Challenges of Physics Education in China, A Perspective of Lab Performance

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Abstract. This paper includes the analysis of Chinese undergraduate students' performance in the field of physics study. Based on the data collected from a survey inquiring the high school students in Beijing about their lab study circumstances, this analysis offers a potential reason for Chinese university students' strong theoretical ability but poor manual dexterity. The result shows that compared with other educational systems, the experiment time for Chinese high school students is generally shorter. In addition, the format of experiments is also inflexible in the way students have to follow their teachers instead of designing their own experiments. In students' opinion, they would like to do more physics experiments since those can stimulate their interests in physics so they are motivated to learn more. However, proper experiments for Chinese high school students are still an issue waiting for an investigation.

Keywords: Lab Study; Physics; High School; Gaokao; Education.

1. Introduction

Higher education is always considered the most difficult stage of formal learning. While secondary education is to learn introductory knowledge and develop interests, higher education is to learn how to learn and think independently, creatively, and critically. More than a subset in the educational system, higher education provides highly-qualified intellectuals for the modern industrialized society [1]. One of the main ways of admission to undergraduate programs in college or university is through examination.

Similar to SAT® and ACT® in America, National College Entrance Examination (NCEE), with its Chinese name Gaokao, has been commonly used for students to enroll in a university in China. Reestablished in 1977, one year after the Great Cultural Revolution in China, Gaokao has existed for forty-five years since then. There are 24944529 high school students in China in 2020, which is a tremendously large number. Among these high school students, 7831965 students, almost 31.3 percent of the whole, are in their senior year, which means nearly one-third of those students will take Gaokao and graduate from senior high school [2]. As expected, there will be 4431154 senior students entering the undergraduate education program (shown in figure 1), which is about 27.9% of the number of undergraduates worldwide (about 15.9 million people in 2020) [3], which is a significant figure in the world's higher education system.

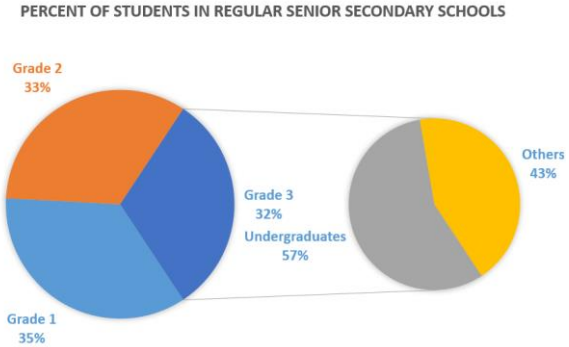

Fig. 1 Percent of Students in Regular Senior Secondary Schools

Of all the undergraduate colleges in China, including Agriculture, Normal School, Language & Literature, and the other nine distinctive fields, the Polytechnic is the most favorable choice for Chinese high school graduates, taking up 31.0% of the potential undergraduates (shown in figure 2). From this segmentation, a conclusion can be drawn that science study attaches great importance to the education system in China [4].

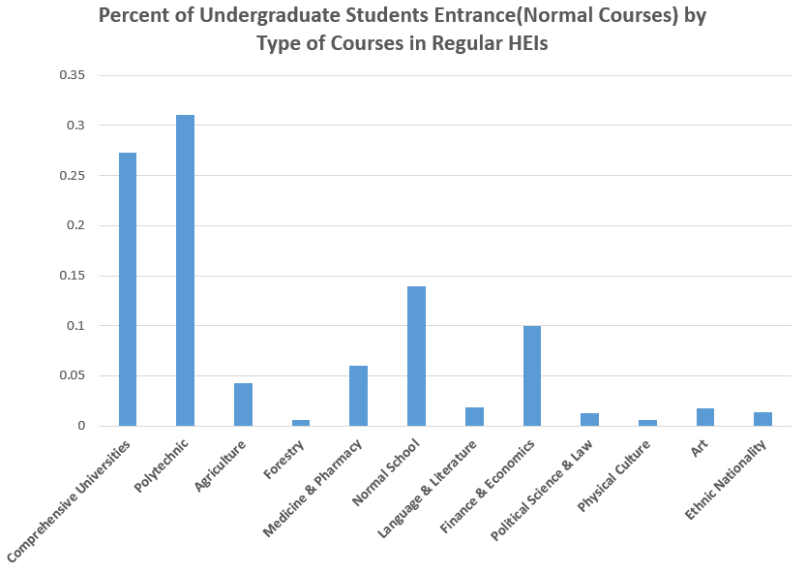

Fig. 2 Percent of Undergraduate Students Entrance (Normal Courses) by Type of Courses in Regular HEIs

The research conducted by Jianlan Wang discovered that Gaokao has no direct impact on the promotion of students' affective learning in physics. Some factors such as the internal engine of learning or the rewarding system may be useful in soothing the external pressure from Gaokao. However, it does not provide a more specific explanation for the potential reasons behind this effect [5].

