrated disciplines, students find it challenging to understand more obscure and complex university knowledge. Coupled with the fact that teachers need to focus on the progress of teaching and can only "emphasize explanation, light on practice, emphasize teaching, and light on application," students' learned knowledge is not consolidated and reviewed. Thus, a vicious cycle is formed: students lack concentration in class, cram for exams just before the test, and cannot comprehend the importance and fascination of the course. Over time, their learning of this course cannot support their subsequent research skills, and the value of the discipline setting is lost.

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4. PBL's "science and education integration" teaching process

4.1 Pre-class preparation stage

The design and presentation of driving questions are essential in the PBL teaching model, as they should be able to stimulate students' interest in learning, their desire for knowledge, and be of appropriate difficulty level. Taking the topic "Solar Desalination for Treating Saline-Alkaline Water in Xinjiang" as an example, three driving questions are formulated to help students gain a better understanding of the course content before class.

(1) Driving Question 1: Where does saline-alkaline water in Xinjiang mainly come from?

China is a large country with saline-alkaline land, mainly distributed in 17 provinces and regions such as northwest, northeast, north China, and coastal areas, with southern Xinjiang being a representative region [10]. Currently, the most commonly used method for treating saline-alkaline soil is flooding irrigation and leaching. However, using limited water resources for flooding irrigation not only consumes a large amount of fresh water but also only provides temporary relief to the problem of saline-alkaline soil. Moreover, direct discharge of saline-alkaline water after flooding irrigation will lead to many new problems. These include exacerbating secondary soil pollution, reducing crop yield and quality, corroding agricultural facilities and equipment, increasing industrial costs, and causing serious water pollution in the Tarim River as saline-alkaline water flows through various levels of alkali drainage channels, resulting in increased water mineralization, massive death of beneficial microorganisms, and harmful effects on human and animal health, as well as ecological damage [11-12].

Therefore, in the context of teaching fluid transportation unit operations in "Fundamentals of Materials Engineering," the problem orientation is focused on the hazards of impurities in water to the pipeline. By discussing the source and hazards of saline-alkaline water in Xinjiang, students are led to explore water treatment issues.

(2) Driving Question 2: Why is saline-alkaline water difficult to treat?

Saline-alkaline water contains a large number of soluble salt ions, such as CO32-, HCO3-, Na+, Ca2+, Mg2+, K+, Cl-, SO42-, etc. The current methods for removing soluble salt ions mainly include electrodialysis, ion exchange, membrane separation, and adsorption. Although these methods have been commercialized, they are still not feasible in rural areas (especially remote areas like southern Xinjiang) due to their high cost, high energy consumption, and complex industrial facilities. In recent years, a new technology has emerged that utilizes solar energy-thermal conversion materials for rapid water evaporation. Clean solar energy serves as the energy source, and light-absorbing materials achieve photothermal-vapor conversion. The energy is localized in the interfacial region to heat a small amount of water internally, obtaining a higher photothermal-vapor conversion efficiency and achieving the separation of water and soluble salt ions. The problem orientation is based on the difficulty and cost of treatment, guiding students to study issues related to industrial and economic costs in "Fundamentals of Materials Engineering."

(3) Driving Question 3: How can solar energy be efficiently utilized for desalinating saline-alkaline water?

Solar energy-thermal conversion materials are located at the interface between water and air, and solar radiation directly hits the solar energy-thermal conversion materials, transforming into heat energy, which is then absorbed by the water in the solar energy-thermal conversion materials, resulting in steam generation. This process reduces heat loss to water, achieving a higher water evaporation efficiency. Therefore, the design of driving question 3 revolves around achieving a more efficient water vapor generation rate and photothermal conversion efficiency through rational design.

