Implementing Collaborative Learning in Second Round Review Stage in Senior High School Physics Class

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Contents

Abstract

This study is a real-life case of the localization of collaborative learning at the second round review stage in senior high school physics classes under the background of the new round of curriculum reforms in Zhejiang Province.

Aiming at both the impact of collaborative learning on academic performance and students' perceptions of their experience, this study takes constructive learning theory and social interdependence theory as the main theoretical support and adopts a pragmatic paradigm and mixed methodology. Both quantitative and qualitative data are collected, including results of college entrance examinations from 70 participants, notes from classroom observations, survey data and recordings of 12 semi-structured interviews.

Data analysis revealed that higher academic achievers (HAAs) achieved more progress compared with medium academic achievers (MAAs) and lower academic achievers (LAAs), and among each academic level, participants who participated in heterogeneous groups made more significant progress. In addition to academic performance, this study also finds a positive influence on students' interpersonal ability.

Overall, students approved of collaborative learning as a learning strategy and a teaching pedagogy. They tend to perceive their collaborative partner as one of the most influential factors for learning outcomes, with the focus being on their partners' academic level, and the concealed reasoning behind this preference could potentially be the role that scaffolding behaviour and cognitive conflict play in learning.

This study also provides insight into theory by exploring the possibility of potential of a drop in academic performance regarding the concept of ZPD as well as discovering ambiguity in the concepts of heterogeneous and homogeneous, thereby enriching the understanding of collaborative learning.

To some extent, this study helps dispel the notion that employing collaborative learning in Chinese high school classrooms is unsuitable, and provides new ideas for its localized practice. Phenomena that are not completely consistent with those in the literature reflect the complexity of the educational world. It shows that practitioner researchers should be very cautious when introducing new theories or pedagogical strategies and the applicability of these theories should be tested through the process of localization and appropriate adjustments should be made.

Acknowledgement

First of all, I want to thank my Alma mater for giving me a complete knowledge system and unforgettable experience of learning. After returning to my Alma mater and becoming a teacher, I want to practice its educational philosophy: "being adaptable and practical", and try my best to support my students to achieve better academic achievement and gain more meaningful learning experience. Here, I met the participants of this study that I would also like to thank to. They are far more than data samples. They are living souls. Because of them, I have the courage to try new teaching methods. They trusted me, actively engaged in this study, enthusiastically shared their experience with me and sincerely put forward useful suggestions.

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Chapter 1: Introduction

Operating under the pressures of the demands of the college entrance examination, following the traditional lecturing approach and pursuing efficiency in problem-solving is commonplace in senior high school classrooms in China. However, the new round of curriculum reforms in Zhejiang Province advocated for education that promotes students' all-round and personalized development and provides students with the ability to develop independently, communicate effectively and collaborate with others.

In light of the above circumstances, this thesis explores the extent to which implementing collaborative learning in the second round review stage is effective for senior high school students in their preparation for the college entrance examination as well as their scientific learning. An in-depth understanding of the theory of collaborative learning is required as well as providing examples of how this approach has panned out locally in China. Its purpose lies not only in improving students' academic achievement, but also enabling students to share experiences and develop their emotional skills and empathy through collaborative learning, so as to promote students' lifelong development (Sheng and Zheng, 2006).

1.1 Context of the Study

1.1.1 The Rise of Collaborative Learning in China

Collaboration is ubiquitous in human society: almost every activity has a collaborative nature. Human beings collaborate in order to achieve mutual goals and to survive. As Montagu (1965) observed,

> Without the collaboration of its members, society cannot survive, and the society of man [sic] has survived because the collaborativeness of its members made survival possible.... In human societies the individuals who are most likely to survive are those who are best enabled to do so by their group.

Collaboration is not so common in schools even though their mission is regarded as supporting students to enter society successfully. Indeed, competition between students is still a dominant aspect of school life. It is rare for students to be able to encourage their classmates' learning, celebrate each other's success, and be willing to study, work and complete common tasks together. This phenomenon is found regardless of the students' differences in intelligence, gender or any other individual factors (Johnson and Johnson, 1994). In an increasingly competitive society, especially the one that currently exists in China, where the college entrance examination is overwhelmingly the most important indicator for entering the university, students are greatly more accustomed to the rules of competition rather than collaboration.

It is necessary to consider how the focus on relationships in Chinese classrooms has evolved in this context. In a traditional classroom in China, teachers are usually in a dominant position, while students are used to accepting knowledge passively and relying on their teachers to control when and how they learn. When lecturing classes, teachers often provide students with concise explanations. This teaching method seems to place an importance on efficiency; however, it actually may have negative impacts on the development of important qualities such as having an independent approach to learning as well as a collaborative spirit (Sun and Zhang, 2012). Contrary to the original intention, research has found that traditional teaching methods have a close correlation to a low learning effect. Hake (2000) carried out a comparative analysis of the teaching effect of 14 classes and discovered that, in traditional classes, students were only able to master 25% of the teaching content, while in the classes where student group discussions replaced lectures from the teacher, the mastery rate significantly increased to 48%. Wieman (2007) and colleagues discovered similar situations in their action research. They elaborated on some non-obvious facts in their lectures, and later gave students a test on those facts. It was found that after 15 minutes, students only remembered approximately 10% of the content. Wieman repeated the experiment at an academic seminar composed of top physicists, and the result was still around 10%. From the perspective of cognitive science, Wieman (2007) explained this phenomenon through the limit of short-term working memory. Furthermore, he pointed out that being told a conclusion directly through lecturing may avoid the benefits of self-discovery. He advocated classrooms with active and interactive engagement, rather than traditional classrooms, and

emphasized the importance of comparing different instructional approaches in such classrooms (Kuo and Wieman, 2016).

With the state's increasing emphasis on the cultivation of high-quality human capital—known as "talents" in China—educators began to introduce western educational theories into the Chinese educational system. Their educational philosophy has constantly evolved and a consensus was reached that in the process of learning, students need to find the connection between the newly learned material and their existing knowledge and construct their own knowledge systems by themselves. Clear and accurate lecturing does not necessarily guarantee a positive learning effect. Educators are gradually taking the perspective that education should focus on learner's activities and the perception is that they are valuable resources in education that are yet to be explored. Therefore, a growing emphasis on educational dialogue in the field of education emerged in China. Traditionally, the relationship between teachers and students was regarded as a crucial aspect in a student's learning and the decisive factor in how students are able to master knowledge and develop intelligence is how they interact with teachers. Nonetheless, substantive learning interactions among students are still underestimated (Wang, 2009) and thought to have no contribution to or even have detrimental effects on learning (Johnson, Johnson and Holubec, 1984; Wang, 2002). As a result, collaborative learning is rarely employed in Chinese classrooms.

In terms of educational practices worldwide, collaborative learning has a long history. Since its rise in the early 1970s in the United States, after more than 30 years of theoretical research and practical development, collaborative learning has been widely implemented there (Liu and Wang, 2004). It had also spread to many other parts of the world as many educational systems across various countries recognize the requirement for effective collaborative learning (Slavin, 1987). Collaborative learning is based on the assumption that learning is most effective when students are collaborating actively in order to solve a mutual task. Most of the research on collaborative learning has come to the same conclusion, namely that collaborative learning not only improve students' academic performance, but it also promote their social competence as well as many other intellectual and non-intellectual abilities. Collaborative learning is regarded as one of the most

influential and fruitful fields in contemporary educational theory, research and practice (Johnson, Johnson and Holubec, 2008).

In China, more than 2000 years ago, the idea of collaborative learning first emerged. In the Book of Poetry, it is said that "there are bandits and gentlemen who like to learn from each other, and like to ponder and polish". In the classical work on education, "the Book of Rites", it is proposed that "if you study alone and have no friends, you will be lonely and ignorant." Another classic, "Xueji" also emphasizes the cooperation of learners in the learning process (Zhang, 2002). In ancient Chinese private schools, a teaching method was commonly practiced, namely "sophisticated students imparting to new students". This idea was admired and echoed by Tao Xingzhi, a famous Chinese educationist, who vigorously advocated a teaching strategy called "little teacher" in the 1930s. These expressions and pedagogical strategies embodied the basic theory of collaborative learning.

Since the late 1980s, through reflection on the problems existing in education, Chinese researchers recognized that with the deepening of the understanding of the essence of teaching and learning, the function of traditional teaching had to evolve. At this time, the successful experiences of collaborative learning research in foreign countries gradually attracted the attention of Chinese researchers as they began to translate and introduce relevant literature to the educational system (Sheng, 1992). In the 1990s, the socialist market economy was established. It raised the public's subjective self-consciousness to unprecedented levels. Chinese educators began to actively explore the relationship between collaborative learning and the development of students' subjectivity and have achieved provisionally successful results (Zeng, 2000). Among these studies, the most representative and influential ones are: the "exploration of personality optimization education" of the Education Department of Hangzhou University, the "collaborative teaching research and experiment" of Shandong Institute of education, the "collaborative teaching experiment" of the Education Department of Hunan Normal University, and the "children's subjectivity development experiment" of the Education Department of Beijing Normal University (Shi, 2006; Sun and Zhang, 2012).

Influenced by the above research, the government and education management departments gradually grasped the importance of collaborative learning. In 2001, The State Council of China issued the "decision of the State Council on the reform and development of basic education" (The State Council, 2001), which specifically refers to collaborative learning and pointed out that "collaborative learning should be encouraged to promote mutual exchange and common development between students and teachers." In order to implement the spirit of the reform, in the same year, the outline of basic education curriculum reform (Trial Implementation) was promulgated and implemented. Since then, collaborative learning has been formally promoted nationwide and large-scale teaching applications aimed at different subjects and different age groups began to be implemented. Statistics indicate that since 2003 relevant research has increased significantly (Zeng and Tian, 2014). A search on CNKI (China National Knowledge Infrastructure) using the phrase of "collaborative learning" indicates that before 1999 there were less than 100 relevant articles each year. From that year onwards, the number increased rapidly and since 2014, more than 2000 articles have been published every year. This can be seen as convincing evidence of its growing status in China's education system.

With the arrival of the era of "core literacy", collaborative learning has become increasingly popular. In the "opinions on comprehensively deepening the curriculum reform and implementing the fundamental task of moral education" (The Ministry of Education of China, 2014) issued by the Ministry of Education in 2014, "core literacy" is deemed a fundamental aspect of education. Core literacy mainly refers to the essential character and key abilities that students should be equipped with in order to continue their life-long development, both socially and academically. Behind this important measure is China's urgent need to adapt to the developing trends in world education reforms and the strong desire to enhance the competitiveness of Chinese education on the international stage. The characteristics of collaborative learning are entirely in line with the needs of core literacy training. It cannot only help cultivate critical thinking and the idea of lifelong learning, but also improve one's ability to collaborate, to show respect and tolerance to others, and to cultivate personal accountability for learning.

1.1.2 Existing Problems

Although the research on collaborative learning suggests various expected results, Sharan (2010) pointed out that the situation may be much more complicated when applying theory to real educational practice. Under the influence of educational reforms, an increasing amount of collaborative learning projects emerged in Chinese classrooms. While some of them did have positive effects, others encountered problems both in theory and in practice (Sun and Zhang, 2012).

A profound problem has been on the issue of efficiency. Despite having the knowledge of the positive results obtained by foreign and domestic research, when observing students' collaborative learning, inefficiencies arose such as: long periods of silence and non-communication when in discussions; classmates giving answers to their classmates which the recipients accept without any query, and also the group deviating from the given topic and instead engaging in irrelevant conversations.

The main reasons for the low efficiency are as follows: since childhood, Chinese students tend to prefer thinking and solving problems by themselves, and upon participation in group tasks, a considerable number of students lack consciousness as well as the ability to collaborate. They do not know the required methods of collaboration or how to divide the roles of group members, nor are they effective at elaborating upon their views logically and in sufficient detail. When faced with solving a task, group members would display signs of not understanding how to tackle the task as a group and a stalemate would possibly ensue, displayed through a lack of any meaningful communication. After being given more time, they were not able to make any progress and the group fell into awkward situations akin to "three monks have no water to drink" (Ding, 2020).

In addition, if there is insufficient guidance or classroom management, some students will gladly regard collaborative learning as an opportunity to chat and play with classmates (Su, 2019), which of course goes against the original intention of collaborative learning. Even where collaboration is smooth and effective, it often takes a longer time to master a concept or solve a problem through

collaborative learning when compared with traditional lecturing, resulting in a perception of inefficiency among teachers and students. Therefore, ensuring the effectiveness of collaborative learning has become a key research concern and research direction for scholars.

Students' lack of collaborative consciousness and communication skills can lead to more obstacles. Influenced by Asian culture and educational systems, some students show a lack of collaborative skills and tend to pay more attention to reaching agreement with others rather than thinking independently (Zhou and Wang, 2010). Opportunities to participate in collaborative learning may be unequal amongst students. Those with strong ability and an outgoing personality will have more opportunities to speak in the group, while students with weaker ability and an introverted personality may get far less of a platform to contribute (Zeng and Tian, 2012). This "silent majority" may gradually become passive and ultimately content to be dominated, and some of them even enjoy the convenience of a free ride. This inequality can easily reduce students' independence and their sense of responsibility (Sun and Zhang, 2012). Furthermore, self-centered high ability students may believe that they can complete tasks independently and therefore there is no need to collaborate at all. There is a tendency for such students to look down on others with lower abilities and view them as an impediment to the completion of tasks (Pei, 2000).

A further problem is that most domestic scholars translate and subscribe to foreign practices and import successful examples but few of them verify whether these theories or strategies are suitable for Chinese classes, let alone carry out in-depth research and provide suggestions for localized practices (Ge, Huang, Li, Tan and Yu, 2011). Furthermore, there are few training courses provided for teachers on how to implement collaborative learning and teachers who have a limited theoretical knowledge can easily misunderstand the theory (Wang and Mao, 2010). Some teachers simply perceive collaborative learning as a group discussion and pay insufficient attention to strategies that are necessary and conducive to collaborative learning, such as the elaborate design of tasks, having reward schemes in place in order to enhance motivation, and teaching students effective communication skills. Collaborative learning can deteriorate into an embellishment in the classroom, usually making it unstructured and therefore having a poor effect on learning (Zhu,

2015). Results that do not match expectations give deep dissatisfaction to teachers and are obviously disadvantageous to the promotion of collaborative learning.

1.1.3 Collaborative Learning in Physics

In contemporary society, physics is an important part of the development of science and technology, and it also plays an important role in our daily life (Karacop, 2017). Specifically, physics has promoted the progress of industry, agriculture and information technology. It has changed people's lifestyles and values and has made great contributions to human civilization and social progress (Compulsory Education Physics Curriculum Standards, 2022). Therefore, the purpose of physics teaching is to help students understand the laws of nature, be familiar with scientific research methods, and form a scientific way of thinking (People's Education Press, 2018). However, researchers have found that students of different ages generally encounter difficulties in learning physics, which may lead to a loss of interest and confidence in physics, and ultimately affects students' future career choices (Karacop, 2017).

In some countries including China, traditional physics classes are often teacher-centred. In such classes, teachers directly transmit information to students through lectures, and students often do not actively participate in the learning process (Astra, Wahyuni and Nasbey, 2015). The traditional teaching approach, sometimes referred to as 'indoctrination', usually leads to the phenomenon that students rely on teachers and lack the ability to think independently (Liu, 2021). In physics learning, it is commonplace that students hold wrong pre-scientific concepts based on their daily life experience before entering physics classes. However, the effect of traditional teaching in promoting the transformation of such concepts is often limited (Wandersee et al., 1994). In addition, traditional teaching usually fails to arouse motivation in students' learning of physics, not to mention helping students gain meaningful learning (Astra, Wahyuni and Nasbey, 2015; Tanel and Erol, 2007). Researchers also found that the traditional way of learning physics is not effective in improving students' high-level cognitive skills (Wambugu, Changeiywo, and Ndiritu, 2013).

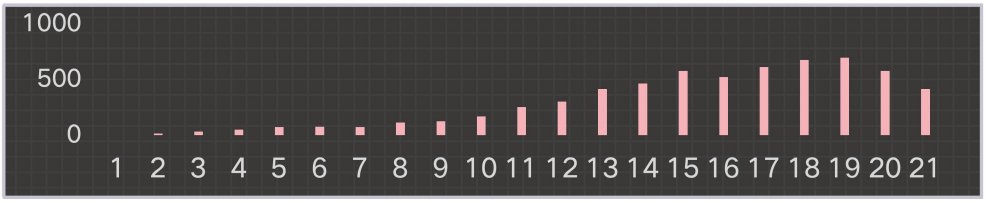
Mistakes and collaboration are very common in scientific research, yet they are rarely found in modern-day science education. Teachers are keen to only expose the correct and most important scientific findings to their students, and delete the circuitous exploration process that scientists must take in the process of obtaining these conclusions (Osborne, 2010). Consequently, for students, science (especially physics) becomes a sacred and authoritative event, and they gradually lose the desire and ability to explore and question its connotations.

However, in recent decades, there has been a broad consensus in the educational world on the need to foster greater engagement and commitment of students in their own learning, which has promoted the focus on positive pedagogical strategies, such as collaborative learning (Oliver-Hoyo, Alconchel and Pinto, 2012). Researchers have found multiple benefits of applying collaborative learning strategies to physics classes. First of all, it can create a favourable environment for students to develop their knowledge system (Petrescu, Gorghiu, and Dragticescu, 2017) and promote students' understanding of physics concepts (Crouch and Mazur, 2001; Roschelle, 1992) as well as improve their academic performance effectively. Meanwhile, it is also helpful for long-term maintenance of knowledge (Freeman et al., 2014; Karacop, 2017; Tanel and Erol, 2007) and cultivating learning skills (Oliver-Hoyo, Alconchel and Pinto, 2012). Furthermore, some researchers came to the conclusion that collaborative learning has a positive influence on students' creativity, reasoning and scientific problem-solving abilities (Mercer, 1996; Webb, 1982). Collaborative learning with an emphasis on argumentation is especially helpful for improving critical thinking (Tudge, 2010). Compared with traditional classes, collaborative learning also helps to more effectively arouse students' interest and enhance their confidence in physics learning (Petrescu, Gorghiu and Dghicescu, 2017; Tanel and Erol, 2007). As Adeoye (2010) believed, collaborative learning is one of the most suitable methods for physics teaching.

Influenced by the general view of collaborative learning in the educational world, an increasing emphasis on the application of collaborative learning in physics education has gradually formed in China. As shown in the following chart, the search for the keywords of both "physics" and "collaborative learning" on CNKI (China National Knowledge Infrastructure) found that the number of relevant journals published each year has increased significantly since 2001. Especially

from 2015 to 2020, an average of about 500 articles were published annually, fully demonstrating the attention of researchers and practitioners in the field of physics teaching in China to collaborative learning. With the deepening of curriculum reform in China, the requirements of collaborative learning have been written into the official education documents (for example, the term "collaboration" appears 21 times in the latest edition of "Compulsory Education Physics Curriculum Standards" (2022) which has important guiding significance for high school physics teachers in the selection of pedagogical strategies).

Fig 1.1 Number of journals on "physics" and "collaborative learning" in CNKI (The horizontal axis represents the year after 2000 (5 represents the year 2005); The vertical axis represents the number of journals published).



1.1.4 Collaborative Learning in the Second Round Review Stage in Senior High School Physics Class

Despite the documented benefits of collaborative learning, high school physics teachers are still reluctant to give students the necessary freedom to carry out collaborative discussions. This reluctance is rooted in several factors, such as the curriculum objectives, the stringent and demanding teaching plan, the insufficient amount of class time and the perceived pressure created by being unable to adequately control students' classroom activities (Robertson et al., 2012).

This situation is particularly serious in senior three classes in China. Under the heavy pressure of the college entrance examination, which is undoubtedly the most important indicator for entering the university, teachers and students are operating in a high-pressure environment. As a result, there has been a desire to pursue so-called "high efficiency" in physics teaching. The classes of third-year seniors usually consist of review and exercise lessons, in which teachers discuss typical

problem examples and explain them to the students. If the learning is carried out in the form of collaborative discussion, students may bypass some crucial information or make errors in their comprehension. However, making mistakes is considered particularly problematic as one must spend more time rectifying this and that is thought to be detrimental to high efficiency.

In order to promote the fairness and justice of the college entrance examination system and more effectively cultivate diversified talents, the Ministry of Education has continuously led the reform of the college entrance examination. On September 3, 2014, the State Council of Zhejiang Province issued implementation opinions on deepening the reform of the examination and enrollment system (GF [2014] No. 35), thus forming the prelude to a new round of reform of the college entrance examination. With its inclusion in the first batch of pilot areas, Zhejiang Province issued "Zhejiang Province to deepen the comprehensive reform of college entrance examination system pilot program" (People's Government of Zhejiang Province, 2014) and began to implement "3 + 3" model for senior high school freshmen. This reform removed the traditional distinction between liberal arts and science. In addition to the three compulsory subjects (Chinese, mathematics and English), students can choose three out of seven selective subjects (physics, chemistry, biology, politics, history, geography and technology) for the college entrance examination. The most important change is that each student will have the opportunity to take two examinations (one in the first semester and the other in the second semester of senior three) for each subject selected and the higher of the two scores is the one that is documented, thereby breaking the conundrum of "one examination decides one's life".

This reform brought new challenges to traditional pedagogical methodologies, especially for the review stage of senior three. There are usually two rounds of reviews in grade three. In the first-round review, teachers work with students to help review all the knowledge that was learned in the senior high school physics curriculum. Following this, in the second round review, greater attention is paid to problems that were exposed in a student's homework and exams. Through the revision of homework and exams, students' problem-solving ability can be improved so to best prepare them for the college entrance examination. As the first college entrance examination after reform is almost a semester earlier than the original examination, in order to increase a student's

chances of achieving a high score in the first examination, strategies such as increasing the number of classes participated in per week or beginning the first round review earlier than is scheduled can be taken as to strengthen the effect of the first round review. As a result, when students enter the second round review stage after their first examination, both their knowledge and problem-solving ability should have developed when compared to the traditional second round review stage. Nevertheless, students have different needs and face a diverse array of problems in their learning in second round review stage (Fan, 2019). Namely, during the first-round-review stage, the class's problems are somewhat similar, but once they enter the second round review stage after the first college examination, although their overall ability in physics has increased, the problems students have may become more diverse. For instance, in the first-round-review stage, a teacher will analyze the problems encountered by students in a given assignment, and the result may as shown in Figure 1.2:

Fig 1.2 Question number and the percentage of participants who failed to solve the corresponding problem in one assignment in the first round review stage **(n=70)**

Question number	1	2	3	4	5	6	7	8	9	10
Percentage of students who failed to solve the corresponding problem	2%	4%	2%	42%	6%	50%	70%	2%	6%	6%

We can see that questions 4, 6 and 7 reflect common problems or misunderstandings that should be emphasized or explained through lecturing. During the second round review, the teacher may find a different outcome. In the case of these students, their results are shown in Figure 1.3.

Figure 1.3 Question number and the percentage of participants who failed to solve the corresponding problem in one assignment in the second round review stage **(n=70)**

Question number	1	2	3	4	5	6	7	8	9	10
Percentage of students who failed to solve the corresponding problem	16%	4%	6%	32%	14%	518%	2%	2%	16%	24%

Here it can be gathered that the number of high error-rate questions (questions 4 and 10) decreased, however, the number of relatively high-error rate questions (questions 1, 5, 6 and 9) increased.