This paper is going to investigate the influence of experimental physics on students' academic performance before and after Gaokao. The convenience sampling method is used to survey students in eleven different high schools in Beijing to collect information about the experimental study in one of the basic science subjects-physics. Students were asked to Then, the data will be integrated and analyzed to connect the potential undergraduate performance in the field of physics study to their frequency of experiments in high school. The result of this analysis would be used to adjust the policy which encourages the improvement of students' comprehensive ability, bringing the same effect as the Compulsory Education Labor Curriculum Standards (2022 Edition) released on 25th March 2022 [6].

2. Preparation for the Research

2.1. Method of Sampling

This paper collects data through convenience sampling. Convenience sampling is an uneven sampling in which the target subjects are easy to access. More specifically, it is in the category of self-selection sampling. The advantages of this type of sampling method are its short time for collecting the necessary answers and its improvement in providing more insight into the research. However, it may lead to potential intrinsic bias and inaccurate representation of the whole population [7]. Despite these defects, convenience sampling is still reliable for analysis in the local area. Therefore, convenience sampling is chosen for the sampling method.

2.2. Preparation for Survey

The survey application is powered by www.wjx.cn. The survey "Questionnaire Survey on Physics Experiment of Senior High School Students" basically includes four parts: basic information, course investigation (physics major), course investigation (non-physics major), and overall feedback. The subject only needs to answer three of the four sections. The "Basic Information" is necessary and includes what and where is the subject's school, which course system (AP, A Level, for example) is subject in, and whether the subject is in physics major or not. Depending on the choice made in the physics major question, the subject tends to answer one of the course investigation sections. This part consists of some fundamental information about the laboratory's physics study, such as how long or how often. The last part is about the subject's feelings towards the laboratory study: whether it is helpful for the current study and the undergraduate physics study. The questionnaire is sent out through WeChat Moments, which is a voluntary response survey. It will last for two weeks from 13 September 2022 to 27 September 2022.

2.3. Sample Chosen Reasons

Figure 3 shows the average daily active users (DAUs) of China's top ten most popular social media websites in 2018. The delivery method is through WeChat Moments since, in China, WeChat is the most prevailing chatting platform, owning almost 619.6 million average daily active users by the end of 2018 [8].

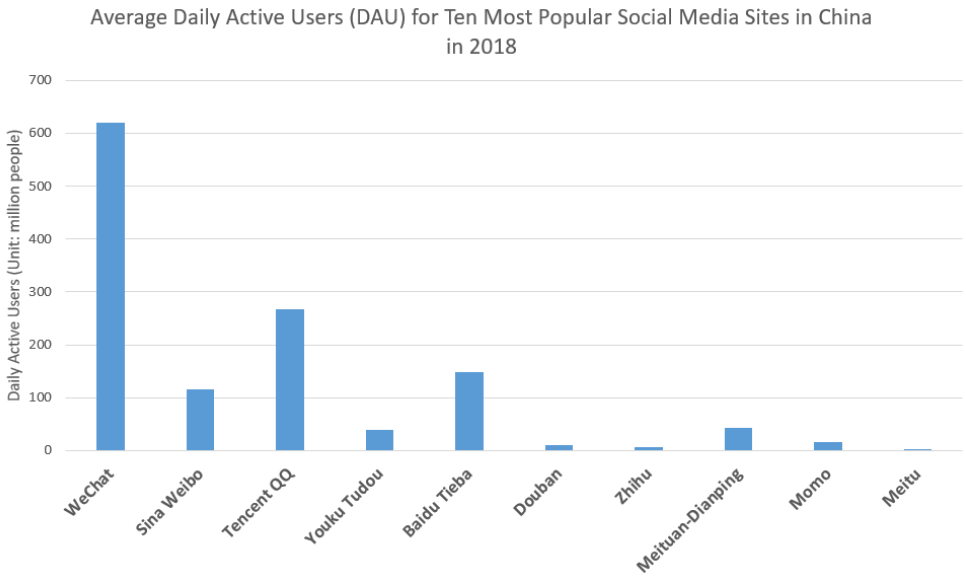

Fig. 3 Average Daily Active Users (DAU) for Ten Most Popular Social Media Sites in China in 2018

Among all the users, nearly 33.5% are under the age of twenty-four, which is the period of high school students and undergraduates [9].

