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# Gender Differences of Theoretical Physics of Undergraduates Major in Physics

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**Abstract**

Gender differences exist in the disciplines of science, technology, engineering and math. There are differences between male and female undergraduates in the learning of various subjects. This paper analyzed the gender differences caused by intellectual and non-intellectual factors, such as math ability, verbal ability, spatial capability, learning motivation, learning interest, and learning attitude. On the base of the scores of theoretical physics, we analyzed the gender differences of undergraduates major in physics, and put forward teaching strategies for the improvement of theoretical physics.

**Keywords**: gender differences, undergraduates, theoretical physics, teaching strategy

## 1. Introduction

It is a well-documented fact that the disciplines of science, technology, engineering and math (STEM) are pre-dominated by male students (Islam Dip, 2017; Steegh, Höffler, Keller, & Parchmann, 2019). In the past few decades, studying issues of gender in physics has been a topic of concern in the physics education community (Barthelemy, Van Dusen, & Henderson, 2015; Brewe & Sawtelle, 2016; Dam-o, Gondek, Karbowiak, & Wibig, 2018; Gee, 2015; Jones & Kirk, 1990; Kelly, 2016; Madsen, McKagan, & Sayre, 2013; Potvin & Hazari, 2016; Rodriguez, Potvin, & Kramer, 2016; Traxler, Cid, Blue, & Barthelemy, 2016; Wilson, Low, Verdon, & Verdon, 2016). Despite some progress has been made in narrowing the gender gap in science in recent years, the number of girls and women in the fields of physics, engineering and technology is still insufficient and marginal (Dam-o et al., 2018). Women are severely underrepresented at all levels in physics and engineering. Physics in particular has stereotypes about being a discipline for brilliant men (Kalender, Marshman, Schunn, Nokes-Malach, & Singh, 2019).

Some studies found that boys were more interested in the physical and technological aspects of the world and girls appeared to be more interested in human and natural aspects (Jones & Kirk, 1990). Johanna Vennix et al. explored the associations between students' perceptions of the outreach learning environment, motivation and attitudes towards STEM and future STEM career intentions. They founded that male students reported slightly more autonomous motivation and more interest in a future career in STEM compared to female students (Vennix, den Brok, & Taconis, 2018). Z. Yasemin Kalender et al. investigated male and female students' physics identities by administering a survey in introductory calculus-based physics courses, and found gender differences in how students identify as a physics person and how their perceived recognition from others (Kalender et al., 2019).

There are significant differences between male and female undergraduates in the learning of various subjects. This paper analyzed the gender differences caused by intellectual and non-intellectual factors, and studied the gender differences of undergraduates major in physics using the scores of theoretical physics, and put forward teaching strategies for the improvement of theoretical physics.

## 2. Influencing Factors of Gender Differences

### *2.1 Intellectual Factors Affecting Gender Differences*

(1) Gender differences in math ability

Math learning is aimed to provide students with not only logical, analytical, systematical, critical, innovative, and creative thinking skills but also teamwork skills (Putra, Suryadi, & Juandi, 2018). Math ability is a

comprehensive ability that is not only about the mathematical calculation alone, but also includes the understanding and application of mathematical principles, mathematical symbols and mathematical models. However, this ability is mainly reflected in the calculation of mass data and solution of mathematical problems.

In general, most girls have certain advantages in their calculating ability, which is not only about their qualifications, but also has a great connection with their personality. The factors such as preferring to learn quietly, calm and thorough, and being careful about study etc., are conducive to their more prominent in calculation. However, this advantage is only manifested in the primary and secondary schools. Compared with the comprehensive problem solving method, girls will be stronger than the boys in the middle school period. However, in the high school or higher level education, boys appear to have more advantages in the comprehensive analysis ability and the mathematical reasoning ability. Furthermore, for the mathematical operations, that is, examinations, the boys generally score better than the girls in the test results, but in another form of the test, that is, the specifications of the girls' assessment in the school are higher than boys, which also reflect the respective advantages of the boys and girls as mentioned above.

(2) Gender differences in verbal ability

When it comes to verbal ability, many people doubt this ability toward the study of gender differences, especially in terms of studying physics. Verbal ability is the ability to process, extract and manipulate linguistic symbols. It is embodied in five aspects: listening ability, verbal ability, reading ability, writing ability and memory ability.