Evidently, the teachers will take time to explain questions 4 and 10, but what they do with the remaining questions is less clear. They cannot explain in-depth all of the questions due to time constraints. Therefore, for some students, there are still unexplained questions that they are unable to solve by themselves.

Under such circumstances, the unified teaching content is difficult to meet the needs of different students, thus calls have been made for the traditional teacher-centered, lecture-based teaching method to be reformed, and a more effective strategy to be found (Fan, 2019). Liu (2012) suggests that an achievable and reasonable way in which to do so is to combine teacher lecturing and collaborative learning, on the grounds that this hybrid model would both enable the advantages of traditional lecturing meanwhile embracing a new learning strategy that can be of the utmost benefit to students. Through collaborative learning, students can discuss their individual problems and seek the optimal solution through a mutual effort. Moreover, high rate-error questions can still be emphasized and explained by the teacher during a class-wide discussion (or lecturing) afterwards. This arrangement fully respects the learning characteristics of each student and can effectively stimulate students' learning motivation and improve the effectiveness of classroom learning (Jiang, 2014), thus it conforms to the concepts inscribed in the new curriculum (Yang, 2015).

1.2 Personal Motivation for the Study

Grade three is a crucial period in senior high school. The most apt word to describe it is "nerve-wracking". Faced with all manners of pressure, including societal, family related and self-imposed, anxiety grips the school, the teachers, the students and perhaps most powerfully, the parents. Although society as a whole advocates for a diversified development, in the eyes of the vast majority of the Chinese public, the college entrance examination is still regarded as a "single wooden bridge" which students must successfully navigate in order to enjoy a successful life. This end of the line represents ten years of hard work, and on the other side of the bridge lay a magnificent blueprint of one's possible future life. This notion is seemingly everlasting and has

not changed in the minds of Chinese society. Therefore, successfully supporting students to the other side of this "single wooden bridge" is the mission of every senior three teacher.

The inspiration for me to begin the journey of producing this study was that my students had just entered senior three. These intelligent and hardworking students were the first candidates to face the new college entrance examination and they would face two opportunities to take the college entrance examination after curriculum reform. During the first and second years of senior high school, we performed a lot of practical work together. My students were enthusiastic and class discussions were enthusiastically participated in, and the average scores of the class in various examinations were amongst the best in the school. However, entering senior three, I could not help but feel the unusually tense atmosphere in the classroom. In the first-round-review stage, I was particularly worried that the time for carrying out review was insufficient and the students would as a result not be prepared appropriately for the first examination. To make full use of the in-class time, my strategy was to avoid posing questions to the students but rather to directly offer explanations for each problem as succinct as possible. It was common that after a 40 minute lecture I would feel exhausted. Somewhat surprisingly, the students who had not vocally taken part in the whole class also seemed fatigued. What was more striking and worrisome was that the once lively demeanor of my students became alienated and the class lost its vitality. Unfortunately, I experienced an unpleasant feeling that I was conducting a monologue for an expressionless audience in a classroom almost completely void of interaction. I had the suspicion that the students did not like this method of teaching. However, this feeling seems to go against the commonly held belief that this is the most effective way of teaching for in the review stage?

This conflict prompted me to seek the wisdom of more esteemed educators than myself and I came across a book written by the Johnson Brothers of the University of Minnesota, one of the most vital advocates of cooperative learning. Although I was aware of cooperative and collaborative learning, these two methods do overlap and confusion does exist in understanding these two concepts even though they can sometimes be interchangeable (more details will be illustrated in Chapter 2). Since none of the physics teachers in my school had ever implemented

this strategy in their classrooms, my understanding of it was superficial at that time. However, I found the preface of this book enticing,

> We are entering an educational era that will change all that… providing more effective learning … focuses on "we" classrooms, coupled with the theme of "we are all involved in this together." (Johnson, Johnson and Holubec, 1984, p.6).

This description epitomizes the type of classroom that I wish to participate in, namely one where everyone is actively involved, where everyone can share meaningful ideas, and ultimately become co-builders of each student's respective knowledge. Teachers are no longer the master or the only sound source of the classroom, but become the organizer, guider and facilitator of collaborative learning (Du and Wang, 2012; Nie, 2006). Fueled by this desire, I delved in to further literature. I need to get insights from research done on this in order to gain an appreciation of how collaborative learning influences students' learning outcomes. These insights outline the process in which students grow into more capable learners and more experienced collaborators, and it also instilled in me the courage and confidence to try this new teaching strategy in my class.

Collaborative learning provides a desirable prospect for my educational reform. Studies that did find positive effects of group collaboration in improving the process and outcomes of physics learning (Astra, Wahyuni, and Nasbey, 2015; Jiang, 2014) brought me more confidence and courage. However, the complexity of educational situations means that the conclusions of existing studies cannot be applied to all learning situations. The classroom of collaborative learning is always specific and situational, and it is impossible for teachers to experience the same collaborative learning scenario twice (Wang, 2003). Therefore, it is solely through authentic and localized study that I can get a clear and in-depth understanding of the impact of collaborative learning on large classes during the second round review stage. In addition to the direct purpose of preparing students for the college entrance examination, I seek a deeper comprehension of the students' learning process and their authentic feelings throughout this journey in order to be a more effective supporter and provider of guidance. My aim is that this localized study can shed

light on some real experiences and be an inspiration for teachers who find themselves in similar situations and also for researchers who wish to study similar situations.

1.3 Research Questions and a Brief Description of Methodology

The purpose of this study is to promote students' academic performance in the second college entrance examination. It also tries to achieve an in-depth understanding of the impact of collaborative learning, since it is a new teaching and learning strategy, on students' overall performance in science learning. Furthermore, the main research question is as follows:

RQ: How does collaborative learning influence students' preparation for the college entrance examination and their performance in high school science learning in Zhejiang Province?

This includes two sub questions.

Sub RQ1: How does collaborative learning influence the academic achievement in the second college entrance examination of students with differing academic achievement levels and across different group compositions?

Collaborative learning contains many variables, among which academic achievement level and group composition were commonly studied (Dillenbourg et al., 1995; Lou et al., 1996; Saleh, Lazonder and Jong, 2005; Slavin,1996; Staples and Zhao, 2006). Since this is a pilot study in the second round review stage in Zhejiang Province, it is necessary to identify the influence of collaborative learning on students with different academic achievement levels and across different group compositions in order to understand whether collaborative learning is suitable for this special stage. In this study, students are categorized into three groups based on their academic performance: higher academic achiever (HAA for short), medium academic achiever (MAA for short), and lower academic achiever (LAA for short). The criteria used for this classification will be detailed in Chapter Three. To answer this question, this study will collect data from two college entrance examinations and then conduct quantitative analysis.

Sub RQ2: How do students perceive their experiences of collaborative learning? What are the differences between students with differing academic achievement levels and across different group compositions?

Considering the complexity of educational situations, the more noteworthy problem is not whether collaborative learning is beneficial for learning, but rather under what circumstances or how can collaborative learning improve learning effect (Nokes-Malach, Richey and Gadgil, 2015). Students' feedback is an important basis upon which teachers can adjust pedagogical strategies (Zhang, 2015), therefore, this sub question will be answered mainly through a survey and a semi-structured interview. Qualitative data, including student's perceptions on collaborative partners, learning outcomes, interactions and other relevant factors are investigated and triangulated with the quantitative data collected. More details of the methodology will be introduced in Chapter 3.

Due to the limited number of participants involved in this study, we should be cautious about quantitative results as they should be triangulated with qualitative results in order to strengthen the understanding of collaborative learning.

1.4 Contribution to Knowledge

As a practitioner research, a major aim of this study is to investigate ways of "improving academic achievement". Specifically, it explores how the theory of collaborative learning fits in the particular context of learning, including which ways of grouping might be more effective; which approach to grouping by ability level might benefit the students more, and which one might be better appreciated by students for handling collaboration, cognitive conflict or scaffolding. Therefore, this study may provide certain contributions to knowledge in both practical and theoretical aspects.

This study firstly contributes to pedagogical practice by providing a valuable case for the localization of collaborative learning theory. Through the process of educational reform, front-line

educators are eager to implement collaborative learning so to better cultivate students' core literacy. However, this involved overcoming many challenges. Among them, perhaps the most important challenge is how to make teachers believe in the advantages of collaborative learning, and consequently surrender their "authoritative position" and return the power of discourse back to the students.

For teachers, they should gain confidence from successful cases of collaborative learning, but what should be seen as more beneficial is a more localized strategy for action. Many teachers are brought up under the traditional education system, resulting in a limited ability and experience in organizing collaborative learning. The large size of Chinese classes, which is rarely a part of western research, also brought great challenges in the implementation of collaborative learning. They are in urgent need of experiences obtained through practitioner researches conducted by front-line teachers facing similar educational situations.

A search of "second round review" and "collaborative learning" on CNKI (China National Knowledge Infrastructure) will produce zero articles. Therefore, this study is exploratory. It will not only provide evidence for Chinese researchers to understand what useful phenomena can come about in the process of the localization of collaborative learning theory, but also enlightenment for senior high school physics teachers in Zhejiang to deal with the reform of the college entrance examination.

This study also contributes to the theory of collaborative learning through its design of a new theoretical framework: taking interaction as the key node and combining two underpinning theories of collaborative learning (constructive learning theory and social interdependence theory) to support the process of collaborative learning across different dimensions. In addition, this study explores the multiple possibilities contained in Vygotsky's key concept "zone of proximal development" and provides a new hypothesis as to the impact of collaborative learning on high ability students, the result of which is quite divergent across different literature.

As front-line teachers, I wish for collaborative learning to become a powerful teaching strategy for navigating the new college entrance examination, by helping each student make more efficient use of the second round review stage, achieving higher scores in the second college entrance examination, improving critical thinking ability and more effective collaboration. Therefore, the results of this study may offer some implications for implementing collaborative learning when teaching a large class.

1.5 Overview of the Thesis

This thesis consists of five chapters. The first chapter introduces the background of this study and puts forward the research questions. The second chapter outlines the definition of collaborative learning according to the research purpose, and then reviews the literature of collaborative learning, mainly covering the following three aspects: underpinning theory, educational effectiveness and key variables, and finally it puts forward the theoretical framework of this study. The third chapter introduces the research methods adopted in order to answer the research questions and describes the use of each method in detail. In the fourth chapter, the data collected in this study is analyzed carefully and the research questions are answered preliminarily. Finally, in the fifth chapter, the conclusions of this study and their implications for science learning are discussed in-depth.

Chapter 2: Literature Review

2.1 Introduction and Overview

This chapter will summarize the literature that guides the direction of this study and provides theoretical support for this study whilst discussing its significance within a broader context. Through dissecting the various definitions of collaborative learning found in the literature and comparing different definitions of cooperative learning and collaborative learning, this study will settle on its chosen definition of collaborative learning according to its objectives. This chapter will also summarize the general effects of collaborative learning on crucial matters such as academic achievement and interpersonal communication as well as the effects on science learning. The descriptions given in the literature on the effects of collaborative learning are somewhat different or even contradicting, and this is one of the driving forces behind this study. In other words, this study seeks to understand the impact of collaborative learning on learners in real-life environments. Furthermore, the main variables of the study are outlined as a way of providing a basis for the study, namely academic achievement, group composition, and treating interaction as an intermediate variable.

This study examines constructive learning theory and social interdependence theory, which are widely recognized in the field of collaborative learning. Regarding constructive learning theory, this chapter provides a comparison of the different views of Piaget and Vygotsky. On the face of it, their theories are seemingly polar opposites, yet there exists the potential for complementation and reconciliation. These theoretical perspectives have implications for setting of the group composition. Consequently, both homogeneous and heterogeneous groups are considered in this study. It also contends with the intricacies of the concept of "zone of proximal development" (“ZPD” for short), which lends itself to an exploration of whether retrogression in students’ development process is present in collaborative learning, in particular for higher-level students. Social interdependence theory provides guidance for setting tasks and stimulating effective collaboration.

Researchers of collaborative learning tend to rely on either constructive learning theory or social interdependence theory but there are few studies that rely on both. However, it is reasonable to state that these two theories can be integrated through an intermediate variable, namely "interaction" in order to support learning across different latitudes. Therefore, the theoretical framework of this study has been established and its aim is to explain how collaborative learning influence students' learning outcomes.

It should be noted that the literature discussed in this chapter focuses on theoretical exploration, whilst the literature on research methodology and methods will be dealt with in chapter 3.

2.2 Definition of Collaborative Learning

Dillenbourg (1999) stated that the word "collaboration" has been overused as it has become applicable to almost any situation. Moreover, he proposed the broadest definition of "collaborative learning": namely two or more people learning something together over time. There are three elements to this definition: team size and time span, so-called collaboration or cooperation, and learning with each element containing a wide range of possibilities. An illustration of this would be that a team could consist of a pair, a group of 3-5 people, an entire class, a community or even a society. Furthermore, the time span could be several hours for completing a project, or several years for carrying out a research. To continue this idea, learning can be the learning of course materials, conducting a group investigation, solving a problem, or even the learning gained from lifelong practice. Collaboration methods can be divided into face-to-face or computer-mediated synchronous communication, and asynchronous communication. This definition satisfies the requirements of most research carried out on collaborative (cooperative) learning. Nonetheless, it is challenging to describe the essence and characteristics of each individual research. Therefore, it may be beneficial and more feasible for each study to adjust the agreed-upon concept depending on its context, thereby arriving at the most suitable definition.

Most of the definitions of collaborative learning can be divided into two categories by researchers depending on their focus areas. Some researchers that are focused on students' learning define it

as a learning strategy (Lin and Yang, 2008). Johnson, Johnson and Holubec (1993) described collaborative learning as a team learning relationship that contains five features: positive interdependence, individual responsibility, interpersonal skills, face-to-face interaction and process analysis. Some researchers that focus on teachers' pedagogical strategies define it as an instructional method (Kagan, 1989; Panitz, 2003). According to Sharan (1994), collaborative learning is the general term for a series of teaching methods that organize and promote classroom teaching and are characterized by autonomy and cooperation. Chinese scholar Wang (2001) believed that collaborative learning is a teaching strategy oriented by teaching objectives that often adopts the form of a heterogeneous group, and evaluates and offers rewards according to the overall group's performance. Indeed, collaborative learning can be viewed as both a learning and a teaching strategy. As a learning strategy, it emphasizes the learner's perspective and collaboration among learners. As a teaching strategy, it focuses on how teachers utilize collaborative learning to organize classroom activities and facilitate interactions among students, aiming to achieve teaching objectives such as knowledge retention and cognitive development. However, very few researchers stress collaboration learning's importance as both a teaching and a learning strategy.

Given that this study aims to both explore the nature of collaborative learning and also the pedagogical implications for teachers, the definition laid out by Li and Lam (2013) is a more suitable definition for this study: Collaborative learning is a kind of pedagogical and learning strategy which is student-centred and teacher-led, and in which group members interact with each other to achieve common goals and exert impacts on both themselves and others' learning outcomes.

Unfortunately, collaborative learning can easily be confused with cooperative learning and vice versa. When conducting a meta-analysis, Roseth, Johnson and Johnson (2008) searched for both cooperative and collaborative learning in PsycINFO and ERIC online databases simultaneously, with the subsequent results fully illustrating the similarity of the two concepts and the considerable degree of difficulty in distinguishing them. Firstly, it must be stated that the definitions of collaborative learning and cooperative learning bear a strong resemblance and even overlap. However, as Roschelle and Teasley (1995) stated, the focus and nature of these two

concepts differ significantly and a distinction between them is therefore necessary. In cooperative learning, tasks are often split up into several sub-tasks and then assigned individually to each member of the group. Moreover, one can complete his own tasks independently without understanding or even participating in those of others, nor would one be held accountable for the completion of other team members' tasks (Roschelle and Teasley, 1995). The final step is for the tasks completed individually to be aggregated and as a result, the task is completed. To some extent, cooperative learning can be considered to be results-driven and it is usually composed of a series of specific steps (Yow and Lim, 2019). In collaborative learning, each team member usually has the same goal, therefore completing the task successfully is highly dependent on mutual engagement. Team members need to understand their level of ability within the team context, propose and innovate ideas through group discussion, and ultimately reach an agreed plan of action for solving the problem successfully (Dillenbourg, 1999; Roschelle and Teasley, 1995). By its nature, collaborative learning incorporates more social interactions, and it pays more attention to the process of mutual learning, the learning motivation and the appreciation of others' contributions (Panitz, 2003).

This study adopted collaborative learning because it emphasized shared learning goals, rather than strictly structured procedures or role differentiation. Furthermore, Bruffee (1995) proposed that cooperative learning is more suitable for learning basic knowledge and collaborative learning can better support critical argumentation and reasoning, and focus more on the learner's responsibility. Therefore, no matter considering the characteristics of the curriculum or the nature of the learning stage, it is more appropriate to adopt collaborative learning in second round review stage in senior high school physics class. More specifically, in this study, the notion of collaborative learning refers to paired collaboration or discussion of pre-assigned problems by students.

However, it is necessary to explain at this point that due to the similarity of and confusion around these two concepts, the literature cited in this chapter contains research on both collaborative learning and cooperative learning.

2.3 Educational Effectiveness of Collaborative Learning

2.3.1 General Effecs of Collaborative Learning

Many researchers have conducted in-depth research on the impact of collaborative learning on student performance and found that, as a teaching pedagogy, collaborative learning potentially has a profound impact on students' academic progress as well as their social growth (EEF, 2023; Gillies, 2016; Sharan, 2010; Slavin, 1989). This section summarizes the perceived positive effects of collaborative learning on learning ability and social abilities, whilst attempting to explain what gives rise to these positive effects. Collaborative learning also has a positive impact on psychological factors, such as improving one's self-confidence (Sharan, 2010; Tao, 2007), but there is insignificant correlation with the purpose of this study so it is not discussed in detail in this chapter. Due to its potential to cultivate students' ability to achieve a balanced development, many countries recognize the requirements of collaborative learning in their education modernization policies (Sharan, 2010). As Hattie (2009) believed, collaborative learning can make "real world differences" (p. 17).

The most scrutinized effect is arguably the impact on academic achievement. In an early meta-analysis, Johnson, Maruyama, Johnson, Nelson and Skon (1981) analyzed 122 studies (which included students of all ages dealing with various learning tasks) found that collaborative learning is more conducive to the improvement of academic achievement when compared to competitive or individual learning. This particular positive effect was found to be present across all manner of subjects (language arts, reading, mathematics, science, social studies, physical education, etc.).

Over the passage of time, the positive impact of collaborative learning on academic achievement has steadily accumulated "overwhelming evidence" (Gillies, 2016). An increasing number of studies and meta-analysis have proven that collaborative learning is an effective strategy for improving academic performance. Through a comprehensive analysis of 60 studies, Slavin (1989) found that 72% of them evidenced that collaborative learning has a positive impact on academic performance. Almost twenty years later, in a meta-analysis conducted by Roseth, Johnson and

Johnson (2008), researchers analyzed 148 research projects and came to a similar conclusion, namely that collaborative learning has a more positive impact on academic achievement than non-cooperative learning does. These results indicate that this positive impact persists and is consistent no matter the different educational policies, syllabi and teaching content, providing educators with a strong basis for their practices. Lou, Bernard and Abrami (2006) elaborated upon this positive impact. They believed that compared to more traditional classes, students received more detailed feedback and guidance from their peers which helped them to engage more actively, to self-reflect and self-regulate more effectively, and ultimately achieve academic success. Wieman (2007) further pointed out that feedback on homework is essential to ensure learning effectiveness, and in a large class, the most effective way for students to receive feedback is probably through peer collaboration, which not only makes their learning more effective, but also provides the possibility of developing meta-cognitive abilities. In addition, Allen (1976) stated that tutors also benefit from collaborative learning, as in order to ensure their ideas are thoroughly understood, they must reconstruct information from a higher cognitive perspective, which helps them to consolidate and enhance their knowledge system.

In addition to academic achievement, collaborative learning can produce better learning results across multiple other facets, such as task design, understanding concepts (Kwon and Cifuentes, 2009) and problem-solving (Arterberry et al., 2007; Barron, 2003; Damon and Phelps, 1989), whilst it also plays a significant part in the development of higher cognitive abilities such as analysis, synthesis and evaluation (Bergom, Wright, Brown and Brooks, 2011). Furthermore, the understanding of multiple perspectives when collaborating results in students becoming more mature socially and capable of understanding more complex issues and overall becoming more independent and reflective learners (Roseth, Johnson and Johnson, 2008). Moreover, some academics theorize that collaborative learning promotes intellectual development (Mercer, 2008) as children acquire and expand skills in the process of sharing ideas with others, accompanied by intellectual development (Rogoff, 2009) and the intelligence gained when studying one subject can effectively be applied to another entirely different one (Adey and Shayer, 2011).

Collaborative learning is also found to have a positive impact on the overall academic performance of a group. According to Peters and Armstrong (1998), the impact of collaborative learning is similar to that of "1 + 1 = 3". The gains earned by a collaborative group are generally greater than the sum of their individual achievements as not only are the individual contributions taken into consideration, but also the collective ones. Due to the interactive nature of collaborative learning, when peers communicate, the speaker's language and actions are understood by the listener according to the latter's background knowledge of the subject, therefore the content laid out by the speaker will then be reconstructed. The result is that collaborative learning is not just a simple superposition caused by knowledge transfer, but rather a form of joint knowledge construction.

The social effects also attract the attention of researchers (Gillies, 2016). Sharan (2010) proposed that in addition to academic achievements, collaborative learning is successful in improving interpersonal relationships, thus increasing its appeal and contributing significantly to its worldwide proliferation. In a meta-analysis of 117 studies, Johnson and Johnson (2002) analyzed several socially dependent variables, such as interpersonal attraction and social support, and discovered considerable effect sizes when comparing collaborative learning with competitive and individual learning, with this evidencing their assumption that collaborative learning has a positive impact on social factors. Furthermore, collaborative learning affords students the opportunity to learn how to listen to different views, and how to communicate and collaborate in order to achieve mutual goals (Bergom, Wright, Brown and Brooks, 2011; Sun and Zhang, 2012). Lou et al. (1996, 2006) affirmed the social benefits of collaborative learning whilst also pointing out the framework that enables such benefits, namely positive interdependence. Only when positive interdependence is established within a group will there be a requirement for authentic and effective interaction that is conducive to the development of social factors among its members (Cohen, 1994a).

The fact that the two main advantages of collaborative learning (academic achievement and social abilities) may be complementary is particularly noteworthy. Roseth, Johnson and Johnson (2008) asserted that operating under collaborative goal structures, the higher the academic progress is, the more positive the peer relationship and vice versa. A conceivable explanation for this is that the

gradual nurturing of positive peer relationships through collaboration may contribute to more effective interactions that in turn leads to higher achievement. Conversely, academic progress and the successful completion of common goals may strengthen relationships among group members and thus lead to even greater academic progress . This can be viewed as a virtuous circle of mutual bonding and success.