Because of the popularity of WeChat in the Chinese student population, it is a comparatively comprehensive way of delivering the sampling questionnaire, which is more likely to accurately represent the whole population. The sample collection's scope is Beijing, China's capital city. According to the Seventh National Population Census in China, Beijing contains the highest number of undergraduates or higher degrees per one hundred thousand citizens, which is approximately 2.7 times the average level, and the third highest of high school students. Figure 4 shows the distribution of WeChat users by age group. Figure 5 shows the ten cities with the largest number of college students per 100000 population in China in 2020.

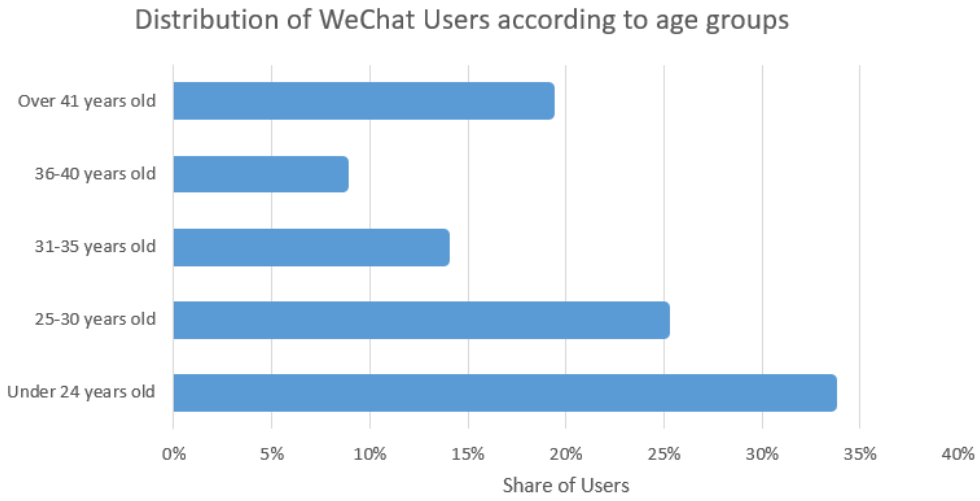

Fig. 4 Distribution of WeChat Users according to age groups

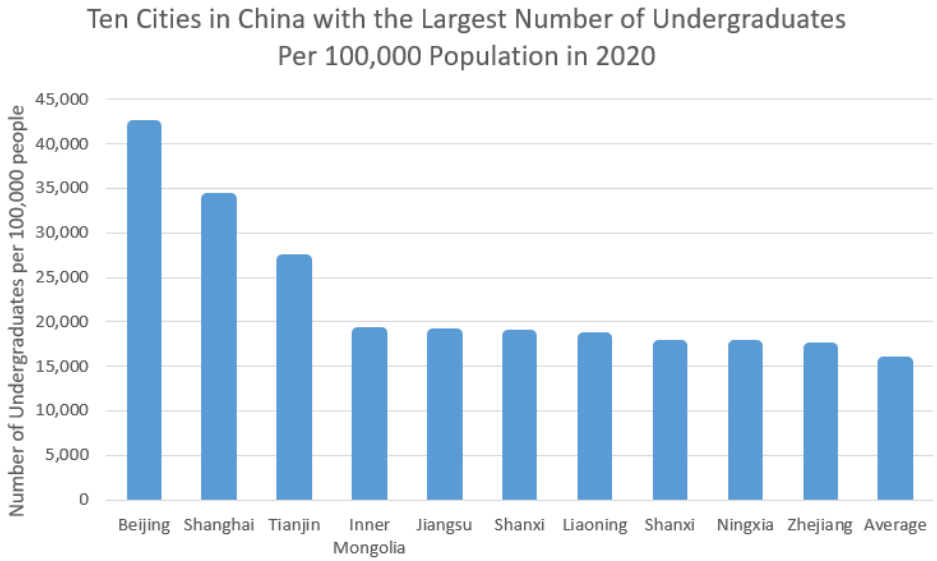

Fig. 5 Ten Cities in China with the Largest Number of Undergraduates Per 100,000 Population in 2020

Besides, it is also the city with the longest years of education, which is 3 years longer than the average time [10].

