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Innovative education in the teaching of physics at university

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ABSTRACT: Drawing on teaching experience, innovative education was tried out on three aspects of college physics courses. First, considering the student as central, an equal, democratic teaching atmosphere was created, focused on mobilising students' initiative, and to stimulate their active co-operation with this innovative method of education. Second, the importance of the knowledge of theory was highlighted during the teaching process, along with the cultivation of innovative ability, and the combining of knowledge with actual example. Application of the physical knowledge of the subject was demonstrated during the university physics classes. The third involved improving experiments that promote innovative education. Three methods are put forward in this article to increase the efficiency and accuracy of experiments. These methods included not only innovation in theory but also in technology. Teaching experience has proved that implementation of innovative education can be effective.

INTRODUCTION

Innovation is the soul of a nation's progress, the inexhaustible power behind a nation's prosperity; a nation of no innovative capability will find it difficult to stand proudly among the nations of the world. Yet the key to cultivating consciousness and capacity in national innovation lies in education, especially foundation education [1]. Education is the main basis of innovation in knowledge, its dissemination and application. It is also the cradle for nurturing innovative spirits and talents [2].

To help with basic education, one of the tasks of higher education reform is to develop students' innovative ability in each basic course and in specialised fundamental courses [3]. This is especially important in developing research and innovative practice by undergraduate students in early years of study, since it is necessary to cultivate competitiveness among college students [4][5]. It is also the focus of current higher education reform. In recent years, staff in the physics department have devoted themselves to the study and practice of innovative education and have achieved remarkable results.

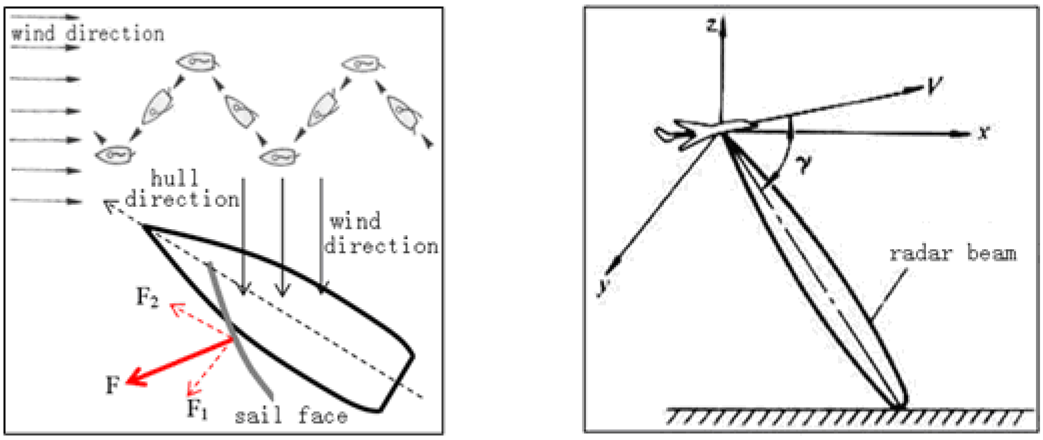
TO CREATE A TEACHING ATMOSPHERE OF EQUALITY AND DEMOCRACY

The selection of teaching content should consider the nature of students. On the one hand, the content should meet students' learning ability and take account of their level of understanding. To attract students' attention and mobilise their enthusiasm teaching aids should be rich and colourful. Innovation requires a psychological orientation of active exploration and discovery. If students feel empowered, they will truly engage in the teaching and learning process, giving full play to their own subjective drives and achieving their full potential. Only by arousing students' enthusiasm will they dare to think and speak freely.

HIGHLIGHTING THE STUDY OF PHYSICS IN TEACHING TO DEVELOP INNOVATIVE ABILITY

Active Study and Application to Acquire Physics Knowledge

The teacher often can inspire students to think about the question: Do you learn to solve practical problems or do you learn simply to pass the examination? Of course, after thinking it through, the students will recognise the final goal of learning; and they will connect the subject to real life, when learning each part of physics. For example, in learning mechanics, the knowledge of it can be applied to many practical problems encountered in students' daily life. As shown in Figure 1a, an athlete sailing a canvas boat in a regatta can sail against the wind. Figure 1b reveals the use of Doppler frequency radar to track a moving target.