2.3.2 Effects of Collaborative Learning on Science Learning

Collaborative learning has also been deployed in science classes. Some researchers found that it helps improve academic performance. Bowen (2000) pointed out that collaborative learning can improve the chemistry performance of high school and college students. Karacop (2017) adopted the jigsaw method based on the cooperative learning model in physics classes and found that compared with traditional learning methods, students achieved higher performance. Tanel and Erol (2008) applied the collaborative learning strategy to the teaching of magnetism and found that it not only improved students' academic performance but also ensured the retention of knowledge. In a meta-analysis, Qin, Johnson and Johnson (1995) found that students who experienced collaborative learning outperformed those who experienced competitive learning in terms of problem solving ability. They also found that compared to linguistic problems, research on non-linguistic problems, including symbols and maths, tended to get more significant results. Similarly, Kyndt et al., (2013) conducted a meta-study and pointed out that collaborative learning should be strongly encouraged in non-linguistic courses (such as mathematics and science), because it may achieve better results in these subjects and explained that this phenomenon may be related to the nature of collaborative learning tasks. The tasks of mathematics and science are often more differentiated and hierarchical, which can better match the differences in prior knowledge of different learners. Furthermore, when compared to mathematics, collaborative learning can achieve even more obvious results when applied to science. It is found that the impact of collaborative learning on mathematics is +5 months (compared to similar students who did not participate in collaborative learning, students who participated in collaborative learning can make an additional 5 months' progress), and the impact on science is even more obvious, namely +10 months (EEF, 2023)!

Generally, collaborative learning is beneficial for science learning. Crouch and Mazur (2001) pointed out that traditional teaching was not conducive to the establishment of basic concepts of physics while Gillies (2014) believed that collaborative learning can enhance understanding and conceptual development in science classes when learners are given the opportunity to participate in discussions with their classmates and teachers. Wieman (2007) expressed a similar viewpoint and proposed using pedagogical methods that promote interactive participation in order to help students achieve higher grades in physics concept tests (such as FCI). Compared with passive participation in traditional classes, learners' active participation in communicative interaction promotes their absorption and recall of concepts (Lord, 2007), and also provides opportunities for them to gradually clarify and refine scientific concepts that were ambiguous and partial, thus gradually constructing more sophisticated understanding of scientific concepts (Roschelle, 1992). In addition, when students draw scientific concept maps, collaborative learning is more likely to result in higher-quality products than individual work (Camilli, López and Barceló, 2012). Moreover, physics often involves abstract formulae and symbols, complex scientific laws and tedious reasoning processes, making it challenging for students to understand and can easily be misunderstood. Tao and Gunstone (1999) argued that both co-construction of shared understanding and peer conflicts in communicative interaction can lead to cognitive change because when students are exposed to conflicting or new ideas, they tend to critically re-examine their own ideas and develop a higher level of understanding through discussing with partners. It is also easier for students to understand their own degree of mastery in comparison with their classmates, and they can adjust their learning methods accordingly and ultimately achieve the desired learning objectives (Zhu, 2015). Finally, collaborative learning is beneficial for the cultivation of scientific quality. Johnson and Johnson (1987) claimed that implementing collaborative learning frequently would help students become more scientific and have better self-awareness. Zohar and Nemet (2002) believed that it is beneficial for students who are interested in science to participate in the discussion of basic norms and standards of scientific work. Besides, if students want to be engaged in scientific work in the future, they will also need collaborative skills (American Association for the Advancement of Science, 1989). Zakaria and Iksan (2007) proposed that in science classes, more teachers should consider encouraging the students to discuss and elaborate their ideas with peers. Other researchers further pointed out that

students learning science should be given the opportunities to listen to what others say and consider it from multiple perspectives, to voice their opinions and accept classmates' queries and challenges. Therefore, it is necessary to create a learning environment in which students can participate critically and constructively in collaborative discussions with their peers and teachers and further reflect on their own thoughts, rather than providing elaborately designed lectures (Gillies, 2016; Karacop, 2017; Tanel and Erol, 2008).

However, students' perceptions of collaborative learning are varying. Luis, Julia and Francisco (2017) found that despite the fact that active learning can promote a better learning effect in terms of scientific concepts and principles, students may still feel insecure and uncertain about the effect of this method, and they feel safer in a traditional lecturing class. This may lead to obstacles to the implementation of collaborative learning in science classes as students are unwilling to be forced to participate in interaction and do not like the increased responsibility for their own learning (Louis et al., 2019).

2.3.3 Review of Related Research Design

This study aims at carrying out collaborative learning in high school physics classes. There are quite a few examples of similar research. Some small-scale studies yielded results that favor collaborative learning. Jabee, Kalsom and Khanam (2020) randomly divided 60 10^{th} grade female students from public school into two equal groups. Students in the experimental group formed heterogeneous groups and underwent collaborative strategy (STAD and Jigsaw), while the control group received traditional teaching. After an 8-week physics course, it was found that collaborative learning has a more significant effect on improving students' performance. Eshetu, Gebeyehu and Alemu (2017) also researched 10th grade female students in public schools. After the Pre-test, students were randomly divided into two groups (30 in each group). The research found that compared to HAAs, collaborative learning was more effective for LAAs. Fong and Boo (2007) conducted an action research on 41 students in high school physics classes. The 8-week study found that collaborative learning improved academic performance and understanding of physics concepts as well as increased learning motivation. The study also found that lower ability

students and ethnic minority students typically benefited more. However, the limitations of the sample size and the homogeneity of the study population in terms of gender may cast doubt on the reliability of the results and the generalizability of the findings.

Some researchers conducted larger scale studies. Keramati's (2010) study on the impact of collaborative learning on academic performance targeted 220 high school students aged 15-16, and found significant differences in favor of the experimental group. In a quasi-experimental study, Gamabri and Yusuf (2014) investigated the effects of computer-supported collaborative strategies on 167 secondary school students from 4 intact classes. They found that those who attended collaborative learning outperformed those who did not. They also found that both gender and achievement level affected the performance. Adeoye (2010) also conducted a quasi-experimental research on 141 senior secondary students and found that collaborative learning not only led to higher achievement but also improved ability of problem-solving. The larger sample size make the conclusion appear more convincing, yet there remain concerns as to whether this sample is sufficiently representative to generalize its findings to a broader population of high school students.

There are also studies on other stages and subjects. Ballen, Wieman, Salehi and Searle (2017) conducted a study on STEM introductory courses, which included over 250 URM (underrepresented minority) students. They found that, compared to traditional teaching, active learning strategies (including collaborative learning) narrowed the learning gap between non-URM and URM students, and improved students' self-efficacy in learning. Besides, Muraya and Kimamo (2011) conducted a 5-week Solomon four-group design for 183 middle school students in biology classes. Their study found that the improvement in average score of the experimental group implementing collaborative learning was significantly higher than that of the control group implementing traditional teaching, and gender had no significant impact. Similarly in high school biology classrooms, Yaduvanshi and Singh (2019) conducted a study involving 63 students, aiming at exploring the impact of structured cooperative learning strategy (STAD methods) on the performance of students with different ability levels. The results showed that

students who received STAD strategies performed better in the cognitive fields of knowledge understanding and application.

Research conducted across various disciplines and stages has deepened our comprehension of the impact of collaborative learning in science teaching. Nevertheless, the majority of these studies have utilized pre-existing measurement questionnaires, such as the FCI, or periodic unit tests to evaluate learning outcomes. Rarely has the effectiveness of collaborative learning been examined in significant high-stakes exams, such as the college entrance exam or other significant assessments that determine students' progress to the next stage of education.

2.4 Theories Underpinning Collaborative Learning

In order to gain an in-depth understanding of the operational mechanisms of collaborative learning, it is necessary to comprehend the relevant underpinning theories.

2.4.1 Constructive Learning Theory

2.4.1.1 Social Interaction in Learning

Constructive learning theory originated from the study of children's cognitive developmental theory and effectively demonstrates the way in which learning occurs, how meaning is constructed, how concepts are formed, and what the main factors are in constructing an ideal learning environment. Most subscribers to this theory accept the following consensus: learners build their knowledge by themselves, learning new things depends on one’s existing knowledge level, social interaction promotes learning, and meaningful learning occurs when dealing with real tasks and situations. Nonetheless, each strand of constructivism emphasizes different concepts.

It is reasonable to consider Piaget’s cognitive constructivism and Vygotsky’s social constructivism as the two pivotall strands in constructive learning theory (Leach and Scott, 2003). Piaget was the founder of genetic epistemology and he believed that the most influential factor in the development of children's psychology is the nature in which children continuously mature. During the process of interacting with society, they are exposed to all sorts of experiences, they

are compelled to constantly coordinate and construct, and gradually they complete their psychological schema from low to high level. Given that knowledge is constructed by the learner, learning is ultimately an internal and active process that children must navigate. The function of education is to enable individuals to adapt to society, therefore it should work in tandem with the characteristics of a child's psychological development, and support children to increase their own ability using the most appropriate methods. In accordance with this, Piaget realized how crucial social interaction is, especially peer interaction, for children's development in their logical and reasoning ability. He affirmed that when children encounter contradictory views when interacting, the cognitive conflict that emerges helps promote children's cognitive development (Yu, 2005).

As the founder of socio-cultural theory, Vygotsky was acutely aware of the role that both culture and society play in the process of cognitive development. His contention was that lower levels of psychological functions can be reorganized to form higher levels of psychological functions, and this necessitates a person controlling his own behaviors. An illustration of this hypothesis is that passively remembering is a lower form of memory, while consciously controlling one's behavior in order to remember is a higher form. Moreover, it is through interacting with the environment and the mastering of cultural symbols that people develop their ability to self-regulate and self-control, and this is illustrated by Vygotsky when he states:

> The basic characteristic of human behavior in general is that humans personally influence their relations with the environment and through that environment personally change their behavior, subjugating it to their control." (Vygotsky, 1978: p. 51).

Therefore, like Piaget, Vygotsky concurs that social interaction is critical in human development. Vygotsky also concluded that higher mental functions like the ability to reason and solving problem are not natural but instead gradually develop through one's internalization of external social interactions. In spite of the meaning of the constructed knowledge being subjective, it is not constructed at will, but rather through constant consultation, coordination and correction through interactions. Social interaction allows us to gain a more profound understanding of each other, as well as ourselves and to establish many different skills (Amhag and Jakobsson, 2009). In

particular, Vygotsky believed that interacting with more competent peers is beneficial for cognitive development.

Despite the mutual views on the importance of interaction, they are fundamentally different in many ways. Firstly, they have differing views on the issue of thinking and language in interactions. Vygotsky stated that social interaction is mainly mediated by language. It was Watson (1920) that first defined the relationship between thinking and language. Through the lens of behaviorism, he was of the opinion that that thinking and language are essentially identical in nature, namely that thinking is silent language, and language is sound thinking. Piaget evidently held a different view and from the perspective of children's cognitive development, he proposed that thinking and language are different from each other in the way they occur as thinking originates from action, while language is derived from learning. Language is seen as conducive to the development of symbolic thinking, but it cannot substantially improve one's level of cognition and intelligence. Therefore, Piaget's theory considers the importance of language to be negligible, whereas for Vygotsky, language is inseparable from thinking (Mercer, Dawes, Wegerif and Sams, 2004), and is also an important psychological tool in cognitive development. Vygotsky categorized language in three ways: external speech, egocentric speech and internal speech. Egocentric speech is the transition between external speech and internal speech, and it improves the consistency of children's internal and external speech. As a result, the correlation between external and internal speech increases, and the way they are expressed is identical.

Secondly, these views that are seemingly in accordance have significant differences when it comes to the role of interaction in children's development. Piaget believed that people learn from cognitive conflicts that are stimulated by interaction but afterwards they construct and reconstruct one's knowledge system in their inner conscience , thus demonstrating that the basic motivation of learning arises from learners themselves. In other words, it is a child's active construction of knowledge that interaction generates, rather than the interaction itself, and this is essential to their cognitive development. In contrast, although Vygotsky also admitted that a child's cognitive development is a process of construction, he opined that it is not a process led by the child himself but it instead originates from social activities. Furthermore, he suggested that individuals learn and

construct knowledge entirely through the process of interaction. Therefore, Vygotsky's point of view, is that interaction should be regarded as the most important factor in children's development. The interaction between children and others, especially those with higher competency, connect children to "the world-to-be-learned-about" (Mercer and Littleton, 2007), thus the nature of learning must be social and cultural.

Although Piaget's research focused more on an individual's construction of knowledge while Vygotsky's placed more emphasis on the role of culture, language and social background, both asserted the importance of interaction. Their differing views on the function of interaction aroused my research interest. Therefore, this study views interaction as a crucial variable and further discussion will take place later in this chapter.

2.4.1.2 "ZPD" and Cognitive Conflict in Children's Development

Vygotsky suggested that every child, no matter the field, has a maximum level of development that is determined by their individual problem-solving ability, and a level of potential that can be reached with the guidance of an adult or a more competent peer. The gap between these two ability levels is the "zone of proximal development" ("ZPD" for short) (Tudge, 1992). The "ZPD" indicates a child's possibility for future development. Education should set its sights beyond a child's actual level to enable them to accomplish their "ZPD" sequentially through a series of logical and hierarchical steps, with this process being named after a terminology in architecture- "scaffolding". The purpose of scaffolding is to help decompose complex learning tasks in accordance with the relevant learning situation and the students' ability level and to offer appropriate clues or prompts bit by bit, so as to gradually equip learners with in-depth understanding. Through these measures, students gradually master the knowledge they require, improve their problem-solving ability, and develop into independent learners. In education, "scaffolding" permits children to accomplish tasks they would not otherwise have done if left to their own devices (Wood, Bruner and Ross, 1976).

Cognitive conflict emphasized by Piaget is a psychological state caused by an individual's awareness of the inconsistency between one's cognitive structure and the environment, or

within one's cognitive structure (Huang, 2013; Zhou and Li, 2019). Stimulation of cognitive conflict is considered to be a common pedagogical strategy to promote conceptual change (Limón, 2001). In collaborative learning, cognitive conflict occurs when collaborative partners hold different information or opinions (Smith, Johnson and Johnson, 1981). However, Mitchell, Nicholas and Boyle (2008) pointed out that merely disagreement or inconsistency is not enough to stimulate conceptual change: discussion or even debate of rival hypotheses or opinions is also essential. As far as Piaget was concerned, the necessity to resolve conflict and reach a collective consensus will encourage learners to look for more sophisticated solutions, thus leading to knowledge creation and conceptual change (Akpnar and Aydodu, 2009; Jehn et al., 1997). In this way, cognitive conflict is constructive and has beneficial value for learning (Shi and Du, 2008). Moreover, conceptual development can also take place during one's self-reflection after discussion. Nevertheless, Piaget stressed that genuine cognitive change is more likely to happen when children collaborate with equal peers. When children interact with adults or more capable peers, the interaction may be dominated by the more powerful partner and children are inclined to conform in front of someone with higher status (Piaget, 1965).

Vygotsky and Piaget 's perceptions do differ fundamentally. For Piaget, it is the cognitive conflict that arouses and supports a child's cognitive development, therefore he stressed the importance of homogeneous group interaction. However, even when the so-called homogeneous group is made up of children that have similar intelligence levels, there are still differential factors at play, such as different ways of thinking (convergent thinking or divergent thinking). In reality, there must exist asymmetric factors or else cognitive conflicts are implausible (Dillenbourg et al., 1995). Yet for Vygotsky, helping children within their ZPD is of the utmost concern, thus he focused on adult-child and heterogeneous group interactions.

Nonetheless, it is noteworthy that some researchers believe these viewpoints to be totally contradictory, while others claim that they complement each other (Shayer, 2003). Early studies on collaborative learning were primarily based on Piaget's theory, among which the conservation experiment was the most significant and is worthy of discussion. Compared to traditional training, it is more straightforward for non-conservers to develop the concept of conservation through

collaborative learning. Moreover, the success of these experiments supports Piaget's theory with new Piagetian scholars believing that the difference in perspectives between conservers and non-conservers helped inspire cognitive conflict and in turn contributed to cognitive development. However, the view of Vygotskian scholars is that the conservers, as more capable partners, offered scaffolding help within the non-conservers' ZPD and both groups achieved a higher level of cognition through collaboration. Comparing these two perspectives in the course of studying the function of interaction and the effect of collaborative learning is critical. However, it is reasonable to ask questions on whether it is cognitive conflict or scaffolding that plays a greater role in learning and how either of these affects students' cognitive development. This study will explore the above questions using the participants' experiences recorded though classroom observations, surveys and interviews.

2.4.1.3 Consideration of a More Complicated "ZPD"

Sociocultural studies usually focused more on how the more competent peer can exert influence on the less competent one, no matter whether is an adult-child interaction or a peer interaction. They usually treat the adult (or the more competent peer) and the learner (or the less competent peer) differently, namely by neglecting the impact of the interaction on the former, whether intentionally or unintentionally, as though the state of the less competent peer is immaterial. However, the less competent peer may also be actively engaged in the interaction thus contributing to learning outcomes amongst other things, and in turn having an impact on the more competent peer (Mercer and Littleton, 2007). Furthermore, one essential characteristic of a genuine dialogue is equality, and the idea of equality demands consideration of both sides. Merely focusing on either side cannot portray the evolving, interactional nature of collaborative learning (Pea, 2004). One may look at this from another angle and seek to understand how the interaction influences the more competent peer.

Learning is a complex process and children's development is highly sensitive to context, thus one should ascertain the circumstances in which we discuss the notion of "ZPD" (Newman, Griffin and Cole, 1984). Vygotsky contemplated "ZPD" in the context of school-based instruction, a scenario that is mainly beneficial for children's development, and as a result he focused on the

child's progress. Yet when he studied disabled children, he conceded the possibility development taking place in more than one single setting (Tudge, 1992).

Considering first the interaction between teachers and students, "ZPD" is also applicable to teachers due to the uncertainty caused by an interaction. Furthermore, there is a relevant Chinese saying, namely that 'while educating others, you can also increase your own knowledge' thus illustrating that the effects of the interaction are mutual and students' behavior also has an impact on the teacher.

In a heterogeneous group, the more competent peer sometimes plays the part of a novice teacher. Some research has led to positive findings for more competent peers, namely that in peer collaboration, a more competent child has the possibility to make progress through collaborating with a less competent one. In research conducted by Mugny and Doise (1978), it is concluded that both the non-conserver and the partial conserver made better progress. Mugny and Doise offer an explanation for the latter's progress when suggesting that opposing ideas proposed by one's partner can arouse cognitive conflict and force one to gain a more mature understanding or a better solution, and so the partial conserver reconstructs their knowledge system and therefore becomes a conserver. Allen and Feldman (1973) experienced similar results in research conducted on older children educating younger children in a family, with both the young "teacher" and the "student" being deemed to have made progress. Furthermore, Cohen (1994a) pointed out that collaborations offer opportunities for high ability students to elaborate on their views which is beneficial for their learning.

On the other hand, other researchers were met with concerning results. Tudge (1992) found that even though the less competent peer made progress (progress means more advanced practices or development in thinking and level), the more competent peer regressed (regress means less advanced practice or regress in thinking and level). He concluded that when more competent peers lacked confidence as they were not able to receive feedback from "experts", they tended to be negatively influenced by the immature ideas advanced by their less competent peers, thus leading to a decline in cognition. Furthermore, he stated that the existence of a drop in academic

performance in collaboration indicated that Vygotsky's "ZPD" should not be recognized as a concept that extends in a single direction but rather as a notional area around a child's actual level of development as the developmental process is not unidirectional but rather contains multiple possibilities. The existence of this area demonstrates the complex and diverse possibilities in a student's development (Tudge, 1992), and as a result means that children's ability either improves or regresses according to different situations and interactions (Messer, Joiner, Norgate, Light and Littleton, 1992).

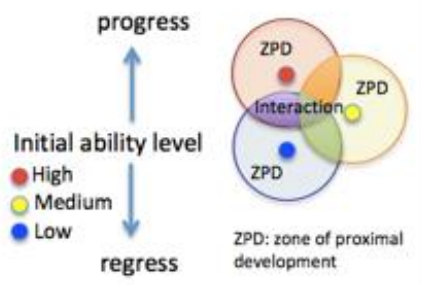
The behaviors of "ZPD" and "scaffolding" are closely related. Bruner (1978) had an appreciation for this terminology and claimed it to be effective in focusing on the most relevant learning possibilities and helping children focus on obtaining the complex skills required for problem-solving. However, in peer collaboration, as the more competent peer is not a professional teacher, the "scaffolding" behaviors are often unplanned or unconscious. Newman, Griffin and Cole (1989) argued that scaffolding behaviors displayed by more competent peers should be perceived as a process of negotiation, rather than a "pre-fabricated climbing frame". The static picture implied by the original meaning of this terminology does not sufficiently reveal the dynamic process that is interaction. In addition, the existence of negotiation suggests influence on both sides and merely focusing on only one side cannot portray its interactive and evolving nature.

Given that the scaffolding process can also influence the more competent peer, one may be inclined to ask whether the overall effect is positive, or under what circumstances is it possible for a child to regress. Tudge (1992) outlined that if the information provided to children is far beyond the scope of their cognitive ability, in other words, it is not in their "ZPD", cognitive development is highly unlikely to occur. Similarly, if the information is within the scope of a child's current cognitive ability, it is unlikely to cause a drop in academic performance. However, when a child does not fully understand pieces of knowledge or his knowledge system is still in the process of maturing, collaborating with a less competent partner without effective feedback from an authority figure such as a teacher may have a negative impact on the former, or even lead to a drop in academic performance.

Mercer and Littleton (2007) echoed Tudge's notion by extending the concept of "ZPD" to IDZ (inter-mental development zone), which is defined as a dynamic, highly contextualized "bubble". During the dialogue, both sides constantly coordinate their thinking and activities in order to establish this harmonious "bubble"-IDZ. When Mercer and Littleton (2007) presented the bubble image, they placed greater emphasis on the interactive process of joint thinking and mutual construction. If the dialogue is unsuccessful in maintaining harmony between the participants' minds, the bubble will burst and the scaffolding support will collapse.

The bubble imagery is quite interesting as it not only exists at the time of the interaction, but it can also be used to express the potential developmental direction of the ability level of the learners participating in said interaction. Given that this study includes high, medium and LAAs, a suitably refined bubble image is presented below. As shown in figure 2.1, the center of each bubble represents one's current capability level and the boundary describes one's potential area of development ("ZPD"). The bubble implies multiple possibilities of development process. In collaborative learning, there are overlapping areas in the bubbles of students with different ability levels. These areas represent the students' common knowledge and experience where their thinking and consciousness interact and through which one's ability may either improve or regress. In order to understand the complexities of children's development process and to test whether possibility of a drop in academic performance is evident in academic achievement in collaborative learning, this study will focus on HAAs who collaborate with LAAs. If this effect is indeed found, to a certain degree, it may have a negative impact on the implementation of collaborative learning, as the potential for a drop in academic performance potentially being established may lead to ethical problems in the encouragement of HAAs to participate in collaborative learning.

Fig 2.1 A refined bubble image to illustrate multiple possibilities in the development process for students with different ability levels



2.4.2 Social Interdependence Theory

Although a large amount of research that is supported by constructive theory has achieved the expected results, namely the affirmation of the positive influence of collaborative learning, and the promotion of interaction as a key method to improve students' performance and cognitive development, some researchers point out that the research carried out in these laboratories is unlike real-life learning in school. Interaction that lacks mutual goals (goal interdependence) or joint rewards based on group performance (reward interdependence) might encounter difficulty in stimulating effective collaboration or revealing the advantages of collaborative learning when compared with traditional classroom teaching.

Social interdependence theory is widely used by researchers in the field of collaborative learning due to its promotion of this learning strategy. Social interdependence theory originated from Gestalt psychology and Kurt Lewin's group dynamics theory, whilst it was first formally proposed by Deutsch (1949), and later developed and perfected by the Johnson Brothers to constitute a systematic theoretical system. Its belief is that merely arranging students into groups and asking them to learn together does not necessarily result in effective collaboration. Instead, it emphasizes the role of goal and reward interdependence on collaborative learning.