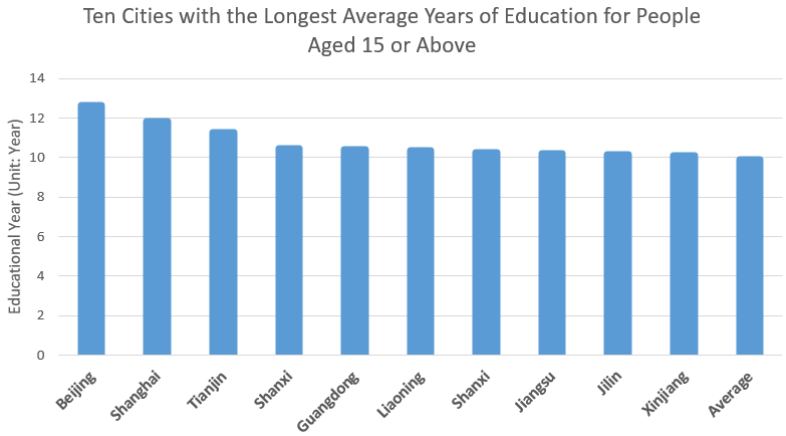

Fig. 6 Ten Cities with the Longest Average Years of Education for People Aged 15 or above in 2020

Figure 6 shows the ten cities with the longest average years of education for people over 15 in 2020. Therefore, Beijing tends to represent the most educational province in China, which is an ideal place for sampling. It provides the most excellent learning environment and the strongest faculty. If Beijing cannot offer the most direct connection between laboratory study and undergraduate physics performance, it can be generalized that other provinces that own weaker educational resources are also not able to provide convincing evidence.

3. Sampling Data and Analysis

3.1. Analysis Model

The reliability and validity of sampling data collected from the questionnaire will be testified by Cronbach's alpha and factor analysis, separately. Cronbach's alpha, typically a number between 0 and 1, was to determine the internal consistency of a questionnaire [11]. Factor analysis is used for measuring how underlying relationships affect the answers to several variables [12]. With the credibility and validity examination, the accuracy of this questionnaire can be guaranteed to some extent. Therefore, it is more likely to be generalized to a greater scale of the population.

3.2. Reliability and Validity Test

The reliability and validity testification platform are powered by spssau.com [13]. For reliability, every multiple-choice question and every sampling answer are selected. The resulting Cronbach's alpha constant is 0.921. Generally, it is at the interval of high-reliability quality (equal to or greater than 0.9). For validity, the factor analysis is conducted in two parts-course investigations (physics major and non-physics major). Concerning the course investigations, the result of the Kaiser–Meyer–Olkin test and Bartlett's test is 0.823 and 0.783, which is slightly higher and lower than the degree that implies excellent validity and is suitable for extracting information, respectively. In generalization, the sampling data collected in the questionnaire is convincing and can act as a solid source to analyze the undergraduate physics study performance.

3.3. Sampling Data

In the two-week questionnaire delivery, sixty-three answer sheets were received. Fifty-four out of sixty-three answers are valid and effective. Among all the useful answers, they include fifty-four senior high school students from eleven different schools in five districts in Beijing. Exactly 50% of students are in the Chinese educational system, which means they are going to take Gaokao in 2022. Other students enroll in different course systems such as A Level, Advanced Placement, or International Baccalaureate (shown in figure 7). Fifteen subjects are going to take physics as a major in university or college while thirty-nine subjects are not.