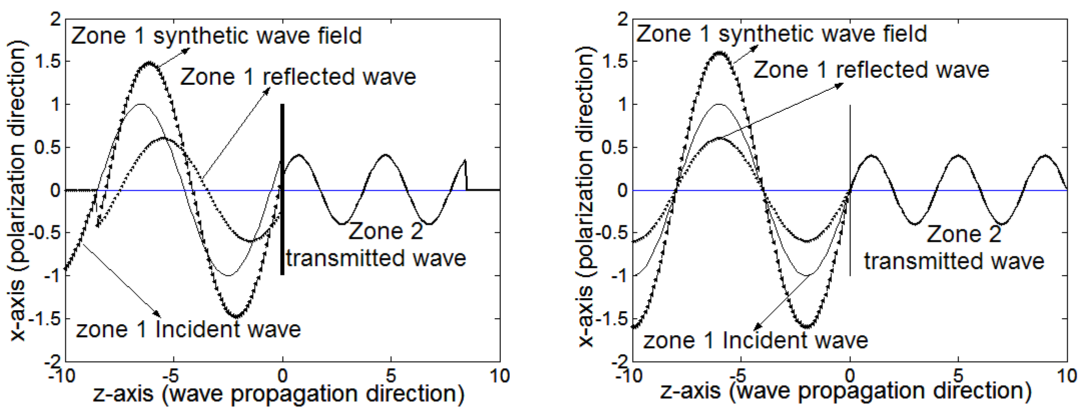
a) b)

Figure 1: Schematic diagram of a canvas boat sailing against wind and a Doppler navigation radar: a) Canvas boat sailing against wind; b) Doppler navigation radar.

How to Inspire Students to Learn Physics

To inspire students to learn physics, a teacher must do the following:

1. Strengthen understanding of the intrinsic nature of physics. For example, the total energy of an object determines its equation of motion; an electrostatic field is a field with a charge source; a static magnetic field is a field without a source. In addition, there are conserved and invariant quantities and symmetries in physics, etc.
2. A teacher should emphasise the interrelation of knowledge in physics and highlight the integrity of that knowledge. Moreover, problems with multiple solutions should be presented; thus, training students to use different methods, from different perspectives, to solve the same problem. For example, to solve the kinematic equations of simple harmonic motion, one can use Newton's second law, the law of rotation, the theorem of kinetic energy or the mechanical energy conservation law. So, the result can be obtained in a number of different ways.
3. Flexible use of physics methods. Different methods are used to acquire knowledge, such as the method of equal effect, paired method, extremism method, conservation method, singular method and image method. A method may be most appropriate, depending on the particular case. Students should learn how to transform and migrate solutions to apply to different areas of physics and, thus, establish the sense of organic integrity between different areas.
4. Multimedia and other modern teaching aids to improve teaching. Multimedia can use animation to make the teaching content rich and colourful. Teaching content associated with a specific image can aid the recall and understanding of abstract theories and this will greatly increase students' interest in learning. For example, the electromagnetic reflection and transmitted waves at an interface can be simulated by computer. Simulation results are shown in Figure 2.



a) b)

Figure 2: Plane waves in layered media composed of three dielectric layers: a) Travelling wave screenshot (at time t1); b) Travelling wave screenshot (at time t2).

The electric field of the incident wave is given by:

$$\text{Zone 1: } \vec{E}_x(z,t) = \vec{e}_x E_{im} e^{-j\beta_1 z} e^{j\omega t} \tag{1}$$

The electric field of the reflected wave:

$$\text{Zone 1: } \vec{E}_x(z,t) = \vec{e}_x \Gamma E_{im} e^{j\beta_1 z} e^{j\omega t} \quad (2)$$

The electric field of the transmitted waves:

$$\text{Zone 2: } \vec{E}_{2x}(z,t) = \vec{E}_t(z,t) = \vec{e}_x \tau E_{im} e^{-j\beta_2 z} e^{j\omega t} \quad (3)$$

The synthetic wave field:

$$\text{Zone 1: } \vec{E}_{1x}(z,t) = \vec{e}_x E_{im}(e^{-j\beta_1 z} + \Gamma e^{j\beta_1 z}) e^{j\omega t} \quad (4)$$

The figures are depicted by numerically calculating the formulas above. So, with the help of the diagrams, not only are the physical formulas easily understood, but also, more importantly, the laws of physics can be visually comprehended.