In 1984, the Johnsons proposed three categories of goal structures in class: collaborative, competitive and individualistic. A collaborative goal structure stipulates that a group only achieves its goal once each member has successfully completed his or her own learning goal. In other words, the success of others is beneficial to one’s own. In contrast, in a competitive goal structure, the success of others can have a negative impact on an individual's chances of succeeding. Lastly, in an individualistic goal structure, there is no correlation between individual success and the success of others. Among the three goal structures, the collaborative goal structure is considered conducive to authentic collaborative learning. Because it is only when there is positive interdependence driving individuals’ goal attainment that students will be motivated to interact and learn together and this interaction will further affect the learning results (Johnson and Johnson, 2005).

Social interdependence theory also specified that groups should be rewarded according to group performance, rather than individual achievement, as it both stimulates students' motivation for effective collaboration as well as promoting individual accountability. More specifically, each student's learning demands are stimulated because their learning outcome influences the group's success and one will therefore feel liable to maximize their efforts (Johnson and Johnson, 2009). Moreover, it motivates one's intent to help their partner and make sure that the latter is also performing optimally. This ensures that an individual's interest is closely related with those of others (Slavin, 1987) and as a result students may establish stronger relationships with their peers in a collaborative learning setting, compared to competitive and individual learning environment. Collaborative learning goals and group-based rewards not only promote positive interdependence within collaborative groups, but they also succeed in improving the results of collaborative learning, such as learners' academic achievement. Deutsch (1962) and Slavin (1987) pointed out that the dynamic change inherent in interdependence strongly influences the behavior of each participant in the interaction and the pattern of interaction in turn significantly affects the learning outcome (Johnson, Johnson and Holubec, 1984). In a meta-analysis of cooperative/collaborative learning conducted by Johnson and Johnson in 2009, it was found that there is a positive correlation between collaborative goal structures and positive peer relationships, and an even more positive correlation between positive peer relationships and academic achievement, however the latter is in an indirect way, namely through collaborative interaction.

As illustrated above, social interdependence theory provides an important theoretical support, similar to cognitive developmental theory, for collaborative learning and it has inspired two themes of this study: one is the importance of creating collaborative goals and a group-based reward mechanism; the other one is the importance of interaction.

Within this context, supporting and encouraging positive interdependence does not signify a complete denial of the value of competitive or individual work. Rather, it is a widely held belief that modern competition is no longer a binary "win-lose" competition, but alternatively is a higher level of cooperative competition. This competition emphasizes seeking collaboration based on learners' respective competitive advantages, and on forming stronger competitiveness through

collaboration, thereby achieving a "win-win" situation (Zheng, 2009). Therefore, some competitive activities between groups will be arranged for this study with the purpose of promoting cohesion and motivation for collaboration within the group.

This study is also supported by the five basic elements of collaborative learning as proposed by Johnson and Johnson (1990). The first element is positive interdependence, as illustrated earlier. The second is personal accountability. Each group member's performance should be evaluated, and feedback should be provided to both the group and the individuals. The third is face-to-face promotive interaction. For students, their cognitive activities and interpersonal dynamics only occur through the process of mutual learning, with the smaller the group size, the more promotive the interactions. Some researchers suggest that collaborative learning in pairs is the best method for promoting dialogue. It is worth mentioning here that in Chinese classes, students are seated in pairs and they are as a result familiar with the aforementioned relationship, therefore this study adopts the minimum unit of collaborative learning, namely a collaborative pair. The fourth element is social skills. These essential skills are not innate and students should be taught and encouraged to use it in practice if there is to be effective and authentic collaboration. Moreover, teachers should emphasize the importance of social skills and pay attention to the students' performance. I found this element especially indispensable as Chinese senior high school students are not afforded significant teamwork experience, thus leading to a lack of ability in interpersonal communication. Therefore, before the beginning of the formal study, there will be a preparatory period aiming at training and practicing on social skills, so as to ensure the effectiveness of collaborative learning. The final element is group processing which has not been explored in this study because of the limited time supplied in the second round review stage.

2.5 Variables of Collaborative Learning

2.5.1 Academic Achievement Level and Group Composition

In Chinese schools, academic achievement is generally seen as the paramount goal, especially for senior high schools facing the pressures of the college entrance examination. In fact, this pursuit for academic achievement is mirrored by schools in western countries (Roseth, Johnson and

Johnson, 2008). According to researches on collaborative learning, academic achievement level is a crucial factor as when students with different academic achievement levels interact, the effects of collaborative learning on each level can vary significantly.

Group composition is another common concern and it has been established that there are significant differences in learning outcomes between heterogeneous group and homogeneous group (Slavin, 1996). A complicating factor is that the concepts of heterogeneity and homogeneity contain a variety of information about the participants, including academic performance, personality, gender, nationality, problem-solving style and etc. and different researchers pay attention to different aspects.

Many researchers perceive that heterogeneous groups are more conducive to effective collaborative learning. In an early study, Hoffman and Maier (1961) found that the number of high-quality solutions produced in heterogeneous groups with different personalities and genders was substantially higher (about three times that of homogeneous groups). Kurtzberg and Mueller (2005) found that diversity of problem-solving styles stimulated greater creativity in collaborative groups. Some researchers even incorporating "heterogeneous" as a rationale for grouping. Watson and Marshall (1995) state that heterogeneous grouping of students is commonly adopted in relevant researches and heterogeneity should be included in the definition of collaborative learning. Chinese researcher (Liu, 2012) made similar claim that heterogeneous groups is the basic organizational structure of collaborative learning.

Nevertheless, some studies have found that homogenization also positively impacts the results of collaborative learning (Pluut and Curşeu, 2012). On a study on the effects of cultural diversity, Staples and Zhao (2006) found that compared with heterogeneous groups, homogeneous groups have stronger intent, higher cohesion and experience less conflicts, but there is no significant difference in academic performance. A possible combination or neutralization to ensure effective collaborative learning is that intra-group heterogeneity and inter-group homogeneity (Pei, 2000).

Since Vygotsky focused on the "scaffolding" behaviors of a more competent peer, he tended to study heterogeneous groups. However, Piaget asserted that cognitive conflict itself is sufficient for children's development and it is even possible that "two wrongs can make a right" (Dillenbourg et al., 1995), therefore there is no requirement for a more superior view to be present. Children with the same cognitive development level but differing opinions can both nonetheless benefit from the conflict. As a result, Piaget focused more on homogeneous groups. One might reasonably ask whether it is "scaffolding" behavior or "cognitive conflict" that facilitate children's development, with this issue seemingly placing Piaget's and Vygotsky's theories on opposing sides. However, these two theories focus on different scenarios, and in some cases, one's strength complements the others' weakness (Cole and Wertsch, 2010). Therefore, it is perhaps imprudent to eliminate homogeneous grouping from the definition of collaborative learning, subsequently this research will take both group compositions into account.

Previous studies indicate that the homogeneity or heterogeneity of collaborative groups will have differential effects on the results of collaborative learning. However, as the composition of the group contains many potential variables, there needs to be a limit to the concept of homogeneity and heterogeneity to guarantee the feasibility of this study. In most high school classes in China, students are relatively consistent in terms of their age, nationality and social class. Moreover, in the second round review stage, particular attention is paid to academic performance. Therefore this study will only consider the academic level as the basis for defining homogeneous and heterogeneous.

Considering both academic achievement and group composition, it has been demonstrated that different group compositions have distinct influences on students with different academic achievement levels. In an early meta-analysis, Lou et al. (1996) proposed that for low academic level students, learning as part of a heterogeneous group may result in better academic achievement whereas for MAAs, homogeneous groups may be a more suitable environment. Swing and Peterson (1982) found similar result that heterogeneous collaboration improved the academic achievement of all students except for MAAs. An possible explanation is that when MAAs are in heterogeneous groups, they are neither as competent at being tutors as HAAs, nor as

fitting tutees as LAAs are, with this ambiguity in role assignment usually resulting in unsatisfactory performance (Swing and Peterson, 1982). with regard to the performance of high academic level students, opinions differ greatly. Some claimed that HAAs achieved clear progress in achievement both in homogeneous and heterogeneous groups (Saleh, Lazonder and Jong, 2005), while some stressed the possibility of a drop in academic performance in thinking in the latter (Tudge, 1992).

2.5.2 Interaction

Slavin (1987) combined several main theories including motivation theory and developmental theory to construct theoretical framework, aiming to explore the role each theory played in the process of collaborative learning. During the establishment of his theoretical framework, he underscored the importance of interaction. Tudge (1992) did likewise when he advised researchers who are interested in collaborative learning that due to the various possibilities of the development process, it is wise to pay more attention to the interaction itself by exploring what transpired rather than making great effort to find a causal relationship in collaborative learning, as these efforts tend to be in vain.

The quality of interaction has been found to be closely related to learning outcomes (Barron, 2003). More specifically, the nature of interaction is influenced by initial variables such as academic achievement level and group composition, yet interaction has a more direct influence on students' learning outcomes.

Due to the importance of interaction, we should ask the question of which perspectives to study interaction from. Different researchers with different focuses have separate views on this problem. Webb (1985) concentrated on the correlation between group behavior and academic performance and also divided interactive behaviors into "group helping, giving help, receiving help, off task behavior, passive behavior and nonspecific". Slavin (1987) proposed several types of interactions according to the nature of the learning activities, namely peer tutoring, peer modeling, peer practice, peer elaboration, peer assessment and correction. Webb, Troper, and Fall (1995) instead

emphasized engagement and defined its three levels, specifically high, medium and low, with high-level activity being a predictor of high achievement. Later in 1998, Webb et al. proposed that the quality of the discussion should be judged from both the level of answer accuracy and the quality of the explanations generated, whilst emphasizing that the provision of correct answers without detailed explanations has a negative impact on learning outcomes. These researchers all perceived interaction as a vital intermediate variable and they explored it based on fixed patterns, types or levels. However, one must explore whether there are any other perspectives.

From the perspective of supporters of constructive learning theory, fixed patterns, types or levels can be deconstructed into more fundamental elements. In science, string theory is a promising theory in terms of its unification of the four fundamental forces. Its principal idea is that the basic units of the universe are not particles like electrons, protons and quarks, but rather these particles are composed of tiny "strings" with different vibrations. In a similar vein, the concepts of cognitive conflict, “ZPD” and the scaffolding behavior from developmental theory can be regarded as fundamental "strings" that are critical for children’s development, and interactions can be viewed as particles that are formed by dynamic changes and interrelationships amongst these fundamental concepts. Therefore, this study will also investigate scaffolding behavior and cognitive conflict and take them as a focus of this study, so as to deepen the understanding of interaction as well as the effect of constructive learning theory in supporting collaborative learning.

Ultimately, interaction should not be considered a black box. Since it plays a significant role as an intermediate variable in collaborative learning, the process of interaction should instead be open to deliberation and studied thoroughly (Cohen, 1994a). This is the only way in which we can understand how collaborative learning influences students’ learning outcomes.

2.6 Conclusion and the Theoretical Framework of the Study

This chapter discusses relevant literature on collaborative learning. Firstly it compares definitions of collaborative learning and cooperative learning, and confirms the appropriate definition

according to the focus of this study. Through the literature review, it has been established that collaborative learning has the potential to positively influence academic achievement and social skills, these also being crucial facets of this study. Combined with the study of real-life scenarios, it has asserted academic achievement level and group composition as the main independent variables of this study, as well as treating interaction as an important intermediate variable.

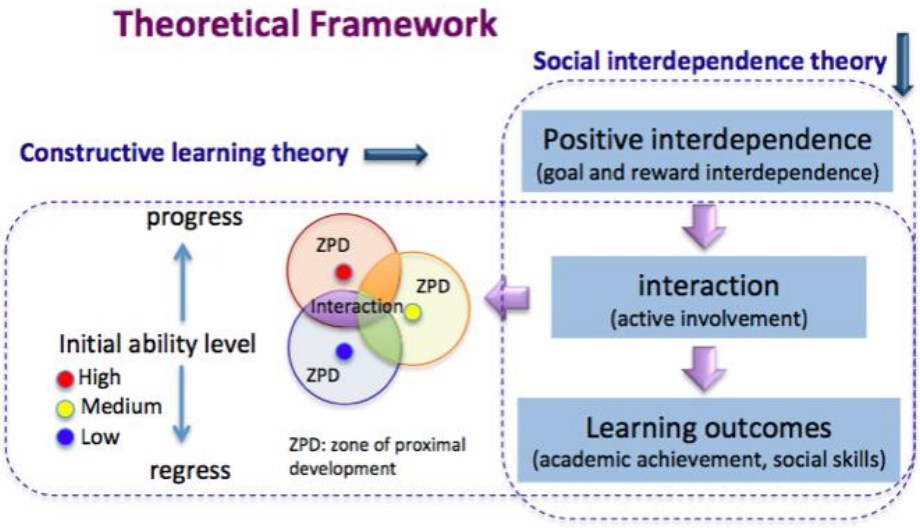
Amongst all the theories underpinning collaborative learning, this chapter mainly discusses constructive learning theory and social interdependence theory. Piaget and Vygotsky, two important figures in constructive learning theory, both focused on interaction in the context of collaborative learning. Through the discussion of Piaget's cognitive conflict theory and the scaffolding concept inspired by Vygotsky, this paper demonstrates that these two seemingly contradictory perceptions can be reconciled. Both can be used to understand students' learning and cognitive development through interaction, albeit from different perspectives. Vygotsky's concept of "ZPD" is capable of being developed into a bubble centered on students' current level. Furthermore, when HAAs collaborate with LAAs, there is the potential that the former may withdraw from proceedings, thus indicating the complexity of the development process. Another crucial theory, social interdependence theory, offers the foundation for the occurrence of effective interaction by promoting collaborative interdependence. It underlines the incentives stimulated by goal and reward structures and also individual accountability, with its objective being to promote active involvement in interaction and more effectiveness in collaborative learning. Although interdependence has no direct impact on students' learning outcomes, it influences the nature of the interaction. For instance, in a competitive environment, individuals tend to strengthen their own ability whilst weakening that of others, resulting in less communication and resource sharing. Moreover, influenced by the fierce competition for academic achievement, senior high school students usually have low motivation for collaborating, therefore positive interdependence is crucial in senior high schools to promote effective collaborative learning (Slavin, 1987). However, merely providing incentives stimulated by positive interdependence is insufficient, it is instead through effective and intense interaction that students make progress, and the support of constructive learning theory to interaction is still crucial.

In summary, neither constructive learning nor social interdependence theory can alone sufficient support for research on collaborative learning. In actual fact, these theories focus on different dimensions. The goal and reward interdependence that social interdependence theory accentuates must be established before formal collaborative learning takes place and must also be emphasized during the process. This would stimulate individual accountability and motivation for active collaboration which can only be beneficial for students' learning when interacting. Meanwhile, constructive learning theory investigates students' specific behaviors and their discussions in interactions and also how the nature of the interaction can influence students' learning. Evidently, the mutual point of these two theories is the interaction (Cohen, 1994a).

All things considered, this study adopts an adjusted model combining social interdependence theory and constructive learning theory as its theoretical framework, as shown in figure 2.2. Vertically, appropriate means, such as collaborative task design and collaborative skill training, will be utilized to establish positive goal and reward interdependence (Slavin, 1987), ensuring students' active involvement in interaction, with the interaction further impacting students' academic achievement. Horizontally, the initial academic achievement level and group composition are key factors that influence interactions. Within the interaction, cognitive conflict and scaffolding behaviors may occur and have an impact on the learning. The bubbles represent the possible range of each student's development with the possibility of progress or decline. Interaction, as an important intermediate variable in collaborative learning and the key point in connecting social interdependence and developmental theories, must be explored extensively.

Accordingly, both quantitative and qualitative analysis will be needed. Quantitative analysis is mainly conducted on learning outcomes. But to gain a deep understanding of the interdependence between group members, various factors in interaction, and how they affect learning outcomes, qualitative analysis is required. For a pedagogical reform, it is also important to investigate the learners' perceptions, which is mainly achieved through qualitative analysis.

Fig 2.2 Theoretical framework of the study (each of the three bubbles represents a student with high, medium and low achievement level)



To some extent, this study makes its own theoretical contribution by combining two basic theories of collaborative learning (constructive learning theory and social interdependence theory). Most studies are either based on constructive learning theory, or exhibit firm support for social interdependence theory whilst few attempt to integrate the two. As illustrated earlier, both theories have strengths and shortcomings and neither of them hold up the process of collaborative learning alone. Social interdependence theory pays more attention to the promotion of collaborative interdependence, thus contributing towards the effectiveness of interaction, but it is relatively weak when it comes to studying the factors in interaction that really promote students' development. In contrast, constructive learning theory deeply explores how collaborative interaction affects learning outcomes, but without the formation of positive interdependence, it is a challenge to ensure the effectiveness of the interaction. Furthermore, these two theories focus on different dimensions of learning, with their intersection being the interaction within collaboration. Therefore, these two theories should be integrated to build a more comprehensive and effective theoretical framework. The results of this research that is based on this new theoretical framework will generate an understanding of the feasibility of the integration. Furthermore, a new concept of "ZPD" is proposed on the basis of Mercer (2007)'s bubble image, expanding on the traditional concept of "ZPD" by indicating multiple possibilities in a learner's development. This study investigates the performance of students with different achievement levels, and it is particularly concerned with whether there exists the possibility of a drop in academic performance when HAAs collaborate with lower-level partners. This will help to form a more comprehensive

understanding of "ZPD", as well as providing pedagogical implications for teachers who wish to carry out collaborative learning.

Chapter 3: Methodology

3.1 Introduction

This study's main focus is on how the implementation of collaborative learning influences students at the second round review stage of senior three, specifically students' academic performance in the second college entrance examination and their learning of science. The data collected in this study includes the results of college entrance examinations, notes from classroom observations, survey data and recordings of semi-structured interviews.

The first part of this chapter introduces the ontology and epistemology of this research. In order to ensure internal consistency, this research fully examines the nature of the topic and has adopted the pragmatic paradigm and a mixed methodology. Moreover, the preparation for this study is discussed, namely the participants, the pre-test, the grouping, the task design, the guarantee of positive interdependence, and the practicing of collaborative learning skills. Thereafter, it focuses on each method that has been adopted in this study, such as classroom observation, audio recording, score analysis, surveys and interviews, and discusses the reliability and validity of these methods. Lastly, ethical issues are considered.

3.2 Ontology, Epistemology and Methodology of the Study

3.2.1 Ontology and Epistemology

Different researchers with different philosophical underpinnings tend to have different ontologies, epistemologies. Depending on which ontological and epistemological positions are being considered, educational researchers will adopt different methodologies and methods when researching the same educational phenomena, and this may have a direct impact on the results. Hence, my own background should be outlined, thereby making it evident the way in which my ontology and epistemology are shaped and how these influences this study.

As a science teacher, I am very familiar with Galileo's scientific research methods: namely, raising questions through observation, making conjecture, designing experiments, ascertaining the relationship between physical variables, testing the conclusions, and forming scientific laws that act as very powerful tools in the prediction of more physical events. Ultimately, predictability is precisely what makes science fascinating.

Nevertheless, exploring the field of education is a very different exercise when compared to science. Firstly, the aim of the scientific method is to pursue a general "truth" that is concise and replicable. Moreover, conciseness is deemed to be vital as scientists follow an aesthetic and simple form of universal law. However, in the real world, this outlook is prone to failure due to the complexity of human nature. Human beings are self-conscious and they hold beliefs about the world that affect their purpose-driven behaviors. In Buddhism, each person is considered to be a mini cosmos, therefore it is challenging to simplify their complexities to that of conciseness. Meanwhile, social science is highly context-dependent, where even the slightest contextual difference can greatly impact results, in a similar mold to that of chaotic systems in science, thus one should avoid generalization or having complete faith in replicability. Secondly, scientific methods are generally value-free and objective, yet many scientists design and conduct their research based on their own scientific or even religious beliefs, resulting in their observation and data collection being intentionally or unintentionally biased. Even authentic science cannot be completely detached from personal values, let alone social science. Furthermore, using quantum mechanics, scientists have established, that observation and measurement carried out in experiments potentially affect the result due to the interaction between the research instrument and the subject. Similarly, in the real world, the researcher and the research subject interact continuously and to a great degree, eventuating in complete value-detachment and objectivity becoming impossible. In summary, the target of educational research is human beings whose activities are entirely different from mechanical motion in physics, therefore utilizing natural science methods to investigate the social world is a questionable practice.

Nonetheless, the previous statement does not equate to a total denial of the significance of scientific methods in educational research. On the contrary, human beings and society itself exist

both objectively and subjectively, and their contradiction and unification require scientific methods to gain a deeper understanding. Meanwhile, taking in to account the opinions of those involved in the field, exploring individual experiences, considering emotion and empathy, not just rationality, in order to understand the living reality are also effective ways of researching the real world (Cheng et al., 2014).

3.2.2 Pragmatic Paradigm

Therefore, due to my professional background and comprehension of scientific methods, it is more suitable for this research to adopt a pragmatic paradigm. Pragmatists believe that the truth is that which is most useful. As Rescher (2005) asserted, they focus on "pragmatic utility" and appreciate the existence of the physical world as well as the social and psychological world (Robson, 2002).

Furthermore, there are other relevant factors behind choosing pragmatism, with the first one being the influence of Chinese traditional philosophy. Throughout history, China has been considered a pragmatic country, with the employment of Confucianism leading scholars to believe that learning statecraft is a purpose in its own right. In contemporary China, Deng Xiaoping called for "crossing the river by feeling for the stones" when practicing the "reform and open" policy. In other words, there is no fixed paradigm when researching a new phenomenon, with the rational action being to focus on the question itself and apply methods accordingly. Expressions such as these are worthy illustrations of pragmatism. Secondly, positivists and interpretivists consider the quantitative method and qualitative methods to be wholly incompatible, however pragmatists regard the contradiction to have been exaggerated as absolute incompatibility does not exist. Consequently, they propose a mixed methodology that integrates these two approaches, with this compromise considered to be appealing to me. In Confucianism, there is a very influential concept called "zhongyong", meaning "the golden mean", where one should adopt a suitable stance between one extreme and another, and ultimately maintaining a balance between the two.

As previously mentioned, the ontology of this study is that reality is socially constructed, and its true and independent existence is not free from influences by mechanisms and context (Robson,

2002). Differing somewhat from scientific truth, educational situations evolve quickly over time and vary depending on context. Therefore, it is fruitless to pursue absolute truth in educational researches. Rather, a worthwhile pursuit is that of understanding educational reality, and this is achievable through exploring objective facts as well as society and the inner workings of people.

3.2.3 Methodology and Methods

In accordance with its ontology and epistemology, this study adopts a mixed methodology and employs a combination of qualitative and quantitative methods.

Quantitative and qualitative methods have both advantages and limitations. The purpose of quantitative methods is to interpret educational phenomena as scientifically and objectively as possible through data collection and analysis, thereby providing support for educational reform and development. Quantitative methods can be effective when studying quantifiable issues, such as the improvement of academic achievement. However, qualitative research views education as highly dependent on context. Educational situations are in essence different from scientific situations and, therefore, it is inappropriate to rely too much on quantitative methods and emphasize causality and relevance. Even though qualitative methods may not arrive at general conclusions, they are capable of describing educational situations in detail and are useful in providing us with an in-depth understanding of educational problems. Qualitative methods are more appropriate when studying issues that are difficult to quantify, such as students' perceptions. Therefore, the strategy of using both quantitative and qualitative methods integrates the advantages of both methods whilst significantly minimizing their disadvantages.