Therefore, verbal ability is not just a single structure, as it involves means of verbal information such as remembering, manipulating, interpreting, arranging, communicating, and so on. For example, memory of a person refers to the process of reappearing or re-recognizing things that have been experienced in the future, and it's divided into mechanical memory and intentional memory. Compared with boys, the mechanical memory of girls is stronger than that of boys, which is embodied in diversified memory methods, large memory volume, and fast memory speed. Comparing with mechanical memory, intentional memory is where boys have their gender advantage. When remembering, boys are more willing to pay attention to the content of memory; they often explore the key points of the desired memory content, and consciously remind themselves whether the problems encountered are something that should be remembered or not, which is more flexible.

(3) Gender differences in spatial capabilities

Relative to the other abilities, as ability that is to describe and articulate difficult for male and female, spatial ability is one of the most prominent ability to reflect gender differences. The spatial abilities predict success in science, technology, engineering, and mathematics education and careers, independently of verbal and mathematical abilities, and that spatial skills can be trained (Hegarty, 2018). Chiara Meneghetti et al. reported that the mental representation derived from route and survey descriptions is perspective dependent. Individual differences in gender and in spatial competence, however, influenced the ability to process spatial information in route and survey perspectives (Meneghetti, Pazzaglia, & De Beni, 2011). Kimura divided space abilities into six categories, including spatial orientation, spatial location memory, targeting, spatial visualisation, disembedding and spatial perception(Pittalis & Christou, 2010).

*2.2 Non-intellectual Factors Affecting Gender Differences*

The theoretical physics course is the core course for physics students in university to learn physics. It not only runs through the major content of the students in the university, but also is the theoretical basis for students to study other courses. In the process of researching and learning theoretical physics, different genders have various differences in the study of theoretical physics, which not only affect the learner's academic performance directly, but also affect the learner's academic performance from the learner's own factors, or from non-intellectual factors of the students such as learning motivation, learning interest, and learning attitude.

(1) Physiological factors

The first is the structure and function of the brain. The girl's brain develops earlier than the boy's. Brain of infant develops often from the right hemisphere to the left, and this transition to the left begins earlier in female than in male. In addition, hormone-driven behaviors are much more than we want to admit. When hormones emerge during the development of students, the brain strengthens its gender changes again after the fetal period, leading to gender differences in various physiological functions of students, thus affecting students' learning behavior. For example, emotional changes and learning behaviors, etc. in the classroom.

However, the influence of physiological reasons is relatively small. From the differences we have found, it can only affect the different cognitive styles and is controlled by individuals. The physiological reasons have been considered as the main reasons before the 1970s, however after the proofs of time and facts, the influence of

physiological reasons can be neglected in the contemporary era, and more importantly, the influence of social culture on psychological factors instead.

(2) Psychological factors

As far as gender differences are concerned, they are not only the physiological factors presented, but also internal psychological factors, which are more difficult to control and to accurately grasp. Psychological factors cover a lot of content, mainly in terms of personality characteristics, and secondly, the impact of the external environment on the person. The development of human society until now, the roles of male and female are more determined by the social environment, not only the gender differences in the biological sense, the society's demands or expectations for female and male are reflected in all aspects.

The influence of social stereotypes is significant. Through the main ways of socialization—family, school, and media—we have learned the behaviors that others expect, as men or women. For psychological factors, the development is still affected by the social factor.

(3) Social factors

Compared with psychological factors, although social factors have no decisive role, the importance of social factors cannot be ignored; as such external factors often affect the development of internal factors. If not taken seriously, they are completely capable of affecting the psychological factors to develop towards somewhere that we would not want to see. What's more, the information technology develops rapidly today, a lot of speech and information can be quickly spread to every corner, thereby social factors tend to be a "steering wheel" of gender differences.

Relative to physiological genetic factors, the impact of the environment on intellectual development is more positive and profound, thus it will play a leading role. The structure of the body is not the whole cause of the intellectual difference between men and women, or even the main reason. For a long time, the society has shaped a male (female) sexual model, through certain definition or insight of gender roles to express people's different expectations of the two sexes. Since childhood, we have influenced and regulated the different behaviors of male and female directly, therefore affected the formation of interest of male and female and the two different directions of intellectual development. Then come to the student period, this period will account for a large part of our growth, but in the school environment, gender differences and social factors are more worthy of our study and attention.