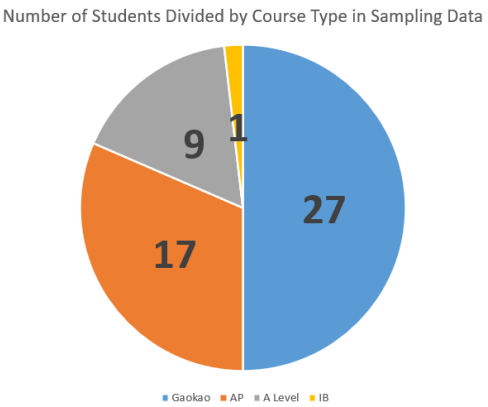

Fig. 7 Number of Students Divided by Course Type in Sampling Data

As for the physics-major students, only one out of fifteen students answers that he or she has fixed experiment classes (one-to-two class hours) every week while all fifteen students except one have more than five physics classes weekly, which indicates the lack of experiment section regularly for even the physics-major students. Nearly 98.1% of students confirm that their high school owns one specific and professional physics laboratory. Only three of those students have not experienced any physics experiments. The reasons for the lack of experiments are the intense course schedule and outdated facilities. There is one interesting exception that the one subject without an official physics laboratory still conducted experiments in his previous study, which implies the importance of experiments in physics since a theory must be proved experimentally to enter the book of knowledge [14]. In most cases, teachers are likely to experiment in class at the start or the middle of the course (shown in figure 8).