Furthermore, this choice is heavily influenced by the necessity for research methods to be closely related to the nature of the research topic. Specifically, this study not only explores the localization of collaborative learning theory, it also outlines a practical teaching strategy aimed at dealing with the consequences of the reform of the college entrance examination in Zhejiang province. Patently, there remain questions around whether this form of collaborative learning is suitable for senior three students at my school to adapt to this latest round of educational reform,

also to what extent it effectively prepares students for the college entrance examination, and lastly what conclusions we can draw that would be helpful in the future implementation of collaborative learning. There are also two other concerns. On the one hand, due to the limitation of the actual situations, I am both the researcher and the participants' teacher. In such scenarios, my personal preferences and expectations will inevitably affect the psychology and behaviour of the participants, while also impacting data collection, and ultimately the results of this study. As a result, the focus of this study is not on the causal relationship between variables, but rather on evaluating the implementation process of this pedagogical strategy, and subsequently discerning how the process affected the students' learning outcomes. On the other hand, this represented the first occasion for these students to participate in collaborative learning and it is important to ascertain how they felt about their experience in this journey and thus offer implications for future implementation of collaborative learning. To answer questions and concerns such as these, it is obvious that both quantitative and qualitative methods are required.

3.3 Preparation for Collaborative Learning

3.3.1 Participants

The school that I work in is a renowned school in Zhejiang Province with a history stretching back over 100 years and it enjoys the privilege of falling in to the category of "the first batch of key high schools in Zhejiang Province". Moreover, its students' academic performance is above national average and their reputation is first-class in the context of the province. The participants in this study consist of 70 senior three students from two classes that I have taught, with these two classes having similar characteristics, such as their averages in academic achievement in physics, proportion of male to female, age, and socio-economic background.

3.3.2 The Basis for Dividing Academic Achievement Level

The quantitative aspects of this study serve to measure the progress of students' scores in the second college entrance examination compared to those in the first college entrance examination. In this sense, the first college entrance examination can be viewed as the pre-test and the second college entrance examination as the post-test.

However, when dividing the students according to academic achievement levels, in order to be as objective and accurate as possible, the basis for grouping is composed of three test scores. One is the first college entrance examination score, which not only has high reliability and validity in terms of examining knowledge and ability but also offers guidance for the second college entrance examination. Another score is from the mock exam that is organized by the local educational bureau at the end of the first semester in grade three. This exam is also high in reliability and validity and reflects any change in students' academic achievement in comparison to the first college entrance examination. The last score is from a pre-semester exam that is organized by the school at the beginning of the second semester. This exam was reviewed by all teachers in the lesson preparation group of the school to ensure that the difficulty and distribution of knowledge are consistent with the exam syllabus of the college entrance examination and that the exam can effectively reflect any changes in students' academic achievement during the winter vacation. Ultimately, the total score is calculated in order to confirm the students' initial achievement level.

3.3.3 Grouping

This study focuses on pair collaboration, where both cognitive conflict and scaffolding support are induced. Furthermore, according to the theory of social interdependence, one is more likely to sense the significance of their contribution to the group's success when in a smaller-sized group, thus installing a higher level of responsibility when completing future tasks and instigating more positive communication among group members (Kerr, 2001).

The form that a two-person group takes helps to reduce the number of variables, allowing researchers to focus more on the nature of the interaction (Wang, 2009). Moreover, group members are arranged in two adjacent seats, thus ensuring sufficient space isolation between groups. This geographically independent space enhances cohesion within a group and stimulates a more positive interaction (Johnson and Johnson, 2009).

This study aims to explore the impact of constructive cognitive conflict and scaffolding behavior on learning. Both types of collaborative groups, namely heterogeneous pairs and homogeneous

pairs, will be formed and studied. Specifically, all the students from two classes (34 in one and 36 in the other) that I was teaching were equally divided into three achievement levels: higher academic achiever (HAA: n=23), medium academic achiever (MAA: n=23) and lower academic achiever (LAA: n=24), and six types of groups were formed, three of which were homogeneous groups (6 h-h groups: HAA collaborates with HAA student, 6 m-m groups: MAA collaborates with MAA and 6 l-l groups: LAA collaborates with LAA) and the remaining three were heterogeneous groups (5 h-m groups: HAA collaborates with MAA, 6 m-l groups: MAA collaborates with LAA and 6 h-l groups: LAA collaborates with HAA). In total, 36 students participated in homogeneous groups and 34 participated in heterogeneous groups. Another noteworthy angle is that 16 students collaborated with more competent partners and 18 collaborated with less competent partners.

3.3.4 Task Design and Pedagogical Sequence

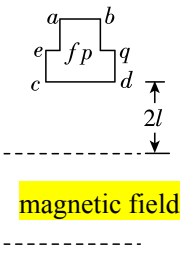
It has been established that learning tasks should be carefully designed to make collaboration effective (EEF, 2023) and appropriate tasks also stimulate goal interdependence within the group, and this is a crucial factor in ensuring the effectiveness of collaborative learning (Johnson, 1984). Furthermore, a productive task should have a clear and concise description of its requirements and be able to be completed within a short time frame (Vermette, 1994).

The whole of the current study lasted for two months (the second round review stage, a period between the beginning of the second semester of grade three and the second college entrance exam). There were four classes every week, each class lasted 40 minutes, and there were 32 classes in total. The traditional class was transformed as collaborative tasks were adopted. In each class, one collaborative task is assigned. There are mainly two types of tasks: homework revision and problem-solving, with each task being around 15-20 minutes. Take the task of homework revision as an example. Before the class, the homework from the previous day was corrected and returned to the students. In the collaborative period, students were required to correct errors in both of their homework through collaborative discussion and to achieve a common understanding of each problem. When students engaged in collaborative discussions, the teacher usually walked

around and observed, provided assistance when students asked for help, and selected groups (usually groups that successfully solve problems or exhibit typical errors) for subsequent class-sharing sessions. The rest of the class remained in the form of traditional lecturing.

The content of collaborative learning tasks covered all knowledge of high school physics: mechanics, heat, electromagnetism, and optics. Some of the problems were multiple-choice questions, while some were comprehensive and difficult calculation questions. For example, in a review lesson on electromagnetic induction, a task paper was assigned to all students before the class, consisting of three problems and one of them is as follows:

A metal wireframe has a mass of m, and each side is in the same vertical plane. The length of ab is *l*, the length of cd is 2*l*, and ab is parallel to cd, with a spacing of 2*l*. The upper and lower boundaries of the uniform magnetic field area are both horizontal and the magnetic field direction is perpendicular to the plane where the wireframe is located. Initially, the distance from the cd side to the upper boundary of the magnetic field is 2*l*, and the wireframe is released from rest. After the cd side enters the magnetic field, until the ef and pq sides enter the magnetic field, the wire frame moves at a uniform speed. After the pq side leaves the magnetic field, and before the ab side leaves the magnetic field, the wireframe also moves at a uniform speed. The heat generated by the wireframe during its complete progress is Q.



Question 1: Calculate how many times the speed at which ab side leaves the magnetic field as compared to the speed at which cd side enters the magnetic field.

Question 2: Calculate the distance between the upper and lower boundaries of the magnetic field.

During the next day's class, all collaborative pairs were equally divided into three problem groups, with all collaborative pairs in each problem group holding an in-depth discussion on one particular problem. After the collaboration period, one pair from each problem group was selected to share their results for each question with the entire class.

In terms of pedagogical sequence, although the sequence of priming, expectations, problems and tasks would vary according to circumstances, a typical sequence would comprise the following (taking a collaborative learning task with the main purpose of homework revision as an example): The teacher first comments on the overall completion of a homework paper (usually the previous day's homework, which has already been corrected by the teacher before returning to students), points out the number of the questions that need to be paid special attention (or the topic covering a specific knowledge point). Students identify relevant mistakes in the homework of both group members, initiate a discussion, identify the cause of the error, and find out the correct answer through mutual effort. After completion, group members can also discuss other problems in the homework until the end of the collaboration period. Students are expected to correct errors in both of their homework through collaborative discussion and to achieve a common understanding of each problem. When students are engaged in collaborative discussions, the teacher usually walks around and observes, provides assistance when students ask for help, and selects groups (usually ones that successfully solve problems or exhibit typical errors) for subsequent class-sharing sessions. After the collaborative learning period, the teacher will make a brief comment on the collaboration process, and invite one or two groups to share ideas for solving a particular problem. The teacher will also explain some centralized problems raised by students in the process of collaborative learning or problems that cannot be solved through discussion.

3.3.5 Guarantee of Positive Interdependence

In the second round review stage, every class is organized in the form of collaborative learning combined with teacher lecturing. Members of a collaborative group are required to discuss problems in homework and complete learning tasks together. Inevitably, the partner’s learning will have an impact on one’s own learning. Therefore, before formally conducting the collaborative learning, I emphasized the importance of achieving mutual goals for one’s own learning and encouraged students to cater for their partner’s learning (such as by discussing the mistakes in the partner’s homework, confirming both oneself and the partner have understood a certain concept, paying attention to the changes in peers' academic performance, and celebrating common progress.)

Moreover, rewards were mainly aimed at collaborative groups rather than individuals, and there were basically two forms: online system evaluation and verbal praise. There was an online evaluation system in my school where teachers rate students' performance after each class as part of a semester's overall grade. Groups with high level of engagement and high quality of discussion during collaboration will receive higher scores. After the collaborative tasks, discussions were usually held among different groups, with excellent performers being rewarded. Every Thursday a mock exam was held and if both members in the group had made progress, their group as a whole would receive reward.

3.3.6 Practicing Collaborative Skills

Prior to the initiation of the formal collaborative learning, this study helped students to practice their collaborative learning skills. As noted in Chapter 2, collaborative skill is one of the five elements of collaborative learning (Johnson and Johnson, 1990). To ensure the effectiveness of collaborative learning, collaborative skill training, namely on clearly expressing ideas, supporting one’s arguments with evidence and listening to others' views must be put in place before collaborative learning officially begins.

Therefore, the first week was a trying-out phase, aiming at establishing the rationals behind collaboration. Firstly, I outlined essential collaborative skills and invited students to demonstrate them through the completion of a specific task. During their collaboration, I observed, gave guidance and offered immediate feedback on the mastery of collaborative skills, intra-group relationships, level of engagement as well as quality of discussion to the students, focusing on how the group functioned and potential improvements to be made (Johnson, 1984; Nie, 2006; Du and Wang, 2012). Afterwards, students were asked to self-reflect on the collaboration in their groups(Cohen, 1994a).

3.4 Methods

In order to answer the research questions, this study employed data from two college entrance examinations, classroom observation, surveys and interviews, and used both quantitative and

qualitative methods. Specifically, during the collaborative learning, in order to understand student behaviours, observation was performed in the classroom, whilst in one of the classes, the student discussions were audio recorded. Following the release of the results of the second college entrance examination, the students' views on collaborative learning were collected through a survey. Lastly, interviewees were selected through a comprehensive analysis of the students' scores, classroom notes and survey data, with semi-structured interviews also being carried out.

3.4.1 Observation

This study was conducted using real-life classes. To undertake simultaneously the two roles of researcher and teacher, participant observation was adopted. To some extent, this entails the observer becoming a member of the observed group. Furthermore, the observer observes and records subjects' behaviour whilst participating in the activities that form the research. It is an effective method for describing, analyzing and explaining that which has been observed (Robson, 2002). During the collaborative learning exercises, I recorded field notes through observation and offered guidance upon the request of students.

The selection of the points for observation is based on both the research question and the literature review. Observational points mainly include the level of engagement, intra-group relationship, quality of discussion, time of collaboration, body language, personal behaviour and effect of interaction.

As illustrated in 2.5.2, engagement is an important factor in interaction as active engagement can help achieve a common goal in collaborative learning (Nokes-Malach, Richey and Gadgil, 2015) thus to what extent were participants positively involved in class activities should be investigated (Cohen, 1994b). The level of engagement can be divided into "active" (almost in a state of mutual communication throughout the entire process), "average" (partially in a state of mutual communication), and "indifferent" (group members generally doing personal work and rarely communicating). More complicated and intriguing phenomena were observed in the field, namely some groups were consistently enthusiastic, some lacked enthusiasm initially but gradually their

engagement levels increased, whilst some groups were found in a state of indifference and their discussion was almost non-existent. The types of Intra-group relationships are mainly divided into "bidirectional" and "unidirectional". As illustrated in Chapter 2, from a constructivist's standpoint, the learning outcomes may be affected by both cognitive conflict and scaffolding support when students interact with each other. The intra-group relationship of the former is more inclined towards "bidirectional" communication, with equal status among members, while the intra-group relationship of the latter is more inclined towards "unidirectional" guidance, with role differentiation appearing among group members. It was found in observations that in some groups, different roles emerged naturally through the collaboration, namely students with higher ability acting as narrators, and their lower-level peers acting as listeners or receivers and rarely expressing their own opinions. Nevertheless, some lower ability-level students also actively participated in the discussion. Another point is that the pattern of interactions on display differed significantly, with some groups engaging in the discussion immediately and continuing for the full duration of the allocated time, while some groups preferred to work individually at first and engage in a discussion afterwards, several groups were very willing to ask the teacher for guidance, while some groups preferred to discuss with other groups in close proximity. Quality of discussion, as mentioned previously in 2.5.2, including the level of detail and logicality, is also a significant factor in determining how effective collaborative learning is. Time of collaboration concerns the time students need for collaborative discussions, including finishing discussion in advance, finishing on time and difficulty to stop when the time is up. Body language includes distance between peers, eye contact and body language. Personal behaviour describes participants' behaviours during collaboration (wandering mind, independent thinking, independent problem-solving, seeking help from the teacher, etc.). The Interaction effect considers the quality of answering questions in the class-sharing section after collaborative learning.

The observational notes for each class covered the above points as much as possible, but due to the presence of about 20 collaborative groups in the classroom, I usually adopted two perspectives: overall observation (e.g. the general level of engagement) and tracking of some typical groups. I also listened to conversations of some groups and recorded the quality of the discussions. During observation, some interesting phenomena were recorded, such as two adjacent groups

spontaneously starting discussions and ultimately forming a four-person collaborative group. A selection of observation notes is presented in Appendix H.

As for the analysis, the contents were first classified according to the observation points, and then the characteristic of each observation point and its change over time was analyzed. To address the research questions, observational records were triangulated with data from other methods. These records were also used in the selection of participants for interviews and to explore the reasons behind their behaviours. For example, one interviewee believed that their group had a high level of engagement; in contrast, it was observed and recorded that both group members were often looking at their own materials individually in periods of collaborative learning. The interviewee mentioned the unique way of collaboration in their group—thinking individually first and engaging in mutual discussions, and explained the apparent contradiction by pointing out the importance of combining independent thinking and collaborative discussion.

3.4.2 Audio Recording

The observation process focuses more on students' behaviours rather than the content of their discussions, and it is difficult to pay sufficiently close attention to a specific group when observing, thus the information obtained tends to be holistic in nature, yet superficial and incomplete. To garner evidence as to what occurred in the discussion, an audio recording of the whole discussion was made. Firstly, a test collection was conducted. On one hand, this can increase the students' familiarity with this study method and in turn reduce its impact on the interaction in the later formal collection process. On the other hand, due to the large number of students and the high level of noise produced in the interaction, the clarity of the tool used, audio recording software on a mobile phone, requires evaluation.

The original intention for this study was that each group would bring their own mobile phone to class and record their collaborative discussion. However, some students did not own a mobile phone or did not get their parents' permission to bring one to school, therefore resulting in an insufficient amount of mobile phones to be used for recording. Furthermore, some students

requested not to be recorded, and the number of recordings collected was only one-third of the total groups. Out of all the audio files collected, the quality varied due to the mobile phone used, therefore the amount that could be analyzed was small. As a result, the audio recordings will only be used as supplementary data.

3.4.3 Score Data

After the second college entrance examination, each participant's academic achievement was collected and compared with that of the first college entrance examination. The average improvement of all participants was compared with that of non-participants (students in the same grade in my school who did not attend collaborative learning classes). This comparison will provide an indication as to how collaborative learning could influence academic achievement and help students' preparation for the second college entrance examination. Before the conduct of this study, I reported my research plan to the department in charge of students' study and teaching issues in my school and received permission to obtain and use the data of the two college entrance examinations of the whole grade for research purposes. See more details in section 3.6.3.

It is worth stating that this study did not set control groups intentionally. The first reason for this is that of ethical considerations. The second reason is the issue of sample size. As most of my colleagues were not capable of or had no intention of conducting collaborative learning, the participants in this study are limited to the two classes taught by myself. In other words, students who attended collaborative learning and those who did not were not fully equivalent in terms of their initial achievement level. However, by comparing their first college entrance examination and the improvement made in the second college entrance examination, the impact of collaborative learning can nonetheless be appreciated (more details in Chapter 4). Due to the limited sample size, the quantitative data will only outline the implications of the results rather than a determined causality.

To gain a deeper understanding of the influence of one's initial achievement level, whether it is high, medium or low, and the group composition, either a heterogeneous pair or homogeneous

pair, the students' respective improvement in their score of the college entrance examination was compared using different initial achievement levels and different group compositions.

This study also wants to explore the complexity of the development process and understand whether there are multiple possibilities of progress and declines in academic performance. Progress in learning can refer to many aspects (for example, more advanced practices or development in thinking), however, in the second round review stage, there is little doubt that the most important thing is academic achievement. Therefore, progress and declines in academic performance mainly refer to improvement and decline respectively in achievements and scores in the college entrance examinations analyzed in the study.

3.4.4 Survey

In order to gain greater insight into the situation and to understand the attitudes of students toward collaborative learning, and also to select students for subsequent extensive interviews, this study conducted a survey after the release of the results of the second college entrance examination. The design of the survey was based on the literature review and theoretical framework, with the aim being to answer the research questions of this study.

The direct purpose of this study is to help students prepare for the second college entrance examination, so the effect of collaborative learning (including academic achievement) must be investigated. Since this study comprises a pedagogical reform, learners' overall feelings about this new pedagogy could affect their learning outcomes, and their perceptions can also provide important guidance for the future implementation of collaborative learning. Besides, the framework of this study integrates social interdependence theory and constructive learning theory. To understand the extent to which the framework works, students' level of engagement and positive interdependence, cognitive conflict and scaffolding behaviours emerging in interaction, as well as how these intermediate variables affect the learning outcomes can be investigated. Finally, the choice of partner is an important factor for group composition and is also considered to affect

the learning outcomes of collaborative learning. All considered, the survey includes the following five categories (shown in Table 3.1).

Table 3.1 Categories in the survey and their targeting research questions

Categories in survey	Targeting research questions
learning effects	How does collaborative learning influence students' performance in the second college entrance examination?
overall view of collaborative learning	
partner	How do students perceive their experience in collaborative learning?
engagement	
interaction	

The "partner" section is concerned with the students' attitude towards, and preferred characteristics for their partners in terms of learning ability and group composition, with these being two key factors to be considered when forming a group.

The "learning effect" section is concerned with the learning effects of collaborative learning. As illustrated in section 2.3.1, there are three fundamental effects, namely academic performance, interpersonal ability and emotional skills (Gillies, 2016; Sharan, 2010; Slavin, 1989; Tao, 2007). Questions 1 to 4 focused on academic performance, in which question 1 and 2 focused on students' personal feelings toward their change in performance. Furthermore, data from questions 1 and 2 were compared with the students' actual situation to discover whether their perceptions were consistent with the facts. Given that this research was centered on the second round review stage, the key collaborative tasks in class were homework revision and problem-solving, enabling students to form a more mature and profound understanding of a variety of problems. Therefore, questions 3 and 4 concentrated on the influence of collaborative learning on homework revision and problem-solving from the students' perspective. Subsequently, questions 5 to 7 investigated the students' interpersonal relationships, considered to be one of the three effects of collaborative learning. Lastly, question 8 deals with whole-person development, and it allows students to provide other advantages of collaborative learning apart from academic performance.

The "engagement" section: Engagement is an important factor, specifically active engagement, as it facilitates the achievement of the mutual goal in collaborative learning (Nokes-Malach, Richey and Gadgil, 2015), therefore to what extent participants were positively involved in class activities should be investigated (Cohen, 1994b). as illustrated in section 2.5.2, Webb, Troper, and Fall (1995) divided engagement into three levels, namely high, medium and low, with high-level activity being a predictor of high achievement. Accordingly, this study also divides it into three levels: “active” (almost in a state of mutual communication throughout the entire process), “average” (partially in a state of mutual communication), and "indifferent" (group members generally doing personal work and rarely communicating). As illustrated in the theoretical framework of this study, positive interdependence is also effective in ensuring active involvement in interactions. Therefore, questions 1 and 2 of this section investigated students’ engagement during interactions, while questions 3 to 5 were concerned with the level of positive interdependence evident in a collaborative pair. For example, question 3 was adapted from Ghaith, Shaaban and Harkous’s (2007) research and concerns participants’ consciousness of completing the learning task together as their mutual goal.

The "interaction" section: The interaction process is affected by many factors and researchers have studied it from many different perspectives. Questions 1 to 4 were inspired by Webb et al.’s (1998) research which examined the quality of discussion from two dimensions, namely the accuracy of the answer and the quality of explanations. Questions 5 to 7 were aimed at understanding the interaction from the constructivists’ perspective, thus including "cognitive conflicts" and "scaffolding" behaviours. Question 8 reflected one interest of this study inspired by Tudge (1992), who discussed the influence of the immature idea on the more competent peer and aimed to establish a comprehensive understanding towards "ZPD". Lastly, questions 9 and 10 focused on the time spent on collaborative tasks and the atmosphere within collaborative groups.

It should be noted that the cognitive conflicts in this study refer to constructive cognitive conflicts. Although generally triggered by disagreement among collaborators, what is more crucial is that when students' original concepts or knowledge structures encounter conflicting situations or opinions, the cognitive conflicts may stimulate their desire to resolve this psychological imbalance

and achieve mutual goals, they then re-examine their own views, analyze, compare and coordinate different opinions through self-reflection and peer discussion, and finally achieve conceptual changes (Cazden, 2004; Johnson and Johnson, 1981; Shi and Du, 2008). Besides, according to the situation of the second round review stage, a partner's "immature mistakes" here mainly include incomplete consideration of problems, fixed thinking patterns, errors in logical reasoning, incorrect analogies, computational errors, confusion of knowledge points, and so on.

The "overall attitudes" section: This aims to summarize the overall attitude towards collaborative learning. More specifically, it investigated the students' evaluation of the advantages and disadvantages of collaborative learning, together with its facilitators and barriers. Moreover, several open questions were also posed in order to explore the students' experience of and attitude towards collaborative learning. An example of one question included is, "What do you find most engaging during collaborative learning".

After deciding the research purpose and categories, the survey questions were designed. Before formal distribution, the survey was piloted and modified to ensure its reliability and validity (see section 3.5.3) When implementing collaborative learning, I informed students of the plan to conduct surveys and interviews in advance. Moreover, a self-study class was used to distribute the survey. As an introduction, the purpose of the survey and the estimated time for completion were communicated, and I thanked the students for their contribution to this study. Even though students were advised that they have the right to refuse participation in the survey, all of them completed the survey. It is noteworthy that for the purposes of interviewee selection and data triangulation, students were requested to assign their names to the surveys, but with their information being kept confidential.