With a research project as the starting point, students are guided to discuss the preparation of an anti-oil, super-hydrophilic composite aerogel (ASG aerogel) using polyvinyl alcohol (PVA), sodium alginate (SA), and polyaniline (PANi) as raw materials. This aerogel can be used in solar energy to achieve water evaporation for desalinating saline-alkaline water. The ASG aerogel not only increases the water evaporation rate at the solar energy interface but also exhibits oil pollution resistance and long-term durability. Even in saline with oil pollution, solar energy interface evaporation can be achieved, resulting in desalination of saline-alkaline water. As shown in Figure 1

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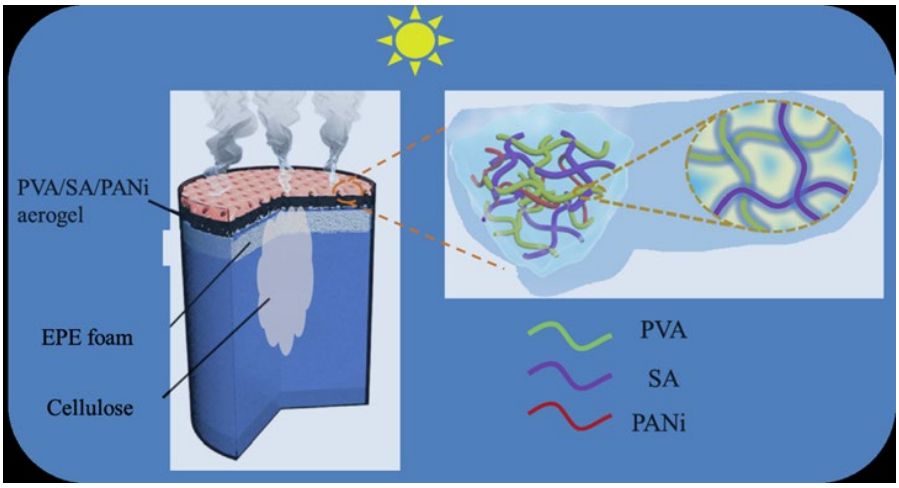

Figure 1: Solar energy interface evaporation mechanism of the ASG aerogel material

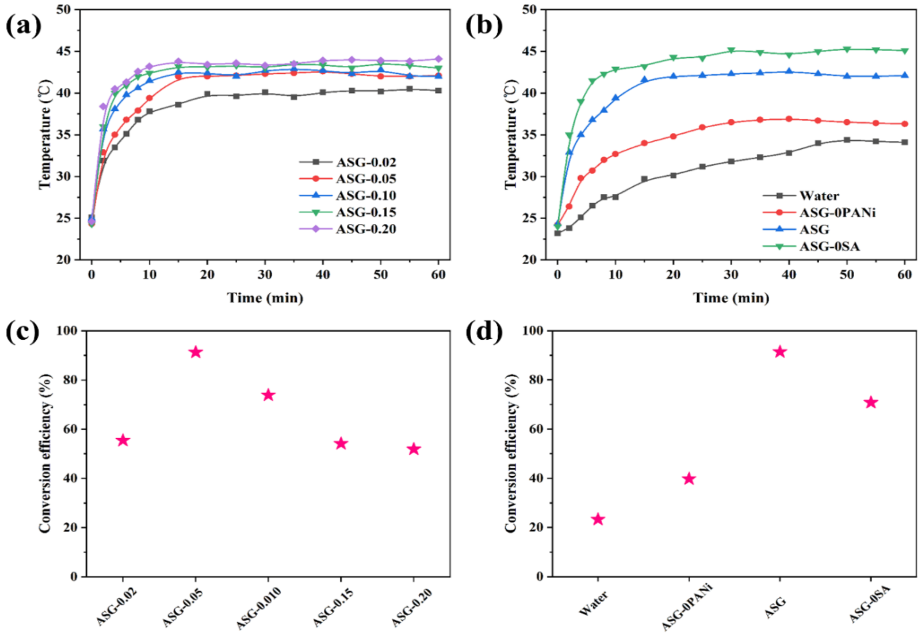

Figure 2: Determination of the aerogel surface temperature and the photothermal conversion rate