PROMOTE INNOVATIVE EDUCATION BY THE IMPROVEMENT OF EXPERIMENTS

Physics is based on practical experiments; the teaching of experiments is an integral part of physics education. Experiments in physics provide theoretical and technical innovations. Therefore, teachers should do more to improve experiments in physics at university.

Designing a Simulation Program to Imitate the Demonstration Experiment

Teachers need to create more classroom demonstration experiments. Circuit analysis software or CAD PSpice can be used, which offers powerful circuit simulation and analysis capabilities. For example, in an RLC series circuit simulation, while keeping the power supply voltage to a constant value, the peak value of the current I in the RLC series circuit is selected as the resonance criterion, the corresponding peak frequency $f = f_0$ being the resonance frequency. Simulation results are shown in Figure 3. Changing the circuit parameters L and C can make the RLC circuit resonant. Maintaining L constant and changing the value of capacitor C of an RLC series circuit will reduce f_0 with increasing C, as shown in Figure 3a and Figure 3b corresponding to capacitances C of 5 μF and 10 μF. Similarly, when C is kept constant, f_0 decreases with increasing L. With the help of computer simulations, verifying the resonance behaviour of the RLC circuit is very easy. By such means, the efficiencies of demonstration experiments are greatly improved. At the same time, the visual reasoning and innovative ability of students are exercised.

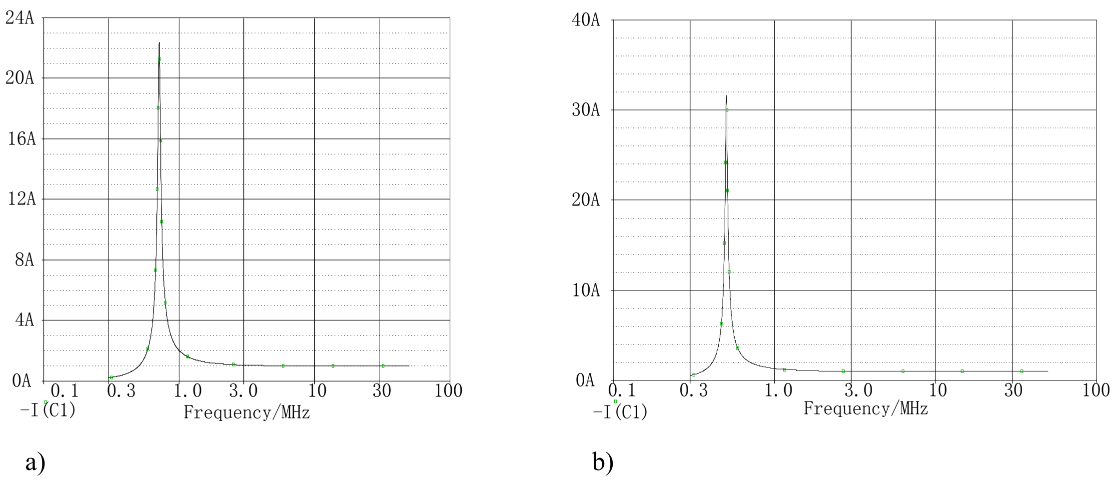


Figure 3: The relationship between resonant frequency and the capacitance C of an RLC series circuit: a) C = 5 μF; b) C = 10 μF.

Improving Experimental Methods to Increase Experimental Accuracy

Better results can be obtained by improving the experimental method and approach. The experiment can be improved simply by adding a small number of facilities to the experiment. As a case in point, the Young's modulus measurement of a metallic material can be improved by using a simple plane mirror with a stent, thus, producing an optical lever amplification device, as depicted in Figure 4. Therefore, through wire elongation magnified under the pull force, the accuracy and experimental effect are greatly improved. Thus, it can be seen that creative education by improving an experiment has two aspects, i.e. theory in innovation and innovation in technology.