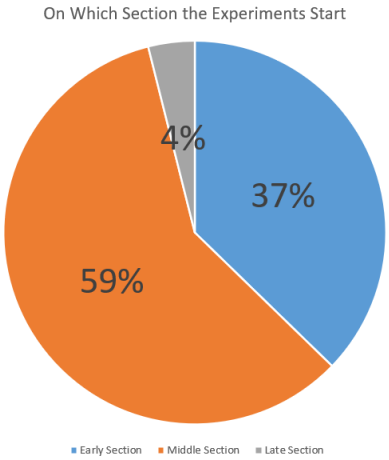

Fig. 8 On Which Section of the Experiments Start

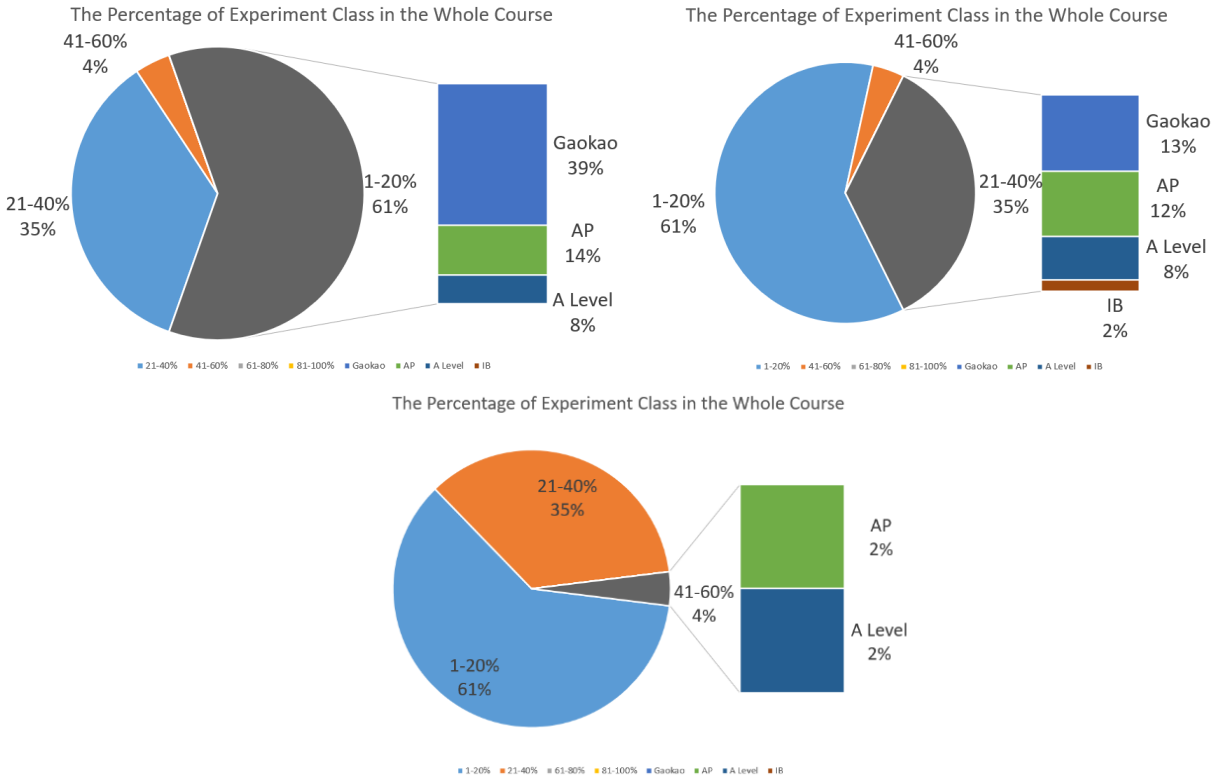

Fig. 9 The Percentage of Experiment Class in the Whole Course

This may connect to the teaching style of each instructor such as starting a section with an experiment or consolidating knowledge with an experiment. However, one issue is that almost a few teachers carry out experiments in the late stage, which implies that doable experiments are scarce

after mastering the knowledge. The duration of experiments is concentrated in 1% to 20% and 21% to 40% of the whole course. Based on the curriculum standards in China [15], the experimental class hour should be 20 out of 144, about 13.8% of the whole class. According to the A Level Physics syllabus and the AP Physics 1: Algebra-Based Course Overview [16-17], the weighting of the experimental part is 23% and 25%, respectively, which is almost twofold the standard in China. This trend is also shown in the subjects' responses: students who are in the foreign educational system are more likely to have experiment classes (shown in figure 9).

Furthermore, the syllabus of Gaokao indicates that Mechanics, Electromagnetism, and Thermodynamics are three necessary experiment sections during the instruction. Most subjects respond that they have done the Mechanics and Electromagnetism experiments but only 27% of them have conducted the Thermodynamics experiment such as Estimation of Oleic Acid Molecular Size by Oil Film Method (shown in figure 10). This implies inadequate attention toward Thermodynamics study.

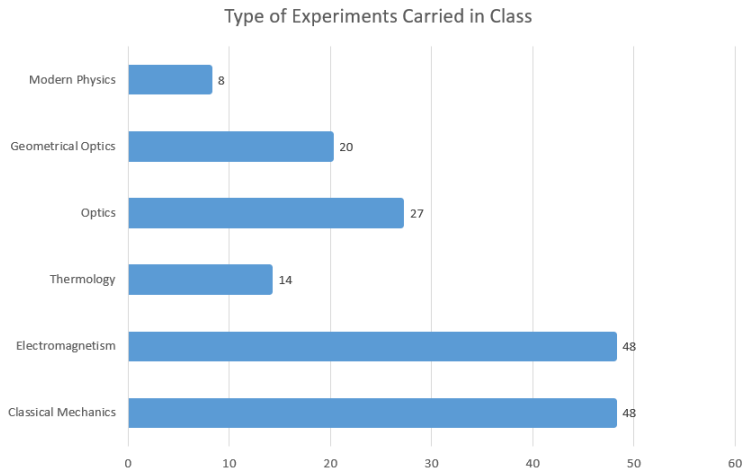

Fig. 10 Type of Experiments Carried in Class

As for the forms of experimentation, there are three main formats and they take up nearly equivalent places: follow the teacher's example, operate by themselves, and corporate with classmates. Nonetheless, the teacher's illustration is the comparatively dominant method, which lacks students' active involvement (shown in figure 11).

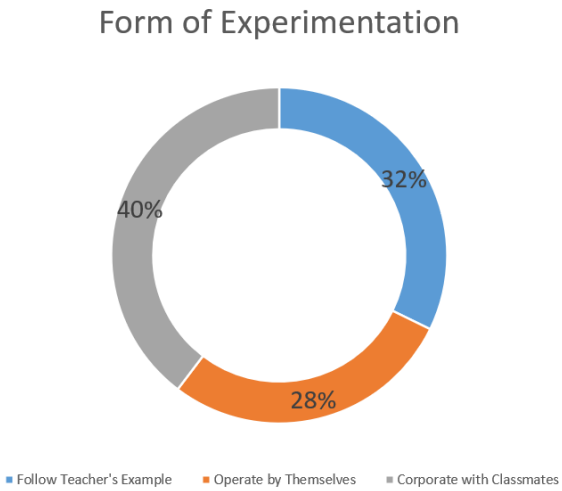

Fig. 11 Form of Experimentation

Then the fifteen physics-major subjects are asked to answer whether they can conduct an experiment by themselves. Ten out of fifteen students think that they are able to finish an experiment independently due to the experimental classes, rich resources, and abundant personal experience. The other five students believe they cannot because of their unskilled operation and poor experience.

