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Learning Difficulties in Theoretical Physics and Teaching Reform Strategies

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Abstract

Theoretical physics is an important subject in physics. The major goal of theoretical physics courses is to help students learn to think like a physicist. The theoretical physics curriculum mainly includes theoretical mechanics, electrodynamics, thermodynamics and statistical physics, and quantum mechanics. These courses play an important role in cultivating students' physics literacy. There are many difficulties in the learning process of theoretical physics, such as the lack of motivation and goals, negative influence of pre-scientific concepts, cognitive impairment of learning and mathematical learning disability. Teachers should use effective teaching strategies to help students to overcome learning difficulties.

Keywords: theoretical physics, learning difficulties, teaching strategy

1. Introduction

Most of the physics taught in school can be described as well-established or consensus science (Hansson, Leden, & Pendrill, 2019). Helping students learn to "think like a physicist" is a major goal of many physics courses from the introductory to the advanced levels (Singh & Marshman, 2015). It is the source of many high-techs and is the forerunner of new discoveries in the field of physics (Djorwe, Pennec, & Djafari-Rouhani, 2019; Jon, 2019; Lee & Park, 2019; Sun, He, Hao, Xiao, & Zhou, 2019; van Dam et al., 2019; D. Wang & Xia, 2019; Z. Wang, Zhang, Baladron-Zorita, Hellmann, & Wyrowski, 2019; Xiaopeng & Liu, 2016; Zang, Tarafdar, Tarasevich, Dutta Choudhury, & Dutta, 2019; Zhang, 2019). Theoretical physics is an important course for physics majors in higher education institutions. The curriculum in theoretical physics mainly includes theoretical mechanics, electrodynamics, thermodynamics and statistical physics, and quantum mechanics, which are commonly known as "four major mechanics" in China. These are extremely important professional foundation courses for physics undergraduates (T. Liu & Sun, 2010).

As these four courses in theoretical physics are difficult for physics majors, the teaching outcomes are not always positive. In today's information age, a teaching reform in theoretical physics seems imperative. At present, domestic and foreign universities are conducting trials and research on the teaching reform of theoretical physics. Dehui Hu et al. investigated high-level, goal driven mathematical problem-solving activities that are found within physical science research labs in academia and photonics workplaces in the industry, and employed epistemic games to guide physics education (D. Hu et al., 2019). Shabnam Siddiqui and Chandralekha Singh discussed the findings from a survey in which 12 university faculty members reflected on various issues related to undergraduate-level quantum mechanics teaching and learning (Siddiqui & Singh, 2017).

For the undergraduate major in physics, theoretical physics courses not only provide knowledge reserves for future middle school physics teachers, but more importantly, enable them to understand middle school physics textbooks from the height of theoretical physics. Therefore, the ability to grasp the basic principles and content of theoretical physics is compulsory for physics majors in college (Hansson et al., 2019; C. Liu & Dong, 2019). In teaching thermodynamics and statistical physics, teachers use micro-courses, mind maps and big data statistics to train students to analyze and compare physical phenomena related to physical thermal motion, so as to accurately summarize physical concepts and laws and solve practical problems. Through the teaching reform, college students' ability in comprehensive analysis and logical reasoning will be developed (Ta, Wang, & CHeng, 2019). Fangxia Guo et al. used the comprehensive quality scale, Colorado Learning Attitude about Science

Survey, e-learning self-efficacy scale and deep learning scale to study the influence of a flipped classroom on learners' key competencies in an electrodynamics course (Guo, Liu, Li, & Wang, 2019). Drawing on many years of experience in teaching electrodynamics, Yaohua Hu et al. analyzed and summarized the reasons for a lack of motivation; and put forward some effective measures to mobilize students' learning enthusiasm (Y. Hu, Han, & Yao, 2018).

Therefore, for students, the study of theoretical physics is a challenging task. Every can admit that physics is difficult for students to learn, and difficult for teachers to teach. However this dilemma is not entirely caused by the abstraction, complexity and esotericism of the subject itself. From our own perspective, we will explore the deficiencies, cognitive errors and learning habits of students in theoretical physics; whether there is disconnection between the teacher and students' knowledge acceptance, and whether there are many drawbacks in the teaching ideas and methods (Euler, Rådahl, & Gregorcic, 2019). This article will focus on these issues to explore the learning difficulties and teaching strategies in theoretical physics.

2. Learning Difficulties in Theoretical Physics

2.1 Students' Learning Goals Are Not Clear, Lacking Perseverance

In middle school, students have clear learning goals; that is, they must achieve excellent results on the college entrance examination and enter their ideal university or major. Under the spur and encouragement of this learning goal, students generally have high self-awareness during the learning process and study very hard. Students are also used to this learning style and study habits. However, after entering the university, the situation undergoes fundamental changes. University study is mainly based on self-directed learning, which causes many students to have no clear learning goals for a long time after entering the school. During such a relatively confusing period, many students are suspicious about "the use of learning theoretical physics." Therefore, when it comes to studying important courses in theoretical physics, such a negatively free mentality directly affects their motivation.