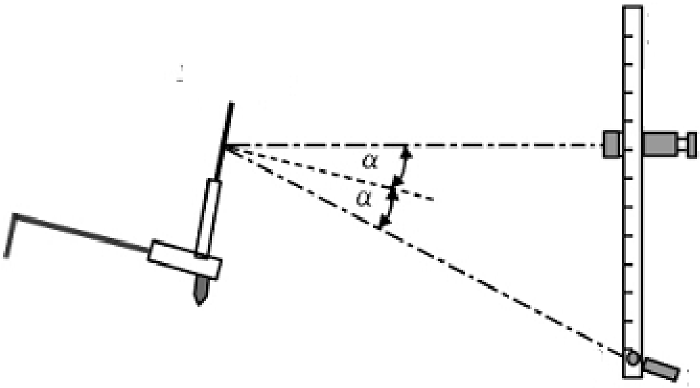


Figure 4: Schematic diagram of the optical lever amplification [6].

Designing Related Software, Improving Data Processing

By using powerful computers, data derived from experiments can be directly processed, and the results visualised. The acquisition and processing of most of the data from physics experiments uses similar software. For the microprocessor-based Zeeman-effect experiment, as an example, the functions of the image processing software include grayscale adjustment, repairing, drawing and automatic calculation. By importing the values of the measured circles' diameters and the magnetic field where the sample is located, the required electronic charge to mass ratio can be calculated, as shown in Figure 5 [7].

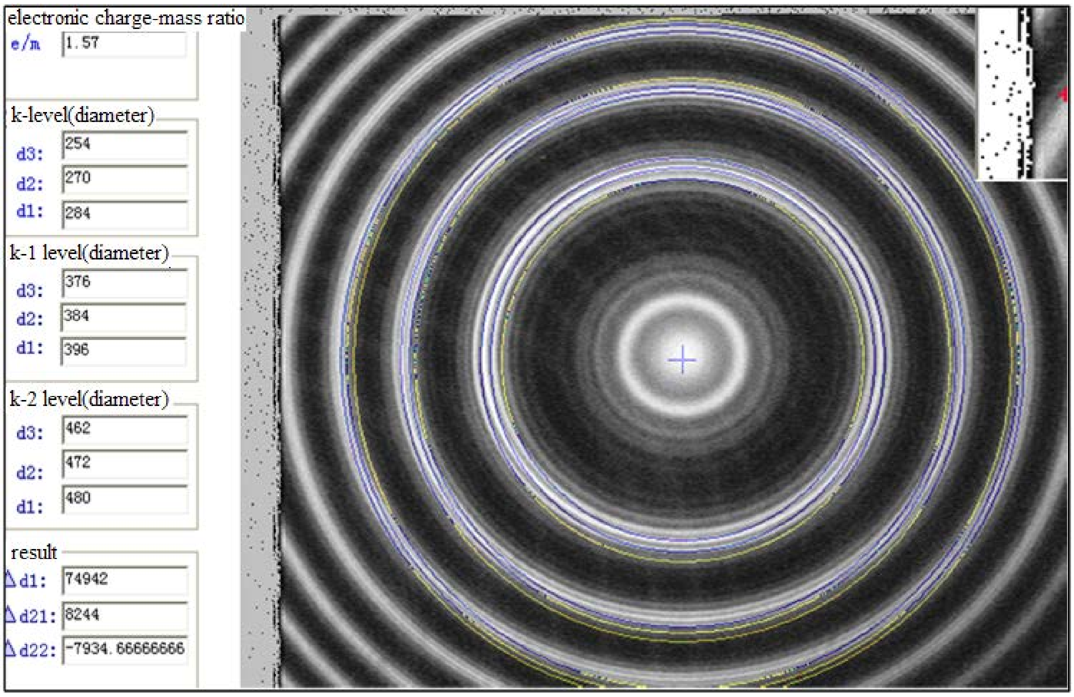


Figure 5: The image processing software for a Zeeman-effect experiment.

CONCLUSIONS

Creative education has shown that as long as teachers adhere consistently to innovation education in university physics teaching, in the end, it is possible to awake students' awareness of innovation. Of course, the reform is difficult [8]. It takes ten years to grow a tree and 100 years to create a cohesive legion of societal people. Changing educational concept is more of a long-term strategy, and whether it is successful is determined by many factors and does not produce immediate results. However, no-one should stand still, and more cannot be done than is being done. The educator has the responsibility in teaching a physics course to implement and explore all educational ideas that may stimulate students' creativity. As the creative mind is formed in students, so will their initiative and innovative thinking.

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