The next section in the questionnaire collects information about the help of experiments in the physics study. Among physics-major students, the main approach to learning physics is following the teacher, teaching themselves, and doing exercises. The role of experiments in the learning process is less significant than the others since only half of the students consider the experiments as their main method of studying physics (shown in figure 12).

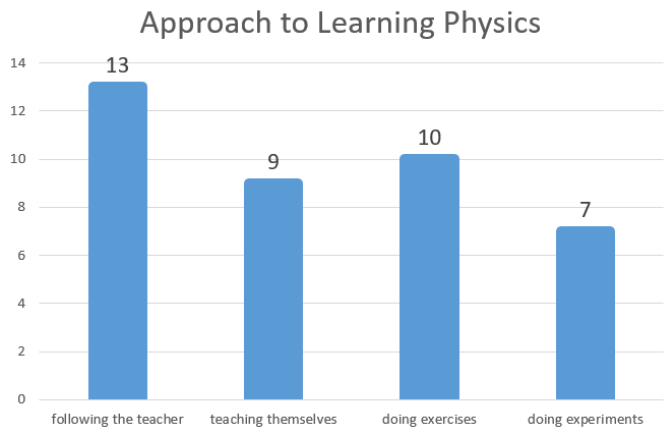

Fig. 12 Approach to Learning Physics

Moreover, from the subject's perspective, the current learning system tends to assist them in theoretical learning and knowledge network construction. This implies that when entering undergraduate, they are more likely to solve theoretical problems instead of utilizing the knowledge in reality. The majority of subjects think that experiments can aid them in the current study of physics and are willing to add more experiments classes to the schedule (shown in figures 13 and 14).

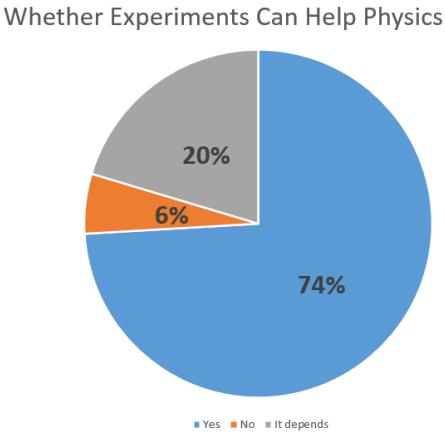

Fig. 13 Whether Experiments Can Help Physics Study

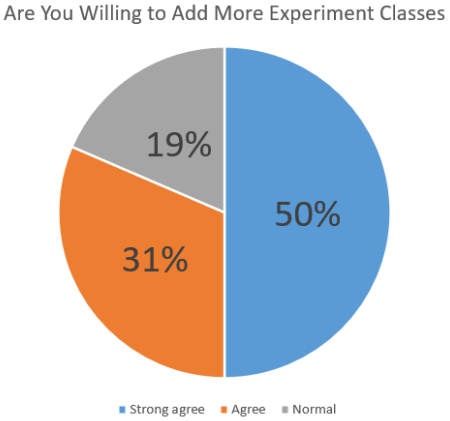

Fig. 14 Are You Willing to Add More Experiment Classes

The key factors pushing students to have more experiments are the interesting process, a better understanding of abstract knowledge, and personal involvement. They believe the experiment experience can help them visually memorize the knowledge, prepare for physics study as undergraduates, explore the theoretical science in reality, and, most importantly, be affected by the happiness of operating on their own. However, some people have no feelings towards the experiments partially because they have poor skill in carrying out experiments and have no affection for physics. In addition, when asked whether they are willing to experiment at home, most subjects respond that they have inadequate skills, especially without instructions from teachers. Besides, the equipment is also too expensive and impractical to use at home. Some students think they should spend more time doing exercises instead. All the responses indicate one phenomenon the majority of high school students pay more attention to theoretical study and less attention to utilizing theories in daily life.