However, theoretical physics is an extremely important part of the learning process for students majoring in physics, and is a necessary step for laying a foundation for future study and research. As such, a clear learning goal should be established when learning theoretical physics.

2.2 Negative Influence of Pre-Scientific Concepts

Conceptions and misconceptions have become an important part of learning in physics. Understanding both is important in learning physics, because it affects the overall understanding of the physics (Cari, Suparmi, & Handhika, 2016).

Due to the ubiquity of physical phenomena, students learn basic physics knowledge with Newtonian mechanics as the core before learning theoretical physics. Physics education in middle school is relatively simplistic, which causes many students to fail to change their middle school learning habits before they move on to study theoretical physics after entering university, and the wrong learning habits and learning styles are formed instead. Moreover, the difficulty of the various courses in theoretical physics is relatively significant, and the difference between these previous learning in physics courses is large. Many students fail to adjust their learning methods in time. These wrong habits become obstacles to learning.

The obstacles to effective theoretical physics learning can be summarized in three main aspects: mental set, dependence psychology and irritability.

A mental set a preconceived way of thinking, as mentioned above. People's mental set when analyzing and thinking about problems always makes them willing to believe in the content that has been habitually and procedurally accepted for a long time. During the long-term study of physics courses (long-term physics study in secondary school and a long period university of physics), students form a more stable way of thinking and answering ideas. This mental set (way of thinking) causes students' to develop their thinking toward a fixed mode; therefore, improvement in the ability to accept new knowledge increases slowly, and the ability to analyze and solve problems declines.

Dependence psychology mainly refers to students' dependence on teaching materials and teachers, which lacks a spirit of active research and exploration. When students encounter problems, they passively rely on teachers' explanations and no not develop the ability to actively discover, analyze and solve problems. At the same time, the lack of observation and thinking abilities makes it difficult for students to improve their learning interests and hobbies. What is worse, it is difficult to mobilize students' enthusiasm for learning.

Irritability refers to the resistance psychology of students to the physics major. Some students are not lovers of

physics. They are not interested in learning physics, they have no clear learning goals after entering the university, and they are in a state of confusion. As such, they are not enthusiastic about physics courses and their consciousness of learning is not sufficient.

2.3 Cognitive Impairment of Learning

Cognitive impairment has devastating effects on individuals, caregivers, and society (Na, 2019). During the learning process, some cognitive behaviors of students will cause certain difficulties and obstacles in the learning process. The psychological factors that result in these bad behaviors are roughly: (1) Wrong ideas—they lack a clear understanding of university life and the social life that they will face in the future, and their life attitude stays in a negative state. (2) Abnormal emotional performance—the habits of impatience, impulsiveness, and hot temper due to the influence of the family environment and the growing environment will be reflected in the learning habits of impetuous learning, difficulty in focusing and other bad habits, which can seriously affect their efficiency during the learning process; and (3) An obvious weak will—the weak will is generally seen in the primary and secondary schools. This phenomenon is seen less often in college students; however, there are a few students who have weak wills and cannot withstand the influence and temptation of negative factors in the real environment.

2.4 Mathematical Learning Disability

2.4.1 Mathematical Learning Disability Formed by Weak Mathematical Knowledge

One of the perennial mysteries of theoretical physics is why the laws of physics should so often have an elegant mathematical formulation a circumstance often referred to as the "unreasonable effectiveness of mathematics" (Chapline, 1999). Theoretical physics is more dependent on mathematical knowledge, especially advanced mathematics, than college physics courses for non-physics majors and middle school physics courses are. Mathematical ability is particularly important in learning theoretical physics.

Theoretical physics is closely related to much of the knowledge in advanced mathematics, and many physical concepts and formulas are expressed in mathematical form. Some students encounter hidden dangers in the process of learning advanced mathematics. When it comes to studying courses in theoretical mechanics and electrodynamics, they find it difficult to understand and remember many mathematical concepts, and this has an adverse impact on curriculum learning. For example, the course Mathematical Methods for Physicists, which is taken by physics majors, is an essential basic course and an important hub for courses in advanced mathematics and physics. Physics is based on mathematics as a language. Theoretical physics has a high requirement for advanced mathematics as well; thus, students need to have a solid foundation in advanced mathematics (Galili, 2018).

2.4.2 Learning Difficulties in Failure to Use Mathematics Knowledge Effectively

As a simple example, the definition of work can be expressed by a vector scalar product, and the characteristics of conservative force can be clearly expressed by a circuit integral. These simple mathematical formulas imply profound physical meanings, and the derivation process of the relevant formulas interprets the meaning of the final formulas. However, due to insufficient learning time, slow progress, and obstacles in the mathematics foundation, many students remember the mathematical expressions of the laws of physics, without understanding the real physical meaning behind the formulas, aware of one aspect but ignorant of the other. When encountering related physics problems, they fail to establish an effective physical model, or solve physics problems with mathematical ideas.

3. Teaching Strategies to Overcome Learning Difficulties in Theoretical Physics

In the teaching process, teachers can adopt various effective teaching strategies to overcome the above learning difficulties and obstacles.