The majority of the survey data is quantitative data. Moreover, this survey adopted the Likert 5-point scale, a widely utilized scale which is more reliable than a scale of the same length. Its five-answer form enables respondents to more clearly indicate their positions, thus the score statistics it generates can be used to illustrate the overall position of all aspects of collaborative learning. In addition, participants' answers to each question in the survey are scored by assigning a

number to each of the 5 options given, namely 1 to 5 points successively. The score given to a particular question reflects the extent to which the participants agree with the views stated in the question. Through comparing the scores given to the questions, it facilitates an understanding of the various effects of collaborative learning on the participants. Aside from the representative statistics of all the participants, the data of participants with different academic achievement levels and from different group compositions should be compared in order to reflect the influence of these two factors respectively (see more in Chapter 4). The open questions in the survey provided opportunities for students to freely express their ideas, thereby helping to discover unexpected problems existing in collaborative learning. The answers, typical or atypical, that emerged from the survey could help in the selection of suitable interviewees.

3.4.5 Interview

For this study, the semi-structured interview serves as a crucial instrument to delve into the impact of collaborative learning on learners, particularly in the context of the second round review stage and its relationship to students' academic achievements in the second college entrance examination.

The focus of this study is to understand participants' experiences in learning, their perspectives on partners as well as collaborative learning as a new teaching strategy and learning method, and how the whole experience influences their learning outcomes. While surveys investigate students' attitudes, each individual attitude is complex, or can change significantly. Therefore interviews are useful for exploring such complexities and changes deeply and thoroughly within the interviewee’s inner world. Through triangulation of data, this study aims to uncover the underlying reasons hidden beneath the surface phenomena. in order to gain a deeper understanding of how collaborative learning can shape students' feelings and attitudes, addressing research questions while providing evidence for evaluating the implementation of collaborative learning.

In terms of interviewees, given that the main objective of this study is to focus on students preparing for the second college entrance examination, the first consideration when selecting

interviewees was a change in score between the first and second college entrance examinations. To be specific, participants who made progress, regressed or remained the same should all be covered. Furthermore, this selection also attempted to cover all three initial levels and group types. More factors are considered, such as whether they are male or female, whether their participation in interaction was active or passive, whether their behaviour was consistent or erratic, or whether they displayed attitudes that were positive or negative.

After a comprehensive analysis of the data regarding academic achievement, the survey and field notes, a total of 12 interviewees were invited to be interviewed. Among the 12 interviewees, four made significant progress (progress of more than 9 points) and four regressed, with this being found to be very rare among the participants in this study, and four remained unchanged or improved slightly (with 3 points being the average level of improvement among all participants). The full list of interviewees' change in score, information including initial level and the type of group they participated in is presented in Table 3.2.

Table 3.2 Interviewee's code name, change in score (+ means improvement, - means regress), initial achievement level and group type

	Code name	Change in score	Achievement level	Group type
4 interviewees that made significant progress	A	+24	Low	Low-low
	B	+21	medium	High-medium
	C	+15	high	High-high
	D	+15	Low	Low-low
4 interviewees that regressed	E	-12	medium	Medium-medium
	F	-6	high	High-high
	G	-9	high	High-high
	H	-9	low	Low-low
4 interviewees who remained the	I	0	high	High-low
	J	0	medium	Medium-medium

same or made slight progress	K	3	Medium	Medium-low
	L	3	low	High-low

It should be noted that the interviewee selection also sought to include students with both typical and unusual characteristics. Specifically, interviewee G was in a group that held a poor-quality discussion, where one student asked a question, another gave an answer without explanation, and then the former noted the answer without further elaboration. Furthermore, interviewee E was placed in a group that displayed a lack of enthusiasm in the interaction, and interviewee I was the sole student who selected the option "regressed a lot" in the survey question on students' change in score between examinations, with the notable thing here being that he actually achieved exactly the same score in the second college entrance examination, therefore this discrepancy aroused research interest and he was subsequently selected as an interviewee. Another example is interviewee A who achieved the greatest progress among all the participants in this study, and he also offered the most suggestions in the survey, therefore demonstrating his interest and his self-reflection regarding his experience of collaborative learning. The reasons behind these behaviours and the factors influencing their attitudes will be studied in the interviews.

The interviews were conducted after releasing the scores of the second college entrance examination that is held in May. In line with Zhejiang Province's latest reforms, Chinese, mathematics and English college entrance examinations are held in June and students were still under great academic pressure. Therefore, there was a conscious effort to ensure the interviews were not time-consuming, with each one lasting approximately 30 minutes. The date and time of each interview were determined between the interviewer and the interviewee, and most interviews were carried out during self-study classes. All interviews were completed within one week to reduce the potential impact of communication between the interviewees and others. Moreover, the site of the interviews was carefully selected. The interviewee's reactions and answers are very context-dependent and their responses are influenced by facts, the relationship between the interviewer and the interviewee, and the environment. Moreover, in a comfortable and friendly environment, interviewees are found to be more willing to express their true opinions (Labov,

1969). Therefore, I made a booking to use the physics laboratory in advance to ensure that the interview process would run smoothly. In order to establish a harmonious atmosphere, I prepared complimentary drinks and snacks to try to replicate a social atmosphere for the interview, with the aim of encouraging open conversation. In order to improve efficiency, a mobile phone recording app was used, thus avoiding the omission of information through taking notes, and it also helps to diminish the collection of information unilaterally depending on the interviewers' subjective interpretation. It is worth noting that the use of recording was approved by the respondents before the interview.

This study adopted semi-structured interviews, which aimed to answer the second sub-research question concerning students' experience and their perception of collaborative learning. The interview incorporates 4 topics and the setting of interview questions is in accordance with the survey. Generally, the first topic is about one's partner, and afterwards the learning effects. The next topic is an in-depth understanding of the collaborative learning experience (including engagement and interaction processes), and the last one is the overall perception and suggestions.

Virtually all interviews began with a discussion about the interviewee's partner, seeking to understand students' preferences and the reasons behind them. This topic is further divided into several subtopics that are in accordance with the survey, such as perception of one's actual partner's ability and personality, past collaborative experience and one's ideal partner. The second topic is usually the effect of collaborative learning with subtopics, namely the effect of homework revision, the change in achievement, interpersonal skills and self-confidence. The next topic is the collaborative experience, including the level of engagement and positive interdependence as well as interaction (namely the quality of discussion, the level of detail of the explanation, the way to solve conflicts and time and atmosphere). To understand the influence of cognitive conflict and scaffolding help in learning, the interviews also involve questions such as the following: What role did cognitive conflict and scaffolding behaviour play in your groups? How do you assess the role of both in your study? Can you provide detailed examples of how you felt during the process? The last topic is the advantages and disadvantages of collaborative learning. More details about interview topics and sample questions are provided in Appendix D "Interview protocol".

In order to create a relaxed atmosphere and facilitate the understanding of the real feelings of the interviewees, the interview was to be conducted in a natural way. Specifically, the wording of interview questions was to be flexible, and the sequence of topic presentation did not have to be fixed. In actual interviews, the pursuit of natural conversation effects may result in unclear segmentation between topics. For example, when discussing ideal partners, in order to provide supporting evidence, the interviewee may recall his/her collaboration experience and compare the effects of scaffolding help and cognitive conflict. At this point, there is an overlap between the two topics of partners and collaborative experiences. However, the interviewer would consciously and naturally guide the conversation to ensure that all topics are covered. Besides, in order to gain more meaningful responses, the interviews also include several specific questions for each interviewee according to their specific situation.

Based on the research questions and actual circumstances, the analysis of interview data flexibly employs various methods including content analysis that involves coding interview content according to pre-set topics and subtopics (as previously illustrated in this section), collating data relevant to each category, and identifying the main themes and viewpoints. In addition to predefined categories, thematic analysis can generate more categories based on the insights obtained during the analysis. This process is based on an overall understanding of the data, achieved through steps such as initial coding, topic identification, topic review, and topic definition/naming. This study also includes comparative analysis that focuses on analyzing the differences and similarities among different interviewees. The basic steps are as follows:

Transcription and Categorization: In the first round analysis, the interview content was transcribed and separated into different categories depending on the topics and subtopics.

Summary of Core Ideas: For each interviewee, the core ideas or key points related to each topic are summarized and themes within each topic are identified.

Marking Special Discourse Paragraphs: Some special discourse paragraphs that contain significant or interesting information were marked for further analysis or as support or elaboration for a certain viewpoint.

Classification of Interviewees: In the second round of analysis, interviewees were classified from three dimensions: academic achievement level, group composition, and progress or declines in academic performance.

Comparison of Responses: The responses of different interviewees were compared to find out if there were commonalities among interviewees in the same group on a certain topic or how different groups may respond differently to the same topic. For example, whether all the interviewees who made progress in academic achievement were satisfied with their partner, are there any differences in the views of interviewees who made progress and those who regressed on collaborative learning?

Forming New Coding Categories: As the analysis proceeds, new coding categories can be formed. One example was when the interviewees described their experience, I recognized the role differentiation within the group, which was not included in the initial coding category. Therefore, a new category "pattern of collaborative learning" emerged.

Category Validation and A New Round of Analysis： To further analyze this potential category, relevant data was be collected, the previously described method were employed for analysis, patterns and themes were identified. The rationality of establishing each category should be validated throughout the process. Through a new round of analysis, this study discovered that each group exhibited a certain pattern of collaboration. A total of four patterns were identified, namely bidirectional, unidirectional, mixed pattern and inter-group pattern. These patterns were judged based on the interviewees' descriptions and interactively verified through observation notes, and it further promotes discussion on the definition of homogeneous and heterogeneous.

Ongoing Analysis: The analysis is an ongoing process that involves iterative rounds of coding, categorization, and comparison. As new categories or themes arose, the analysis continued to undergo further rounds of refinement to gain a deeper understanding of the data and the whole story. For example, factors related to the change in academic achievement were explored as the direct purpose of this study is to help students achieve better performance in the second college entrance examination. The transcriptions were analyzed repeatedly to establish the factors that existed in all interviewees who made progress, as well as factors that existed in all interviewees who regressed or had no significant changes. This focus helped form an in-depth understanding of how collaborative learning influences students' academic achievement and offers valuable insights into how to implement collaborative learning more effectively in the future.

3.5 Validity and Reliability

3.5.1 Validity and Reliability in Score Data

As a practitioner researcher, I conducted this study in two classes that I taught, with the remaining classes in senior three not participating. Moreover, non-equivalence, such as the number of students, the average score of the first college entrance examination and the ratio of male and female did exist among different classes. Therefore, this study is not a quasi-experiment and there are no control groups.

The participants' scores in the first and second college entrance examinations were collated, alongside that of students who did not participate in collaborative learning. Subsequently, the increase in scores of the participants is compared with that of the other students. However, according to the scoring system of the physics college entrance examination as described in Chapter 1, for students of different initial levels, the same gain in score has a different significance or signifies different learning effects. Consequently, utilizing score data is not likely to bring about a solid conclusion but rather a reference point.

The performance of the participants possessing different achievement levels is also analyzed. Given that the number of participants was only 70, and they are divided into different academic

achievement levels, evidently the sample number for each level is even less. Therefore, an in-depth understanding of the score data must be verified through triangulation with other data.

3.5.2 Validity and Reliability in Observation

The reaction effect is defined as the phenomenon of the subject observed changing their behaviour, be it consciously or unconsciously, when under observation (Robson, 2002). However, since I taught these students for over two years, students were accustomed to my presence in the classroom. During the collaborative learning exercise, I did not directly participate in discussions but did offer help when asked, in a similar fashion to what I did during regular student discussions. Therefore, this "habituation" helps to eliminate the impact caused by observation, thus ensuring validity.

In order to guarantee the authenticity and validity of the records, Robson's (2002) suggestion was put into practice. His assertion was that the observer should take notes of their observations when observing, thereby capturing particularly important, interesting or unusual moments more clearly and accurately. Post-class, the notes were read to certify that the contents were clearly recorded and easy to understand. If the notes were in any way unclear, they would be supplemented accordingly using my recollection of events.

In addition, this study did not explicitly inform the students that they were under observation and that notes would be taken during collaborative learning. In this manner, the students may mistake my recording for something entirely run of the mill, such as preparation for the next lesson, thus reducing the students' psychological burden and minimizing the potential influence on their behaviours.

3.5.3 Validity and Reliability in the Survey

Survey questions should be sufficiently clear and accurate to make certain that they elicit valid information regarding the students' views on each aspect that the research aims to tackle (Robson, 2002). Therefore, a pilot study was conducted after the initial design of the survey, with three

students from different achievement levels being invited to complete the survey and offer feedback. Thereafter, confusing or ambiguous choices were modified. An example of such an amendment is the first question in the "learning outcomes" section which was initially as the below:

“Through collaborative learning, I think my academic performance has improved

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree”

However, when a student selected "strongly disagree", this could be interpreted as either "my score remained the same" or "my score regressed", thus causing confusion. Therefore, this question was revised as per the following:

“Through collaborative learning, I think my academic performance has

1	2	3	4	5
improved a lot		unchanged		regressed a lot”.

In this version, he or she would choose 3 to indicate that "my score remained the same" and either 4 or 5 to indicate that "my score regressed". Furthermore, irrelevant questions were removed, such as "my interaction with the teacher increased during collaborative learning". This issue is not sufficiently relevant to the purpose of this study. In contrast, some questions with regard to the process of interaction were added, such as the following question that aims to explore the possibility of a drop in academic performance when a HAA collaborates with a less competent partner: “My partners’ undeveloped ideas or mistakes can easily lead to confusion”. To ensure adequate clarity and accuracy, the revised version was presented to the three students for their feedback.

During the formal survey, in order to make students' answers as authentic as possible, the following measures were adopted. Firstly, I introduced the purpose of the survey. Students were fully informed that they can choose to participate in this survey voluntarily. I then relayed my gratitude to the survey participants for their contributions, thus stimulating their sense of responsibility and encouraging them to answer truthfully. Secondly, in order to reduce ambiguities,

the survey's design endeavored to be as clear and readable as possible. Thirdly, there is a reminder at the beginning of the survey: "Record your responses by checking a blank section that corresponds to your own views". Due to the necessity for data triangulation and interviewee selection, students need to sign this survey, thereby leading to external validity problems. Therefore, answers given to sensitive questions should be carefully verified through triangulation with data gained from other methods.

The Likert scale is the most frequently used attitude scale in the fields of social investigation and psychological testing (Qi, 2006). This study employed a 5-level Likert scale to describe the participants' attitude through the assignment of 1-5 points to each option. This scale distinguishes between individuals who hold more positive attitudes towards the topic and those who hold less positive or even negative attitudes. However, different individuals may understand the five options differently, with students who chose "strongly agree" not necessarily having a more positive attitude than those who chose "agree". Along the same lines, the same choice does not necessarily indicate the same attitude. In addition, the calculation of the mean score assumes that there are equal intervals. In truth, the interval between "agree" and "strongly agree" may have different meanings compared to "disagree" and "strongly disagree".

3.5.4 Validity and Reliability in the Interview

Issues of validity and reliability may originate from either the interviewer, the interviewee or the interview questions. The following measures are adopted to ensure the reliability and validity of the interview.

Firstly, although the fixed questions and the questioning sequence in a standardized interview ensure internal consistency and reliability, this comes at the cost of validity. Important information may be obstructed from discovery due to the ignorance of those participating in, and a lack of openness in each interview. To maintain a balance between reliability and validity, the interviews were semi-structured using some general questions, but the sequence was flexible according to the different interviewees. In order to avoid the expectancy effect, the questions are descriptive

without displaying tendentiousness, such as "talk about one thing that impressed you most in your collaborative experience", rather than wording it as "are you satisfied with this collaborative experience?"

Secondly, the relationship between interviewer and interviewee should be equitable. During the interview implementation, the interviewer is usually in a leading position, therefore the behaviour, attitudes and personal preferences of the interviewer would have a significant influence on the interviewee. This is particularly evident when the interviewer talks excessively, potentially creating a one-sided conversation where the interviewee's right of speech is suppressed. This results in incomplete and inaccurate expressions, with the interviewee even potentially fabricating stories to satisfy pre-conceived objectives for the interview. Ultimately, the interview should be centred on respecting the interviewee. From arranging the time to agreeing on the interview location, the interviewees' feelings should be fully catered for. At the beginning of the interview, the interviewer should take time to show gratitude to the interviewees for their contribution to the study and diligently encourage them to relay their experiences and feelings. During the interview, the interviewer must strive to talk only when necessary, listen intently, express interest and affirmation to the interviewee, and encourage the interviewee to take their time when recalling and expressing what ensued during the interaction, with the objective to ensure the information is as complete and precise as possible.

Thirdly, a digital audio recording device was used to ensure the validity of the data recording. This provides reliable first-hand information that can be listened to repeatedly, and it avoids the scenario where the interviewer has taken notes that differ from the facts as there has been an excessive influence in terms of personal expectations or a misunderstanding of deviation. In addition, the interviewer is allowed to focus on the conversation, leading to a more natural atmosphere.

3.6 Ethical Issues

Calvin (1977) stressed that human dignity is of high value and human rights must be respected when conducting educational researches. In order to avoid the dilemma of ethical issues in the design and implementation stages of research, Nachmias and Nachmias (1981) proposed the concept of the "cost-benefit ratio", which aims to find a balance between potential social benefits and individual costs. Specifically, we should not only consider the efforts taken by the participants and the concomitant potential harm to their privacy and welfare, but also be aware and appreciate the gains made by the participants, such as the knowledge they have acquired, the improved self-confidence and the contributions they have helped make to educational theory and practices. Considering the balance of cost and benefit, the ethical issues of this study are handled accordingly.

3.6.1 Researching Senior Three Students

Researching students at senior three level in high school is a sensitive issue that can raise ethical problems. However, the ongoing reforms of the college entrance examination in Zhejiang province requires changes in teaching, particularly at the second round review stage. Furthermore, this study indicates that collaborative learning is a feasible choice that is suitable for students' learning characteristics at this unique stage. Considering that collaborative learning and teacher lecturing take place simultaneously in a classroom, the advantages of both of these pedagogical strategies can be integrated to satisfy the needs of all students to the greatest degree. After collaborative learning having been implemented for more than a month, the mock exam organized by the local bureau saw the students in these two classes perform very well. Furthermore, in terms of the average scores, the ranking of these two classes in the context of the whole grade has improved, and the effectiveness of collaborative learning has been demonstrated.

3.6.2 Interviewing One's Own Students

Limited by my personal situation, I carried out the roles of both the teacher and the interviewer. Due to the power relationship inherent between teachers and students, some researchers claim that students are unable to speak honestly in an interview that is conducted by their own teachers, with a workable solution being to replace the interviewer with another teacher that employs similar

teaching strategies (Seidman, 1992). Nevertheless, my colleagues have insufficient knowledge of collaborative learning and some were in fact unsupportive of this pedagogical strategy, therefore the notion of requesting other teachers to interview the students was impracticable.

The collaborative learning scrutinized in this study occurred between students, while me as the teacher, or interviewer, was not directly involved in the process of interaction. Moreover, students are more likely to attribute the learning outcomes of the interactions to working with their partners and collaborative learning itself as a learning strategy, rather than the teacher, or interviewer. Consequently, the concern around students' unwillingness to speak openly due to their discomfort with the interviewer's potential reaction is not a serious one. In addition, both the survey and the interview were conducted after the second college entrance examination, at a time when the physics curriculum in senior high schools was completed, therefore the power relationship between the interviewer and participants is less significant.

3.6.3 Gaining Access to the Field

Prior to formally beginning this study, I submitted the ethical form and obtained permission from Nottingham University to carry it out.

Furthermore, I reported to and discussed my research plan with the department in charge of students' study and teaching issues in my school and received permission to conduct this study. I am also allowed to use the data of the two college entrance examinations of the whole grade for research purposes.

I also reported to the Teaching and Research Offices in Ningbo and Zhejiang Province (departments of the Education Bureau that are responsible for implementing education policy as well as supervising and managing teachers' teaching and researching). Permission was granted and I was subsequently informed by staff in the Teaching and Research Offices that it was not appropriate to approach parents for consent. The explanation was that pedagogical initiatives such as collaborative learning and the collection of feedback (including from students) are expected to

be the normal practice of the school. This teaching and research culture of my school was understood and accepted by parents. To approach the parents for permission was an ethical risk in that it might cause confusion and disquiet and harm the relationship between the school and the parents. On these grounds, I decided that seeking parental consent might itself be unethical. Instead, I ensured that the students participating in the study—in my judgement—were sufficiently mature and sufficiently briefed to make a fully informed decision to participate or not.

3.6.4 Informed Consent and Fully Respecting Participants

Before the formal conduct of this study, I prepared a written document which mainly includes the introduction to this study and the participant's rights and presented it to the students with explanations in detail. Participants were firstly told that the conduct of this study was approved by the University of Nottingham Ningbo, and they were advised as comprehensively as possible of the purpose of this study, the potential risks, its time duration, the participants' responsibilities and the possible improvements to their knowledge due to their participation. The participants' rights to refuse attendance, leave the study, and also rejoin the study were also clarified. I confirmed with participants that if they wished for their data, such as recordings of the interaction, the scores for the first and second college entrance examinations and also the audio from the interview, not to be analyzed, then their data would be destroyed.

Before undertaking the survey, I first introduced the purpose of the survey and the participants' rights (i.e., they can decide whether they want to participate in the survey and those who agreed to do the survey can complete it at their will, and nobody was forced to complete the survey against their will). They were also informed in writing (at the beginning of the survey sheet) that the survey data was for academic use only and all of their data will be strictly kept confidential (because of the need for data triangulation, students needed to sign their names). 66 out of the total 70 participants handed in the survey sheet.

The rights and privacy of the interviewees were fully respected. Prior to conducting the interviews, I presented the participant consent form and fully informed each interviewee about the purpose of

the interview and the interviewee's rights. I emphasized that the interviewees had the right to take time to recall previous incidents, to discuss anything they found noteworthy, that they had the right not to answer certain questions and also initiate the discussion of relevant topics of their choosing. Finally, I explained the use of audio recording. Each interviewee then signed a consent form. During the interview, the interviewer listened compassionately and remained attentive to the interviewee's responses. Sensitive questions, such as the interviewee's feelings towards their decline in academic performance in the second college entrance examination, are only discussed after an amicable relationship has been formed.

3.6.5 Issues of Anonymity and Confidentiality

At every stage of this study, the privacy of each participant was fully respected. Due to the requirement to triangulate data received using different methods, it is a challenge to guarantee anonymity. Nonetheless, I confirmed to the participants that their data would be held confidentially and not shared with their classmates, teachers and parents. Additionally, when writing up the reporting section of this thesis, privacy would be respect and pseudonyms would be employed.

3.6.6 Non-Participants

This study also pays attention to the non-participants' rights and well-being. Every effort was made to ensure that this study would not have a negative impact on them. Firstly, since they are taught by other teachers, I had no authority to decide the teaching strategies employed by their teachers, nor did I have the power to compel them to participate in this study. Their autonomy was fully respected. Secondly, this study ensures the protection of the privacy of non-participants. As illustrated earlier in section 3.6.3, with the approval of relevant school departments, I obtained the non-participants' scores in the college entrance examination. However, the data only contained scores without corresponding personal information, and all the data were kept confidential. In addition, I shared the theory and operational methods of collaborative learning, as well as the progress of my own practice, with other teachers who taught the non-participants.