## 3. Gender Difference Analysis of Theoretical Physics Learning

We analyzed the final exam scores of the four theoretical physics courses for undergraduates majoring in physics, as shown in Table 1. There are a total of 46 students, including 35 boys and 11 girls. The scores are divided into 5 segments in the range of 100 to 90, 90 to 80, 80 to 70, 70 to 60, and below 60, and then count the number of boys and girls in each segment. Table 2 shows the percentage of boys and girls in each score segment.

Table 1. Distribution of scores of theoretical physics

| | ~≥90 | | 90~80 | | 80~70 | | 70~60 | | ＜60 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Quantum mechanics | 5 | 2 | 10 | 3 | 15 | 1 | 4 | 3 | 1 | 2 |
| Theoretical mechanics | 6 | 2 | 11 | 2 | 14 | 1 | 3 | 4 | 1 | 2 |
| Electrodynamics | 5 | 1 | 14 | 2 | 12 | 2 | 3 | 5 | 1 | 1 |
| Thermodynamics and Statistical Physics | 4 | 2 | 13 | 1 | 13 | 2 | 3 | 5 | 2 | 1 |

Table 2. Percentage of scores for male and female students

| | ~≥90 | | 90~80 | | 80~70 | | 70~60 | | ＜60 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| quantum mechanics | 10.87% | 4.35% | 21.74% | 6.52% | 32.61% | 2.17% | 8.70% | 6.52% | 2.17% | 4.35% |
| Theoretical mechanics | 13.04% | 4.35% | 23.91% | 4.35% | 30.43% | 2.17% | 6.52% | 8.70% | 2.17% | 4.35% |
| Electrodynamics | 10.87% | 2.17% | 30.43% | 4.35% | 26.09% | 4.35% | 6.52% | 10.87% | 2.17% | 2.17% |
| Thermodynamics and Statistical Physics | 8.70% | 4.35% | 28.26% | 2.17% | 28.26% | 4.35% | 6.52% | 10.87% | 4.35% | 2.17% |

From Table 1 and Table 2, we can see that not only boys but also some girls are ranked in the excellent score range, but the number of females is still too small compared with boys, and there are a large number of males

ranked between 90-70, which shows that the scores of the males are quite good in general, only a few of them are not satisfactory. Females on the other hand, the number is relatively small in the interval of 90 to 70, and most females are still below 70.

Table 3. Proportion of male and female students in their respective total numbers

| | ~≥90 | | 90~80 | | 80~70 | | 70~60 | | ＜60 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male% | Female% | Male% | Female% | Male% | Female% | Male% | Female% | Male% | Female% |
| Quantum mechanics | 14% | 18% | 29% | 27% | 43% | 10% | 11% | 27% | 3% | 18% |
| Theoretical mechanics | 17% | 18% | 31% | 18% | 40% | 10% | 9% | 36% | 3% | 18% |
| Electrodynamics | 14% | 9% | 40% | 18% | 34% | 18% | 9% | 45% | 3% | 10% |
| Thermodynamics and Statistical Physics | 11% | 18% | 37% | 9% | 37% | 18% | 9% | 45% | 6% | 10% |

From Table 3, we can see that the proportion of boys in the 90-70 range is significantly higher than that of girls, and they account for a large proportion. However, in the score range above 90, the gap between girls and boys with excellent grades is not as big as what we think, some girls have advantages in certain subjects even, such as theoretical mechanics and thermodynamics and statistical physics, in which the advantage of female students is obviously reflected, because there are relatively more text descriptions, and more parts to be remembered in these two courses compared with other theoretical physics courses. This shows that girls do not lack well-known abilities in learning theoretical physics, furthermore they have considerable performance in memory and linguistic ability, but compared with boys, the proportion of those who master this part of the ability is still a minority.