3.1 Establish Motivational Learning Goals

Moving from secondary school to university is a major turning point for college freshmen. College students should establish their own learning goals as early as possible. A Learning goal is a dynamic, long-term plan, which should be adjusted correctly and in a timely manner as the environment changes.

A college student should establish the correct learning goals and life goals at the moment of stepping into the university. As a development platform to improve their level and ability, college students should adjust their mentality needed to cope with the surprises and challenges of university life.

Based on the environment, students who major in physics should improve their learning styles and living habits, increase their learning efficiency, and thereby enhance their interest in a professional knowledge of theoretical

physics to strengthen their self-confidence in learning physics and to form a benign circle, which can greatly improve learning efficiency and learning outcomes.

3.2 Exploring Solutions to Mental Impairments

To guide students in overcoming the mental obstacles in theoretical physics learning, first of all, we should improve the attractiveness of the teaching process and insist on self-fulfilling the "four emphases" for students to enjoy the learning process. The "four emphases" refer to: the reality, the foundation, the process, and the methods (Li, 2010).

(1) Recognizing the importance of theoretical physics

Theoretical physics is an important part of physics knowledge structure. As a student of physics, the main work direction after graduation is to teach and educate people as a physics teacher. Therefore, students should build a solid foundation in physics during university study. The courses in theory for physics majors are meant to improve their knowledge of physics. Students should be able to recognize the practical significance of theoretical physics learning and correct their own learning attitudes.

(2) Emphasis on the foundation

Theoretical physics itself is difficult to learn. Therefore, it is more important to emphasize the study of basic content for students to build a solid foundation at the beginning of learning, thus breaking through the key points and difficulties and ensuring that they understand the content. The emphasis on foundation can effectively improve students' interest and enthusiasm for learning.

(3) Actively adjust the mood during the learning process

As the difficulty of learning increases, students may experience greater psychological fluctuations during the learning process, such as irritability and the desire to give up learning. When such a phenomenon occurs, it is necessary for students to adjust their mentality, and communicate with classmates or teachers in time, to overcome the current learning problems or psychological difficulties, instead of passively giving up, thereby entering a vicious circle.

(4) Master the theoretical physics learning method

The learning method of theoretical physics in universities is totally different from the learning method in middle school. When students study theoretical physics following the learning method of secondary school from the very beginning, they will feel uncomfortable and will not be able to achieve a high learning efficiency. When this happens, do not be impatient or passive. Take the initiative to find a learning method that is more suitable for the current academic study, actively communicate with the teacher for help, and strengthen the ability to learn independently so as to find a way to achieve learning with less effort.

3.3 Improve Cognitive Behaviors

Bad behaviors in learning will have a great adverse impact on future college students' postgraduate tests, study, and work. Students should correct these behaviors in the early stages of learning.

(1) Cultivate correct ideas

Due to the lack of correct thoughts and ideas and the failure to correctly understand the ideology of theoretical physics, some students may make mistakes in cognition. At this point, the teacher should communicate with the students so that they can fall in love with theoretical physics through the teacher's guidance.

(2) Cultivate students' learning emotions and eliminate negative emotions

Students with negative learning attitudes have similar problems in other aspects, such as making friends and taking part in community activities. Helping them to improve their socializing ability can thereby eliminate overall negative attitudes and change their learning attitudes.

(3) Develop good learning habits

After entering university life, students' living environment changes greatly, and they are exposed to more new things. At the same time, students are more likely to be affected by a bad atmosphere in the society, thereby ruining the good experiences of learning. College students should have the ability to distinguish between right and wrong, use self-monitoring and self-adjustment, and take a serious and positive attitude in professional courses.

3.4 Proficiency in Advanced Mathematic

Mathematics is an important tool for studying and researching physical science and is a language for expressing

physical phenomena. Therefore, mathematics is an important part of physics education. The study of theoretical physics requires a solid foundation in advanced mathematics, which is understandable. A good foundation in advanced mathematics can have a multiplier effect on theoretical physics.

When students have a good mathematical foundation, they can relate to the relevant content of theoretical physics. For example, they can grasp the physics meaning of the formula itself through the derivation process when using mathematical means to derive physical formulas, and establish smooth correlation between the mathematical formulas and physical meaning.

Students with good mathematical ability can actively study advanced mathematics while learning theoretical physics, to make full use of spare time in solving theoretical physics problems. While improving the level of mathematics, students must pay attention to the connection between mathematics and theoretical physics, and learn to reflect the essence of physics phenomena through mathematical derivation.

4. Conclusions

As an extension of general physics, theoretical physics is important. The theoretical physics courses play a vital role in cultivating students' physics and scientific literacy. College students majoring in physics will encounter various difficulties in the learning process, such as the lack of motivation and goals, negative influence of pre-scientific concepts, cognitive impairment of learning, and mathematical learning disability. Teachers can adopt various effective teaching strategies to overcome the above learning difficulties and obstacles. Teachers can also use various effective methods to stimulate students' learning interest, cultivate students' ability to use mathematics knowledge to solve physics problems, and help students to overcome learning difficulties and improve their academic achievements.

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