3.7 Conclusion and Timeline of Study

In accordance with the research questions raised in Chapter 1, in combination with the literature review in Chapter 2, this chapter outlines the methodology and methods utilized in this study. This is a practical study carried out on two classes that I teach, with the number of participants being limited, therefore gaining meaningful results from quantitative research is to some extent challenging. Consequently, this study focuses on understanding the students' experience of collaborative learning and adopts the strategy of interactive verification of both the quantitative and qualitative data. Specifically, the scores of the college entrance examinations, observation notes, and data originating from both the survey and the interviews will be triangulated to form a conclusion in Chapter 4. Finally, the timeline of intervention and data collection of this study is presented as follows:

Table 3.3 Timeline of intervention and data collection of this study

Time	Process of study	Data collection	Number of participants
Early February	Reporting to the department in charge of students' study and teaching issues in my school and get permission to conduct this study		
Early February	Fully inform the participants of the study; Grouping the participants	Collect the results of the 1st college entrance examination	70 participants and 202 non-participants
Mid-February	Collaborative Skills Training		70 participants
Mid-February to early April	Formal implementation of collaborative learning	Record field observation notes in each class	70 participants
Early April	Students participate in the 2nd college entrance examination		70 participants
Mid-April	Design survey, conduct a pilot study and make revisions		
Late April	Release of the score of the 2nd college entrance examination (by Examination Institute of Zhejiang Province)	Collect the results of the 2nd college entrance examination	70 participants

Early May	Formal conduct of the survey Select 12 interviewees based on their 2nd college entrance examination scores and responses in the survey	Collect survey data	66 participants out of 70 handed in the survey
Mid to late May	Conduct interviews	Collect interview data	12 interviewees

Chapter 4: Data Analysis

4.1 Introduction

This study collected and analyzed both quantitative and qualitative data, including scores achieved in the first and second physics college entrance examinations, survey data, interview data, classroom observation notes, and audio recordings. Ultimately, the objective was to answer the following research question: How does collaborative learning influence students in Zhejiang Province in both their preparation for college entrance examinations and their performance in high school science learning?

This chapter will first provide an analysis of the learning outcomes of collaborative learning. The literature discussing this subject asserts that collaborative learning plays an active role in improving students' academic performance and social skills (see more in Chapter 2). Therefore, a comparison is made between the participants' scores in the first and second college entrance examinations, thus illustrating the extent to which collaborative learning is useful in students' preparation for the second college entrance examination. In order to provide an in-depth understanding of the influence of academic achievement levels and group composition on learning outcomes, data is analyzed using three variables: different academic achievement levels, different group compositions, and different types, namely the level of students in each group, such as a HAA in a heterogeneous group, with there being six types in total. The statistical methods employed in this study analyzed score data primarily through the use of the T-test, which is well-suited for small sample sizes ($n<30$) and serves as a preliminary step in statistical analysis. This enabled the assessment of significant differences in mean values between datasets, such as the improvement in scores among participants and non-participants. If significant differences were identified, a correlation study was conducted to further investigate the strength and directionality of relationships be tween variables. In the context of this study, for instance, the correlational analysis might explore the association between HAAs' improvement in score and group composition.

Concerning the influence on social skills, the students' answers in the relevant parts of the survey were considered, whilst the interactive verification was conducted using interview data and classroom observation notes.

The second part dissects the participants' perceptions towards collaborative learning, including their perceptions towards collaborative partners, engagement, positive interdependence, the quality of discussion, task time, and the strengths and weaknesses of collaborative learning and etc., it also explores the complexities of interaction and how it affects learning outcomes. This part utilizes survey data, interview data, and classroom observation notes as evidence of its findings.

Finally, it is noteworthy that this study is not only a practical pedagogical assessment but also a study of theoretical exploration. Specifically, it proposes a new framework for collaborative learning by combining constructive learning theory and social interdependence theory, and research into the important intermediate variable "interaction", through which the important concepts of "scaffolding behaviour" and "cognitive conflict" and their impact on students' learning is examined, and moreover, the question of whether there is possibility of retrogression in students' development process is investigated.

4.2 Influence on Academic Achievement

One intention of this study is to prepare students thoroughly for their second college entrance examination and ultimately to improve their academic achievement. Consequently, the quantitative data, including the scores of the first and second college entrance examinations of participants and non-participants (the remaining students in the third grade of my school who did not participate in collaborative learning in the second round review stage), require analysis.

4.2.1 Comparison Between Participants and Non-Participants

By comparing the performance of participants and non-participants in the two college entrance examinations, as indicated by Table 4.1, it can be found that participants achieved a 3.1-point improvement on average while non-participants who were subject to traditional lecturing classes made only a 0.6-point improvement. At this point, it is important to confirm that this study is not a

quasi-experiment as no control group was set, therefore the average scores of the first college entrance examination of the participants are not the same as the non-participants. Nevertheless, the college entrance examination employs a scoring system that assigns a particular score in accordance with one's ranking among all the examinees. For example, students ranked in the top one per cent will be assigned a score of 100 (The correspondence between ranking and the assigned score is partially outlined in Table 4.2) rather than one's specific score. Given that participants achieved a higher average score, compared to non-participants, in the first college entrance examination, they must surpass higher achievers if they want to improve by the same score as non-participants. The fact that their progress is greater than that of non-participants demonstrates that the positive effects of their learning in the second round review stage exceed that of non-participants.

Table 4.1 Comparison of College Entrance Examination scores between participants and non-participants

	Participants (n=70)		**Non-participants (n=202)**	
	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Highest score	97	100	97	100
Average score	85.2	88.3	84.0	84.6
Standard deviation	6.9	7.3	8.6	9.7
Improvement	3.09		0.19	

Table 4.2 Correspondence between one's ranking among all the examinees and one's assigned score

Ranking (%)	**1(the toppest 1%)**	**2 (the successive 2%)**	**3**	**4**	**5**	**6**	**7**	**8**	**7**	**7**	**7**
Assigned score	100	97	94	91	88	85	82	79	76	73	70

The student t-test is conducted to investigate the differences in progress in academic achievement between participants and non-participants. The result is shown in Table 4.3:

Table 4.3 The student t-test of student types (participants and non-participants) on progress in academic achievement

	Student type (mean ± standard deviation)		t	p
	non-participants(n=202)	participants(n=70)		
progress in academic achievement	0.19±2.24	3.09±7.96	-3.004	0.004**

* p<0.05 ** p<0.01

the table, it can be seen that the student type shows a significant level of 0.01 (p=0.004) for progress in academic achievement. It can be concluded that the average value of non-participants (0.19) is significantly lower than the average value of participants (3.09), indicating that whether to participate in collaborative learning shows a statistically significant difference in the degree of progress.

In order to further study the correlation between participation in collaborative learning and progress in academic achievement, the Pearson correlation coefficient is used to express the strength of the correlation. Assign "0" to "not participating in collaborative learning" and "1" to "participating in collaborative learning" respectively. The result of the analysis between participation in collaborative learning and progress in academic achievement (improvement in the 2nd college entrance examination compared to the 1st college entrance examination) is shown in Table 4.4:

Table 4.4 Correlation analysis between participation in collaborative learning and progress in academic achievement

	Whether to participate in collaborative learning
progress in academic achievement	0.274**

* p<0.05 ** p<0.01

The result shows that the correlation coefficient between participation in collaborative learning and progress in academic achievement is 0.247, and it shows a significant level of 0.01, which indicates that there is a statistically significant positive correlation between participation in collaborative learning and progress in academic achievement. Therefore, there is a comparatively distinct possibility that collaborative learning, as a new teaching pedagogy and a learning method, may positively influence participants' academic achievement.

4.2.2 Comparison between Participants with Different Academic Achievement Levels

The initial academic achievement level is a vital factor when forming collaborative groups, and an essential variable that impacts learning outcomes. In order to ascertain its influence on participants' academic performance, the scores from the first and second college entrance examinations are compared in line with the different academic achievement levels. As shown in Table 4.5, students across all three levels progressed with their average scores all improving. Specifically, the HAAs improved by 3.8 points, the MAAs by 2.5 and the LAAs by 3.3.

Table 4.5 Comparison of College Entrance Examination scores among 70 participants of different academic achievement levels

Achievement level	**HAA (n=23)**		**MAA (n=23)**		**LAA (n=24)**	
test	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Highest score	97	100	97	100	91	97
Lowest score	76	82	73	73	67	70
Mean	89.0	92.8	85.9	88.4	80.8	84.1
Standard deviation	5.1	6.2	6.2	5.6	6.6	7.4
Improvement	3.8		2.5		3.3	

To understand the relationship between academic achievement level and achievement progress, assign values to academic achievement level (assign "1" to "LAA", "2" to "MAA", and "3" to "HAA"), and conduct correlation analysis, as shown in Table 4.6:

Table 4.6 Correlation analysis between participants' academic achievement level and progress in academic achievement

	progress in academic achievement
Achievement level	0.055

* p<0.05 ** p<0.01

From the above Table, it can be seen that the correlation coefficient between academic achievement level and achievement progress is 0.055, close to 0, and the p-value is 0.653>0.05, indicating that there is no correlation between academic achievement level and achievement progress.

However, as illustrated earlier, the same increase in score may indicate different degrees of progress. Due to the fact that scores are assigned based on rankings in the college entrance examination, the higher the score in the first examination, the greater the challenge it is to improve upon it. Therefore, the fact that HAAs made relatively the greatest amount of progress may suggest that collaborative learning is more beneficial for HAAs.

4.2.3 Comparison between Participants from Homogeneous and Heterogeneous Groups

Group composition is another crucial variable in collaborative learning. In this study, half of the collaborative groups were homogeneous with the rest being heterogeneous. Comparing participants' scores in terms of whether they were in homogeneous or heterogeneous groups helps reveal how group composition affects students' academic achievement in collaborative learning. As outlined in Table 4.7, both students from the homogeneous groups and the heterogeneous groups improved their average scores in the second college entrance examination. Nevertheless, the average score of those in heterogeneous groups improved by 5.5 points whilst that of those in the homogeneous groups only improved by 1.1 points. Given that the average score in the first college entrance examination for both group compositions was very similar, and the number of participants in each group composition is the same, this result implies that heterogeneous groups may benefit more from collaborative learning in terms of improving their academic achievement.

Table 4.7 Comparison of average score of College Entrance Examination between homogeneous groups and heterogeneous groups

Achievement level	**Heterogeneous groups (n=34)**		**Homogeneous groups (n=36)**	
test	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Highest score	97	100	97	100
Lowest score	67	70	70	70
Mean	84.8	90.3	85.5	86.6
Standard deviation	7.8	7.4	5.9	6.8
Improvement	5.47		1.08	

The student t-test is conducted to investigate the differences in progress in academic achievement between participants in different group compositions. The result is shown in Table 4.8:

Table 4.8 The student t-test of group compositions on progress in academic achievement

	Group composition (mean ± standard deviation)		t	p
	Heterogeneous groups (n=34)	Homogeneous groups (n=36)		
progress in academic achievement	5.47±7.87	1.08±7.49	2.390	0.020*

* p<0.05 ** p<0.01

From the table above, it can be seen that the group composition showed a significant level of 0.05 (t=2.390, p=0.020) for the progress in academic achievement. It can be concluded that the average value of participants in heterogeneous groups (5.47) is significantly higher than that of participants in homogeneous groups (1.08), indicating that participating in different group compositions shows a statistically significant difference in the degree of progress.

To further understand the relationship between group composition and achievement progress, assign "1" to "heterogeneous group" and "2" to "homogeneous group", and conduct a correlation analysis, as shown in Table 4.9:

Table 4.9 Correlation Analysis between group composition and progress in academic achievement

	Group composition
Progress in academic achievement	-0.278*

* p<0.05 ** p<0.01

From the above Table, it can be seen that the correlation coefficient between group composition and progress is -0.278 and shows a significant level of 0.05, indicating a significant negative correlation between group composition and progress. That is, participants in heterogeneous groups showed more significant progress.

4.2.4 Comparison between Different Group Compositions under Each Academic Achievement Level

Since both academic level and group composition may influence participants' academic achievement in this study. As a result, it is necessary to separate these two variables in order to formulate a more precise analysis whereby the academic achievement of high, as well as medium and low, level students in both group compositions is compared. However, it is critical to stress that the small sample size of this study (70 students in total) means that the number of students of

each type (HAAs in homogeneous groups, e.g, 6 types in total) is not large enough to provide statistically significant conclusions, therefore, the results can only provide implications.

As shown in Table 4.10, as far as the average score is concerned, HAAs that participated in heterogeneous groups improved by a remarkable 7.9 points in the second college entrance examination, while those who participated in homogeneous groups were unchanged.

Table 4.10 Comparison of average scores of HAAs in different groups

	Heterogeneous groups (n=11)		**Homogeneous groups (n=12)**	
	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Mean score	88.8	96.7	89.3	89.3
Improvement	7.9		0	

The student t-test is conducted to investigate the differences in progress in academic achievement between HAAs in different group compositions. The result is shown in Table 4.11:

Table 4.11 The student t-test of group compositions on HAAs' progress in academic achievement

	Group composition (mean ± standard deviation)		t	p
	Heterogeneous groups (n=11)	Homogeneous groups (n=12)		
progress in academic achievement	7.91±6.61	0.00±7.01	2.778	0.011*

* p<0.05 ** p<0.01

From the table, it can be seen that the group composition shows a significant level of 0.05 (p=0.011) for the HAAs' progress in academic achievement. It can be concluded that the average value of HAAs in heterogeneous groups (7.91) is significantly higher than that of HAAs in homogeneous groups (0.00), indicating that participating in different group compositions shows a statistically significant difference in HAAs' degree of progress.

Moreover, as shown in Table 4.12, the result of correlation analysis between group composition and progress in academic achievement of HAAs revealed that the correlation coefficient between group composition and progress is -0.518 and shows a significant level of 0.05, indicating a significant negative correlation between group composition and progress ("heterogeneous group"

is assigned a value of "1" and "homogeneous group" is assigned a value of "2"), which means that a HAA is more likely to make progress when working in a heterogeneous group, with their less competent peers not very likely to hold them back.

Table 4.12 Correlation analysis between group composition and progress in the academic achievement of HAAs

	Group composition
progress in academic achievement	-0.518*

* p<0.05 ** p<0.01

An analysis of MAAs leads to somewhat different results. As shown in Table 4.13, MAAs who participated in heterogeneous groups improved by 4.6 points while those who participated in homogeneous ones only improved by 0.5 points. This result demonstrates that heterogeneous groups may be more beneficial for MAAs. However, as shown in Table 4.14, the result of the student t-test showed that samples of different group compositions do not show significant differences in progress (p>0.05), indicating that for MAAs, there is no significant difference in academic performance between those participating in homogeneous and heterogeneous groups.

Table 4.13 Comparison of average scores of MAAs in different groups

	Heterogeneous groups (n=11)		**Homogeneous groups (n=12)**	
	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Mean score	85.8	90.4	86.0	86.5
Improvement	4.6		0.5	

Table 4.14 The student t-test of group compositions on MAAs' progress in academic achievement

	Group composition (mean ± standard deviation)		t	p
	Heterogeneous groups (n=11)	Homogeneous groups(n=12)		
progress	4.64±7.15	0.50±6.50	1.454	0.161

* p<0.05 ** p<0.01

Regarding LAAs, no matter whether they are in heterogeneous or homogeneous groups, they all achieved considerable progress. As shown in Table 4.15, the former achieved clearer progress of 4

points compared to the latter's 2.75. However, as shown in Table 4.16, the result of the student t-test showed that samples of different group compositions do not show significant differences in progress ($p>0.05$), indicating that for LAAs, there is no significant difference in academic performance between those participating in homogeneous and heterogeneous groups.

Table 4.15 Comparison of average scores of LAAs in different groups

	Heterogeneous groups (n=12)		**Homogeneous groups (n=12)**	
	First college entrance examination	Second college entrance examination	First college entrance examination	Second college entrance examination
Mean score	80.25	84.25	81.25	84
Improvement	4		2.75	

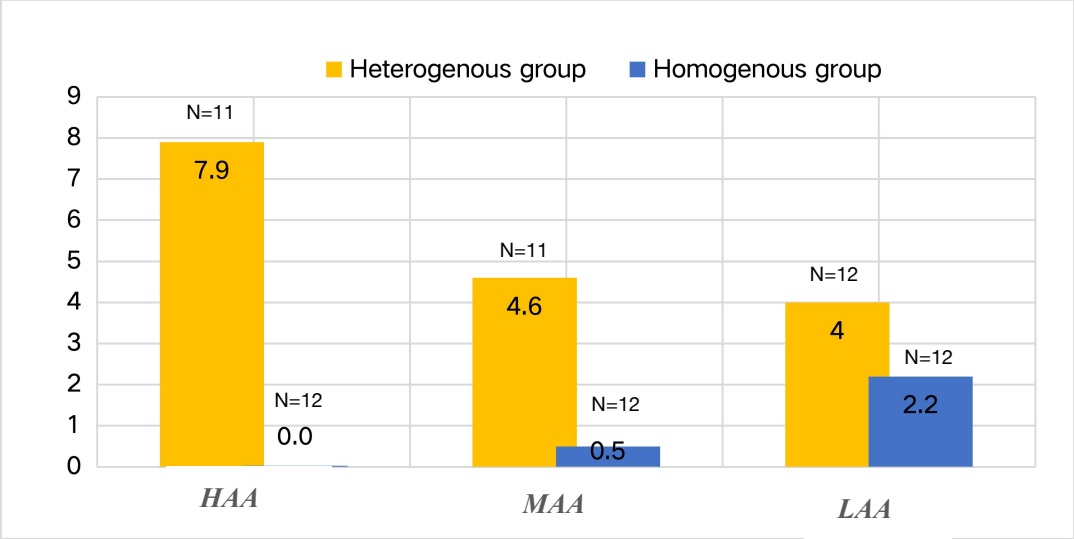
Table 4.16 The student t-test of group compositions on LAAs' progress in academic achievement

	Group composition (mean ± standard deviation)		t	p
	Heterogeneous groups (n=12)	Homogeneous groups(n=12)		
progress	4.00±9.52	2.75±9.09	0.329	0.745

* $p<0.05$ ** $p<0.01$

A histogram is suitable for displaying students' improvement in their academic achievement across all three levels in both homogeneous and heterogeneous groups. As shown in Fig 4.1, the vertical axis represents the average progress in the second college entrance examination compared to the first college entrance examination, and the horizontal axis represents the HAAs, MAAs and LAAs (for each level of students, the left column represents the progress of those participating in heterogeneous groups, and the right column represents the progress of those participating in homogeneous groups. For example, the HAAs who participated in heterogeneous groups improved by 7.9 points, and those who participated in homogeneous groups improved by 0 points).

Fig 4.1 Comparison of progress in academic achievement among students of different levels in homogeneous and heterogeneous Groups



Note: the horizontal axis represents three different level students in heterogeneous group and homogeneous group; the vertical axis represents the improved score value in the second college entrance examination.

4.3 Students' Perception of Collaborative Learning

4.3.1 Students' Perception of the Influence on Academic Performance

To gain an in-depth understanding of how collaborative learning influences students' science learning, the students' perception was recorded through survey, interview and classroom observation. Among them, the survey investigated the views of all participants, so this study first analyzes survey data and triangulates it with the data obtained by the other two methods, trying to ensure the rationality of the conclusion and have an in-depth and complete understanding of the participants' perceptions.

It is worth noting that the results of the second college entrance examination had already been released by the time the survey and interview were conducted. The students' subjective views can be compared with the actual data in order to fully understand the participants' views on collaborative learning.

The majority of the questions in the survey adopted the Likert scale and the options are set below (otherwise in a similar format):

A.strongly agree B.agree C.undecided D.disagree E.strongly disagree

In order to better understand the participants' attitudes, options A to E were assigned a number from 5 to 1, and a value was to be calculated according to the percentage of participants that selected each option, for example, the higher the value, the higher the preference for option A. Furthermore, if the middle option. "undecided", is considered to be the neutral option out of the five, a score higher than 3 points would indicate a positive attitude towards this topic. Finally, the closer to 5 points the value is, the higher the appreciation of the topic is.

4.3.1.1 Perception Amongst All Participants

Five questions in the second part of the survey mainly concern academic performance. Questions 1 and 2 investigated students' perceptions of their change in academic performance in relation to collaborative learning. As shown in Table 4.17, most participants believed they made some progress, with a few students even stating that they made great progress. This indicates that most students agree that collaborative learning helps them improve their academic achievement. In the context of the interview, some interviewees expressed satisfaction with their academic achievements, thereby echoing the results of the survey. However, one student chose "regressed a lot" for question 1, with this being a surprising choice given that this student in fact achieved the same score in both the first and second College entrance examinations. This particular student was chosen as an interviewee in order to shed light on the reasons behind this unexpected choice. Afterwards, the interview demonstrated that his negativity in fact originated from his dissatisfaction with his partner, and this will be elaborated upon in the "partner" section later. In addition, students overall believed that their partners' academic achievement also improved and that the degree of progress made was equal to their own.

As the collaborative tasks in this pivotal stage, namely, the second round review for the college entrance examination focused on homework revision and problem-solving, questions 3 and 4 are designed to garner an understanding of students' perceptions of the effectiveness of these collaborative tasks. It was found that students believed that collaborative learning is also useful for revising homework and understanding problems.

Through a comparison of the values of questions 1 and 2 with those of questions 3 and 4, it was

established that participants consider the most direct impact of collaborative learning to lie in the completion of collaborative tasks, whereby the resulting improvement in academic achievement is relatively indirect. This finding surmises that there is a correlation between the success of specific collaborative tasks and the development of the overall academic level, in which time and effort accumulation is required.

Question 8 is a multiple-choice question and it provides an understanding of other relevant aspects of science learning (see Fig 4.2). The statistics indicate that some students believe they also made progress in multi-perspective thinking and logical reasoning. In the interview, the use of different thinking angles in learning is elaborated. One interviewee who pinpointed this improvement also made big progress in the second college entrance examination. This student described his partner as very meticulous, especially when questioning details that tend to be neglected. Furthermore, after a lengthy debate, his partner's attitude would ensure that any gaps in both of their knowledge systems would be filled. This student opined that having different knowledge structures and different perspectives helps to inspire each other and complement each other's knowledge systems. Notably, another interviewee whose academic achievement actually regressed a little in the second college entrance examination was nonetheless satisfied with her learning outcome of collaborative learning in the survey. In the interview, she mentioned her belief that physics revolved around one's way of logical thinking, rather than focusing purely on academic achievement. In other words, participating in collaborative learning enabled her to improve her logical thinking ability, and her knowledge system became more reasoned.