The determination of surface temperature of different PVA contents of ASG aerogel (a) and different materials (b) under a certain light intensity, and the photothermal conversion efficiency of different PVA contents of ASG aerogel (c) and different materials (d) were studied. The temperature of ASG-0.20 increased from 24.6°C to 44°C. In addition, the highest temperature of ASG-0.02 aerogel was 40.4°C. With the increase of PVA content, the water absorption capacity of the aerogel decreased, and the surface temperature increased. ASG-0.05 aerogel showed the highest photothermal conversion efficiency, reaching 91.2%. After 1 hour of solar irradiation, the temperature of ASG-0SA aerogel and ASG aerogel increased rapidly, while the water surface temperature remained relatively constant. Through the above analysis, it can be concluded that based on the local heating effect, a solar energy interface evaporation material was designed using oil pollution-resistant and low-cost photothermal aerogel. This aerogel demonstrated excellent solar energy absorption, super-hydrophilic, and water evaporation performance. As shown in Figure 2

Through the integration of science and education in teaching, students deeply appreciate the development of modern new water treatment technologies and pollution-free treatment of water quality. They also actively practice the ideological concept of green chemistry and environmental protection in their study of "Fundamentals of Materials Engineering," which is a unified goal.

4.2 Learning stage in class

Table 1: Teaching process of PBL and "Integration of science and education"

Teaching task	Student activities	Teacher activities
Task 1: Prespresentation of three driving problems	(1) Members of each group shall report in turn (2) Teachers should make comments on the performance of each group member	(1)Record the highlights and deficiencies in each group's report, and make comments. (2) Prepare for the course explanation after the report
Task 2: Show the group communication after the presentation	(1) Students listen to the reports of each group carefully, record and comment (2) Free communication between the groups	(1) Guide students to comment (2) Organize exchange activities (3) Grasp the communication time
Task 3: Theoretical explanation of saline-alkali water desalination technology	(1) Listen carefully, record the knowledge points that you are more interested in (2) Mark the places where you do not understand the theoretical knowledge	(1) Explain the relevant theory (2) Communicate with students

4.3 After class promotion stage

4.3.1 Student promotion

(1)Ability enhancement

Through the problem-driven teaching model, students can preview the upcoming content before class, using literature research to find one or several answers suitable for the questions. During group cooperation, they can consolidate each person's answers and optimize the presentation plan. This not only cultivates students' collaborative learning abilities but also fosters leadership and presentation skills in some students.As shown in Table 1.

(2)Literacy promotion

In the high school stage, the cultivation of chemical literacy follows five core literacies in the field of chemistry. In the university stage, the training of chemical literacy should continue to inherit these core literacies. After the teaching process, students' problem-solving abilities, collaborative exploration abilities, and practical chemical operation abilities are enhanced. Additionally, under the "integration of science and education" teaching model, students' interest in the discipline of chemistry is also enhanced, which will be more conducive to the development of future teaching activities by teachers.

4.3.2 Teacher promotion

Through the implementation of PBL and the mixed teaching model of "integration of science and education," teachers' teaching skills are improved. Teachers no longer follow a fixed teaching style but instead return the classroom to the students, making them the main body of the learning process. Teachers act as facilitators, guiding students step by step towards finding the answers to problems, ultimately developing their own abilities and literacy.

At the same time, the relationship between teachers and students is elevated in this teaching model. The teacher's role is no longer mysterious, and students can be guided by teachers to enter the teacher's area of expertise, standing on the shoulders of giants to further study, discover, and research.

5. Conclusion

Through the research and exploration of the PBL and "integration of science and education" teaching model, we have discovered new ideas for education and teaching. It became apparent that scientific research and teaching are complementary to each other. By using research projects related to local economic development, we can combine theoretical teaching and laboratory experiments, transforming abstract and difficult-to-understand chemical and chemical engineering knowledge into tangible and experiential research for students. However, this teaching model requires teachers to

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possess strong organizational skills in education and teaching and the ability to develop meaningful driving questions. Undoubtedly, this will significantly increase the workload for teachers. Teachers should always bear in mind their responsibilities and devote more time and energy to facilitate more effective learning for students.

Acknowledgement

Fund project: This paper is the research project of Education and Teaching Reform of Shihezi University (JGY-2023-01; ZG00760603; JGZ-2023-02), and the research result of the first-class undergraduate course construction (material engineering foundation) of Shihezi University.

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