4. Data Interpretation

4.1. Potential Trend in Theoretical Physics

According to the comparison of different educational systems, there is no statistically significant alignment between learning resources and the final test for Chinese. This is partly because of a shift in learning abilities from the coursework to the examination such as Gaokao [18]. Therefore, due to the high-stakes testing, Students devote most of their time to practicing and doing exercises for the exams, which shapes their proficiency skills in earning scores and theoretical study rather than implementing the knowledge in real life. Besides, Chinese physics is Subject Matter Knowledge, which means the score is the standard of assessment. This orientation drives students to care more about memorizing theories and to overshadow other necessary constitutions of physics, like scientific attitudes and experimental capacity [19].

The determinant of this potential trend is the significance of Gaokao in China. Compared to university admission in China, admissions in the United States are not based on a single test that takes into account the entire profile of a student. Instead, students have to develop comprehensive qualities, which makes them all-rounded students [20]. In China, the score of Gaokao is so predominant that it requires students to devote all their effort to cultivating highly concentrated talent in dealing with theoretical problems. Unless experimental studies can be proven to improve the academic score in Gaokao, there will not be any educational renovations. Nevertheless, this educational format can lay a solid foundation of theoretical knowledge for students, which will help them absorb abstract theories in university quickly. The data collected from pre- and post-high school physics classes shows that first-year students in college generally perform better than high-school students do [5]. As a result, whether this typical educational system provides more or less for students is likely to remain debatable in university.

4.2. Potential Results for the Experimental Study

From the questionnaire, a conclusion can be drawn that most high school physics courses in China can meet the standard of the syllabus. However, generally, the time is shorter than the average experiment duration of educational systems in America and England, which is an obstacle to the development of manual dexterity (shown in figure 9). Additionally, how does the experiment carry out also plays an important role in students' physics identity. Most students follow their teachers to experiment; this is called cookbook teaching, a kind of teaching technique in which all steps are predetermined and all need to be done is to follow the guide. Another popular technique is Inquiry-Based Teaching which requires students to design and carry out their experiments. In a paper published by Shi Weizhao in 2020, students in conventional lab classes usually have negative knowledge views while students in the method mentioned above tend to have better performance [21]. This study provides future improvements to the experimental setup during the instruction.

Another key format of an experiment is a collaboration among students. Peer instruction also offers a deep insight into the importance of corporation-collaborative students, especially with constantly

changing peers, are more likely to change in the positive direction of attitudes and beliefs than solo students [21]. Thus, the corporation part should remain significant in the experimental study for it will cultivate the attitude of participants towards physics [22-23].

5. Conclusion

According to the data collected through questionnaires, the development of experiments is appropriate but still not enough. In comparison with the system in other countries, the time and variety of experiments are fairly short of importance. Consequently, it reveals a common problem for Chinese students: when they have to solve the actual issues, they are at a loss for what to do at first. Instead, with a few instructions, they can finish the task smoothly. As for the extrinsic factor influencing the affection of students, through the investigation of students' willingness, experiments tend to be useful in stimulating the desire to learn physics since most students want to add more experiments in their class no matter whether they will study physics in university or not. But this investigation has several defects such as low sample capacity and variety. The future study may concern how the design of experiments can help students actually improve their academic scores in Gaokao and how many experiments are appropriate for the current Chinese education.

Since the foundation of China, Curriculum Reform has been implemented. In 2003, the New Curriculum Reform, one of the most significant educational innovations, was put into effort. New standards for fifteen subjects have been enacted for high schools in some areas of China. The consequence of the reform is prominent: considerable progress has been made with respect to theoretical study; however, there is no significant improvement with regard to scientific literacy cultivation. In other words, the level of theoretical skills was improved while the operational ability was neglected. The Curriculum Scheme and Curriculum Standards of Various Disciplines for Ordinary High Schools published in 2017 stipulates a series of required experiments in physics, chemistry, biology, and other subjects, requiring the school to encourage students to do experiments as much as possible. This reform attaches importance to training students' experimental skills and improves students' core scientific literacy. Every time the national meeting is held, the administrative department will answer questions about strengthening the experiments in elementary school and high school. This phenomenon indicates the central government starts to pay attention to the role of experiments in basic education and promotes students to apply what they learn in class to their daily life. Although this idea is prevailing and promoted annually, the implementation of specific details, which requires the corporation between the administration and school board, is untraceable. Therefore, the actual result of this approach is uncertain and waiting for verification. After all, the future of the prevalence of experiments is bright but ambiguous.

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