As the majority in the 90~70 score range are boys, this not only shows the advantages of boys in theoretical physics learning, but also reflects that they have their own unique and correct insights in terms of spatial thinking and mathematics, which means that most boys learning theoretical physics are still at the upper-middle level, and also fully shows that boys have advantage in learning theoretical physics; for most girls, there are few people at the intermediate level, relatively, they are still lack of thinking and mathematics ability, psychological factors are also one of the potential reasons. The influence of long-term social factors will always bring more or less unfavorable factors; thereby there is rather weak learning interest.

In general, the gender differences the undergraduates major in physics are not only reflected in intellectual factors but also in non-intellectual factors. In terms of intellectual factors, the advantages of boys are still reflected in their mathematical analysis ability and spatial thinking ability. For example, in the courses of electrodynamics and quantum mechanics where there are more calculations and analysis relatively, the boys' performance is obviously superior to girls, and throughout the theoretical physics courses, the advantages of boys in non-intellectual factors are also reflected. The long-term belief of the society that male students are excellent in science than female students often makes boys better than girls in self-confidence; on the contrary, it generates a lot of pressure to girls, which will be reflected in the girls with average scores, and it also represents the mentality of most girls, but in terms of linguistic and memory abilities that girls are good at, the advantages are reflected in other two theoretical physics courses that have more conceptuality relatively, which shows that in regard of the non-intellectual factors, girls prefer to study in a quiet environment, stay calm, and treat work and study carefully and earnestly.

## 4. Teaching Strategy Advice for Theoretical Physics Teaching

In order to improve the quality of theoretical physics teaching, teachers and students should take corresponding measures in the process of teaching and learning.

As a student, one should be able to understand the personality traits according to the gender difference, and grasp the psychological personality to overcome the psychological defects, to accordingly realize balanced development of physiology and psychology, and optimize psychological structure, thereby effectively improve the learning efficiency respectively and achieve good development.

Male and female students should combine gender differences to rationally deal with problems that arise in studying. In dealing with the influence of intellectual factors, girls should confront their disadvantage in mathematical intelligence, strengthen spatial analysis ability and mathematical reasoning ability, and try as much as possible to involve themselves in image space imagination and mathematical formula reasoning, so as to make up for the disadvantage of spatial thinking and mathematical thinking; boys should start from the observation, memory and language abilities in regard of intellectual factors, try to participate in some public activities, and try

to remember more formulas and concept of theoretical physics learning, to lay a good basic knowledge foundation, and avoid the phenomenon of having high aims but low abilities, in terms of language ability, it is to communicate with classmates and teachers as much as possible.

In terms of non-intellectual factors, male and female students should focus on themselves, prepare themselves well in psychology, and then properly deal with other external factors. Although the male and female students of the same major in the university should have little difference in interest of studying the major, there is still a big gap in their personality traits. In general, most boys are more cheerful and lively, or active in more straightforward term. Comparing with girls, more girls are quiet and restrained. In this way, it will always be easy for boys to accept new things, and adapt to the new environment; while girls will be calmer, patient, and no mistakes. Therefore, non-intellectual factors shall be paid attentions to as well, to make up for their own deficiencies, and to learn more about the other's methods of learning, methods of doing things, and ways of life.

As a teacher, the most important is to make different teaching methods according to the intellectual and non-intellectual presentations caused by gender differences, to teach students in accordance with their genders, which will not only help to deal with the different learning problems of male and female students, but also make it easier to come up better teaching methods in the targeted teaching to urge students to learn continuously, and motivate male and female students in the respective aspects that they are good at to achieve positive development to overcome the old-fashioned learning concept, which will optimize the teaching work and enable students to develop in an all-round way. This is the purpose of analyzing gender differences.

It is necessary to eliminate the traditional negative gender bias and the gender concept of male and female, as they often hurt the self-confidence of boys or girls themselves, which not only limits the development of students' interest, but also is not conducive to their physical and mental growth. In teaching work, teachers should eliminate stereotypes, actively encourage the development of students' interest, promote students with outstanding personalities; also eliminate the old-fashioned teaching concepts in the students' impressions so that they will not be alerted and are able to play their strengths.

Make efforts to change the traditional teaching mode, endue male and female students the ability to exercise their independent thinking and independent judgment in areas they are not good at. When they encounter problems, help them in time, guide them, and eventually let them find the answers themselves. This will promote their interest in learning and strengthen their self-confidence. And this is a kind of cultivation in the attitude of students.

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