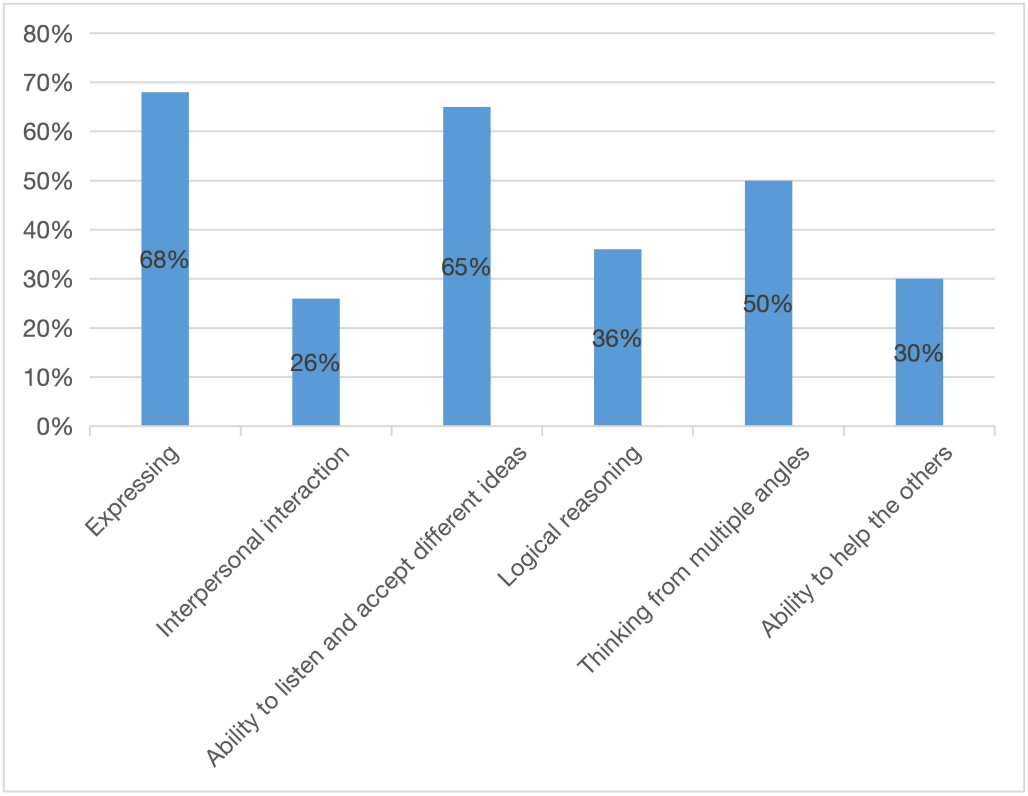
Table 4.17 Perception of learning outcomes of all participants (n=66)

Question	Options and the corresponding choice proportions				
1、Through collaborative learning, I think my academic performance has	Improved a lot	Slightly improved	Unchanged	Slightly regressed	Regressed a lot
	6%	73%	17%	3%	1%
Value	3.9				
2、Through collaborative learning, I think my partner's academic performance has	Improved a lot	Slightly improved	Unchanged	Slightly regressed	Regressed a lot
	11%	64%	25%	0%	0%
Value	3.86				

3、Through collaborative learning, I can understand problems in my homework (exams) more clearly and deeply	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	26%	67%	7%	0%	0%
Value	4.19				
4、Through collaborative learning, my homework correction is more effective	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	29%	65%	6%	0%	0%
Value	4.23				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

Fig 4.2 Choice of question 8 "I think I have also made progress in" of all participants (n=66)



Note： the horizontal axis represents a specific option content within this multiple-choice question; the vertical axis represents the proportion of the respondents' choices.

4.3.1.2 Comparison between Participants from Homogeneous and Heterogeneous Groups

Out of the 70 total participants, nearly half participated in heterogeneous groups with the other half in homogeneous groups. Except for the fact that participants in homogeneous groups scored a little higher than participants in heterogeneous in question 3 (about homework revising), there is no significant difference between homogeneous and heterogeneous groups in terms of

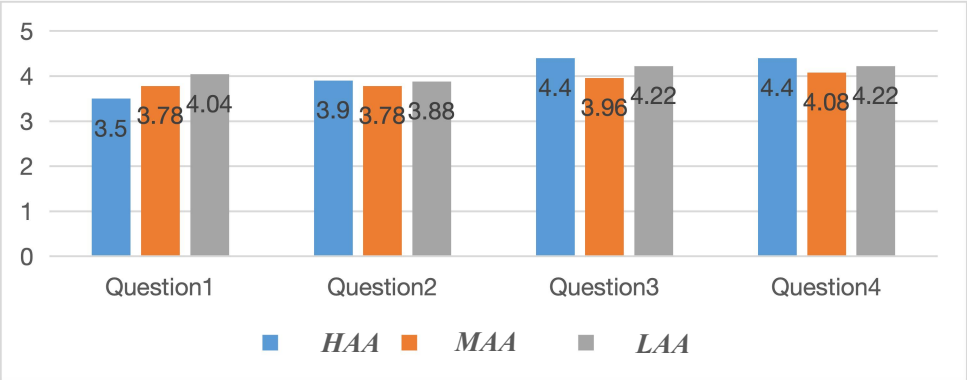
participants' perception of the rest questions (See Appendix G, Table 1 for more details).

4.3.1.3 Comparison Between Students with Different Academic Achievement Levels

In accordance with their level of academic achievement, participants are divided into three levels, namely high, medium and low. The number of students at each level is equal, therefore each one accounts for one-third of the total participants. Figure 4.3 compares the scores of students with different levels in four questions (See Appendix G, Table 2 for more details). The first question concerns participants' perception of their academic progress. Among participants at all three levels, the LAAs were the most positive in terms of how much their academic achievement improved as they scored the highest in question 1, while HAAs were the least positive as they scored the lowest, with MAAs in between. However, when comparing students' answers to questions 1 and 2, namely the perception of the change in their own academic achievement and that of their partners, the reverse is true. The result shows that HAAs believed that their partners benefited more than themselves as they scored higher in question 2. In contrast, LAAs scored lower in question 2, indicating their judgment that they benefited more than their partners through collaborating. As for MAAs, they chose the same score in questions 1 and 2, indicating they felt they benefited the same amount as their partners.

In terms of both problem-solving and homework revision, HAAs displayed the most positive sentiments, with LAAs in the middle, and MAAs scoring the lowest. This can likely be accredited to HAAs having more opportunities to elaborate on problems when working with their partners, as well as being able to develop their thoughts into mature ideas, while LAAs tend to receive direct help from more competent partners which enables them to make a certain level of progress.

Fig 4.3 Comparison of perception of learning outcomes among participants in different levels (HAA: n=20; MAA: n=23; LAA: n=23)

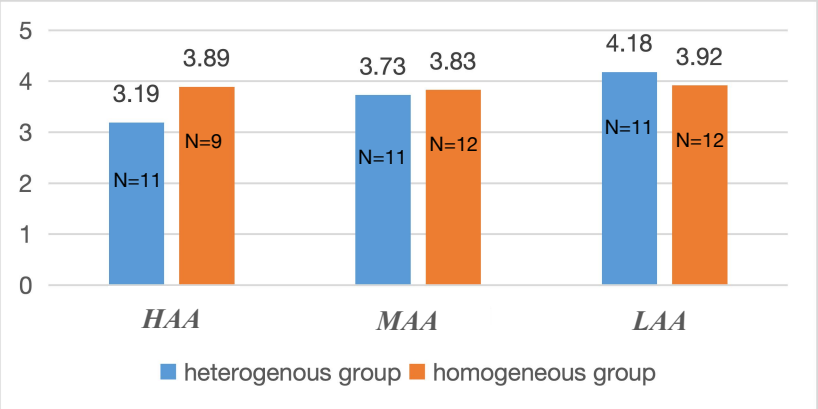


Note: the horizontal axis represents the question number for the "learning outcomes" part in the survey ; the vertical axis represents the score converted from the proportion of the respondents' choices in the Likert scale (each option is assigned a score from 5 to 1).

4.3.1.4 Perception of Participants with Different Levels of Academic Achievement in Both Homogeneous and Heterogeneous Groups

How do students of different levels perceive their academic achievement within different groups? Are the students' opinions consistent with their actual performance? Fig.4.4 compares scores of question 1 among participants in different levels in both heterogeneous and homogeneous groups. It indicates that for HAAs, those who participated in heterogeneous groups scored obviously lower in question 1 compared to those in homogeneous groups. Actually, they scored the lowest among all six types of participants. Interestingly, quantitative data analysis provides exactly the opposite results. As outlined in section 4.2.4, among all six types of participants, HAAs in heterogeneous groups achieved the most significant progress in the second college entrance examination. In contrast, although HAAs who participated in homogeneous collaboration showed a more optimistic view towards their academic progress, their actual average score in the second college entrance examination told a quite different story as it roughly remained the same as it was in the first college entrance examination. In other words, the HAAs who participated in homogeneous groups and indicated a positive attitude toward their learning outcomes in fact attained the least progress, while those who participated in heterogeneous groups achieved the greatest progress but registered the least positive sentiments.

Fig 4.4 Comparison of the score of question 1 (perception of one's academic performance) among participants in different levels in both heterogeneous and homogeneous groups



Note: the horizontal axis represents three different level students in heterogeneous group and homogeneous group; the vertical axis represents the score converted from the proportion of the respondents' choices in the Likert scale (each option is assigned a score from 5 to 1).

Moreover, none of the low or MAAs indicated that they had regressed, but some HAAs did select the "regressed a little" and even the "regressed a lot" options for question 1. Most notably, these students all participated in heterogeneous groups and collaborated with less competent partners. This may reflect a widely perceived psychological trait of HAAs, namely that they prefer to collaborate with partners of at least equal ability.

This also indicates that students may think that there is a positive correlation between the learning effect and the academic level of the partner. Through the above analysis, it can be found that students' subjective feelings about their learning may not necessarily be consistent with their actual grades. This discrepancy will be discussed in Chapter 5.

In the survey, four students indicated that they have "improved a lot", and coincidentally, they were all LAAs, with no students from medium or high levels selecting this option. Among these four students, two collaborated with more competent partners in heterogeneous groups and two collaborated with equal-level partners in homogeneous groups. This implies that LAAs, no matter whether they are in homogeneous or heterogeneous groups, all have the possibility of achieving significant progress. Furthermore, it is noteworthy that as the survey was carried out non-anonymously, therefore, making it simple to track one's partner's answers, the LAAs' partners also believed they made progress, demonstrating that the improvement of LAAs was not necessarily at the cost of their partners' drop in academic performance.

Nonetheless, it must be conceded that LAAs tend to feel that they are more likely to make progress in heterogeneous groups, and this may be attributed to the support they received from their higher-level partners' intentional or unintentional scaffolding behaviours. Furthermore, one LAA who collaborated with a HAA partner recollected that during the collaborative learning process, the majority of problems were raised by himself whilst his partner performed the role of a "little teacher". In contrast, a LAA who collaborated with an equal-level partner stated that due to their limited ability, both members toiled and spent too much time on a given problem, thus demonstrating an inability to use time efficiently. As illustrated in section 4.2.4, compared to students who participated in homogeneous groups, LAAs in heterogeneous groups showed more significant improvement in their academic performance. That is to say, LAAs' perception is consistent with their actual performance.

As for MAAs, whether in homogeneous or heterogeneous groups, their perception of the progress in academic performance is almost the same. However, the analysis of the score showed that compared to students who participated in homogeneous groups, those who participated in heterogeneous groups actually made more significant progress.

In light of the above analysis, it seems that apart from MAAs, students are more confident in making progress when collaborating with high-level, or higher-level, partners, thereby reflecting their expectations for the academic level of collaborative peers. See more in the "partner" section.

4.3.2 Students' Perception of the Influence on Interpersonal Factors

The literature review concluded that collaborative learning also has a positive impact on students' interpersonal skills. This section analyzed multiple data sources, including survey, interview and field notes, in order to determine the impact of collaborative learning on interpersonal factors. In particular, several questions in the second part of the survey ("on the effect of collaborative learning"), namely questions 5 to 8, discussed interpersonal communication, including awareness of self-confidence, and communicative ability. The participants' answers are shown in Table 4.18.

4.3.2.1 Perception of All Participants

Firstly, it was found that students were generally aware of the importance of interpersonal factors through collaborative learning. In a traditional Chinese classroom, students are usually assigned to a fixed position with a fixed desk mate. This study entailed breaking up the usual group settings with most participants being paired with a new desk-mate. Through the interviews, it was found that students wished to make a positive impression on their new partner, thus allowing collaboration to run more smoothly. Moreover, one interviewee described his feeling as follows,

> Collaborating with a new desk mate is like going on a trip to an unfamiliar place. I felt nervous but also excited. I was eager to perform at my best in front of my new friend.

Most groups displayed intimate relationships during collaborative learning. The classroom observation established that in most groups, members worked at a close physical distance, with their bodies and heads facing each other, whilst they often used the same paper or homework to base discussions on.

Analysis of survey data showed that students' interpersonal awareness and skills were found to have improved through the experiences of collaborative learning, although not as prominent as improvement in learning since students scored lower in interpersonal relationships. As shown in Fig 4.2, Almost 70% of students believed they made progress in oral expression as well as their ability to listen and their likelihood to accept opposing ideas.

More is discovered in interviews. Students found that even though they had experience discussing problem situations prior to this study, their experience of collaborative learning was distinct. Due to the learning goals being mutual, they consciously practised their communicative skills. Moreover, they were more cautious when raising questions and explaining their ideas, and they expressed ideas as clearly and logically as possible to ensure that their partners clearly understood them. They were also aware of the importance of listening and viewing issues from other perspectives. Lastly, when there was a conflict in the discussion, they were able to reflect and solve it in a rational way.

It was found that students learned how to collaborate effectively through their experience of collaborative learning. As one interviewee pointed out, prior to this study, he and his close friend

John (Pseudonym) would usually engage in heated discussions when their opinions conflicted. Furthermore, he and John have the same personality trait, namely that they are both eager to have their opinions accepted by their partner, with quarrels sometimes ensuing when neither can persuade the other to accept their opinion, with the problem ultimately remaining unresolved. However, this interviewee's experience of collaborating with Simon (Pseudonym) in collaborative learning was entirely different. Simon has a calm personality, therefore when a conflict arises, he is not overly eager to persuade his partner to accept his opinion, but rather he prefers pausing and contemplating in order to fully understand the problem, and then ultimately offering his opinion rationally. The interviewee asserted that he did not feel anxious when collaborating with Simon and they were able to resolve problems successfully in an amicable and effective manner. In light of this experience, the interviewee gained an appreciation of the importance of listening and seeing things from others' perspectives in interpersonal communication. He stated that,

> Through the experience of collaborating with Simon, I understand the need for a cooperative and tolerant attitude during discussions. The key to the success of collaboration is to understand how your partner thinks.

The interpersonal relationships built were not limited to the classroom, they also extended to after class. Moreover, data from the survey demonstrated that after the collaborative learning had taken place, the frequency of discussion among classmates, and not limited to one's collaborative learning partner, was higher, with the capability of solving problems through discussion enhanced and interpersonal communication, not limited to discussion of problems, increased. This was evidenced through after-class observation. It was observed that after class, students who were unfamiliar with each other prior to this study were able to establish friendships during collaborative learning, thus leading to informal conversations and discussions of personal problems in their free time.

Collaborative learning also had a positive effect on self-confidence. In the survey, over 40% of students stated that they felt more confident and willing to communicate with others after the collaborative learning experiences. Furthermore, it was found that these experiences can alter students' original views on interpersonal communication. In the interview, one student considered

herself on the periphery of the class and was a reluctant participant in interpersonal communication, feeling uneasy when talking to someone one-on-one. Her partner was someone she seldom talked to before collaborative learning, therefore she was shy initially. This behaviour is in accordance with the classroom observation, where the group as a whole was not enthusiastic at first. Nonetheless, Because they have mutual learning tasks, they have to start collaborating to ensure that all members of the group solve problems, and during this process, she gradually established a positive relationship with her new partner through discussing and solving problems together. She stated that,

> Now I feel that I am willing to communicate with classmates I am unfamiliar with, and I have found that in fact most of them are very friendly.

Furthermore, there was one student in particular who had been very unwilling to interact with others, and sometimes even avoided group activities completely. However, upon being paired with a new desk mate in this study, her behaviour changed dramatically. As was recorded through classroom observation, she became active in the discussion and did so with a very positive attitude, indicating that she was in a relaxed state and less tense than usual. Also, she would regularly interact with her new partner after class, and ultimately they developed a friendship.

Table 4.18 Perception of interpersonal factors of all participants (n=66)

Question	Options and the corresponding choice proportions				
5、After class, my awareness and frequency of using discussions to solve problems have increased	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	14%	50%	30%	6%	0%
Value	3.72				
6、As a whole, my interaction with others has increased	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	11%	58%	29%	2%	0%
Value	3.78				
7、After collaborative learning, I feel more confident and willing to communicate with others	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	11%	29%	45%	15%	0%
Value	3.36				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

4.3.2.2 Comparison among Participants with Different Academic Achievement Levels

Among all three levels, HAAs achieved relatively higher scores among all three levels in questions 5 and 6, while LAAs achieved relatively lower scores (See Appendix G, Table 3 for more details). The classroom observation led to the finding that HAAs tend to be more dominant during collaborative learning, acting as interpreters and finding more opportunities to express ideas and thereby improve their interpersonal skills, thus offering a reasonable explanation for their higher score. In contrast, LAAs are more passive, especially when they are working with more competent partners, where they have a tendency to play the role of listeners or bystanders. Consequently, they enjoy fewer opportunities to improve their communicative skills. Nevertheless, there are also a handful of introverted HAAs who do not participate enthusiastically in collaboration. However, the differences among participants of different levels are not particularly evident.

In terms of self-confidence when communicating, low and MAAs experienced more improvement. During the interviews, two MAAs shared and reflected on their experiences, specifically, they stated that collaborative learning offered them opportunities to ascertain both the strengths and weaknesses in thinking of both their partners and themselves. Moreover, they added that they were able to accomplish this in a more rational and comprehensive manner than they could before, thereby increasing their self-confidence when communicating with higher-level partners.

Kang (pseudonym) was in a heterogeneous group alongside a HAA. Initially, he was embarrassed when he was not capable of keeping pace with his partner, therefore he occasionally pretended to have understood the ideas of his partner as he did not want to be viewed as impotent or be blamed for slowing the progress of the group. However, he gradually came to the realization that he too was able to propose worthwhile ideas, for example when he offered a more suitable method for solving a particular problem which led to the approval of his partner. This success increased his confidence and he asserts that he will no longer be overly concerned about being embarrassed when asking questions or expressing ideas again. He stated that,

> I feel that everyone has his own strengths and weaknesses…you need to have strong self-confidence. If you feel like you can't compete with your partner in any aspect, you

will be completely subordinated in a group. However, once you realize that you are at the same level in some regards, you dare to voice your own ideas... But in the beginning, you have to overcome psychological barriers.

4.3.2.3 Comparison Between Participants from Homogeneous and Heterogeneous Groups

It was found that participants in homogeneous groups scored marginally higher in both questions 5 and 6, therefore indicating that homogeneous groups may be more conducive to stimulating genuine communication and supporting students to improve their collaborative skills. Moreover, when self-confidence in communicating is investigated in question 7, HAAs achieved similar scores in both group compositions, as did MAAs. However, there was some disparity among LAAs in different groups as those who participated in homogeneous groups scored higher. As illustrated earlier, for LAAs, both homogeneous and heterogeneous groups are beneficial in improving academic achievement, however, in terms of interpersonal factors, homogeneous groups tend to be superior. However, due to the small sample size, the difference between these two groups is insignificant (See Appendix G, Table 4 and Table 5 for more details).

4.3.3 Students' Perception of Collaborative Partner

Collaborative partner is a crucial factor in collaborative learning. In this study, students paid close attention to their partners. Through surveys and in-depth interviews, it was established that students believed their collaborative partner to be one of, if not the most important factor in collaborative learning because every aspect of collaborative learning, including behaviours, engagement and learning outcomes, is influenced by their partners. Consequently, most students have expectations and preferences for their partners.

4.3.2.1 Perception of All the Participants

As shown in Table 4.19, students are most likely to select academic achievement as the basis for their grouping. Moreover, half of the students desired to collaborate with higher-level partners, with nearly half of the remaining ones preferring equal-level peers, and no one wished to collaborate with less competent peers.

In the interviews, almost every student expressed opinions about their collaborative partners, with the most common being comments on their partner's academic level and its impact on themselves. Students who collaborated with more competent peers expressed mostly positive views of their peers. One participant considered his partner "a nice learning partner who can broaden my horizons and we had a great relationship", with another considering her partner to be "eager to ask questions, willing to share", and another considering his partner to be "nice and capable". In contrast, students who collaborated with less competent partners tended to express their regret for not being able to collaborate with a higher-level partner, with one interviewee even expressing strong dissatisfaction. This interviewee was unique in that he was the only one who opted for "regressed a lot" for the question that discusses one's academic achievement in the survey. His reasoning for this choice was that his partner's ability was clearly lower than his, therefore they had "no common language" and he spent the majority of the collaborative learning teaching his partner, which made the experience as a whole seem inefficient. Even though this student achieved the same score in the second college entrance examination, he was very disappointed as he felt as though he should have scored higher, and in his opinion making no progress actually meant a drop in academic performance. Also, this student displayed a relatively negative attitude towards collaborative learning as a learning method.

Through combining survey and interview data, it is evident that students initially perceive that the benefit of collaborative learning derives from the support offered by their partners, with higher-level partners being equivalent to tutors that are freely available. As a result, HAAs are popular partners, with a partner with the same ability being deemed acceptable. However, a partner of a lower level might not be ideal since students believe not only is it highly unlikely to receive help from lower-level partners, but it is also necessary to expend time and energy to help them, potentially affecting their own learning. After their experience of collaborative learning, even though students have differing opinions, such as how cognitive conflicts in homogeneous groups are able to trigger one's deep thinking, and elaborating on problems to one's partner can promote clearer ideas, this pre-impression is deeply rooted, and changing it is a difficult task.

There are other factors that students take into consideration. Survey data indicated that personality

is the second most important factor for a partner as students care about whether one's partner is an introvert or an extrovert. Furthermore, if both group members have introverted personalities, the effectiveness of collaborative learning may be in jeopardy. The classroom observation included one homogeneous group in which both group members were HAAs with introverted personalities. Initially, they did not discuss anything with each other, rather they were solving problems individually, with this potentially attributable to shyness. However, once I explained and emphasized the importance of collaboration in learning and encouraged them to voice their opinions, they gradually began to cooperate. In some sense, one's character is even more important than one's ability, as one interviewee described,

> Although my partner has a HAA, he is too introverted, sometimes it's like squeezing water from a rock when we discuss a problem.

Students also paid particular attention to their partner's communicative skills. In collaborative learning, a partner who is open-minded and an effective communicator is often one of the most popular, as evidenced by one interviewee,

> I am very lucky because my partner is very positive, she often puts forward edifying questions, therefore we can promote each other's learning, and I feel that I have gained a lot through this experience.

In contrast, a partner with poor communicative skills has a proclivity to cause dissatisfaction. For instance, one interviewee pointed out the incoherence in her partner's thinking in a sarcastic fashion and labelled her partner "a philosopher", due to her partner not being able to adequately express ideas with sufficient clarity during the discussion, tending to deviate from the topic, and seemingly forgetting her presence and talking to himself.

Another important factor is friendship. Some students opined that the fact that there was no pre-existing friendship between group members may lead to poor collaboration. At the beginning of this study, one student requested for their partner to be changed with the reason being that his assigned partner was a girl that he had barely spoken to prior to collaborative learning. Subsequently, once his partner was switched to a boy, he became rather enthusiastic. Nonetheless,

the interviews saw some students asserting that effective collaborative partners do not necessarily have to be close friends as they may be too familiar with each other's thinking, thereby obstructing the stimulation of new ideas, and also close friends tend to enjoy the conversation that deviates from the task at hand, and is therefore detrimental to collaborative learning.

Table 4.19 Perception of partner of all participants (n=66)

Question	Options and the corresponding choice proportions				
1、What do you think is the rationale of the collaborative group	Personality	Academic performance	Friendship	Random	I am not sure
	14%	37%	6%	33%	10%
2、What do you prefer to be the rationale of the collaborative group	Personality	Academic performance	Friendship	Random	I am not sure
	28%	32%	19%	17%	4%
3、I prefer my partner to be	With higher academic level	With similar academic level	With lower academic level	I am not sure	I don't care
	40%	50%	10%	0%	0%
4、I think my current partner is	With higher academic level	With similar academic level	With lower academic level	I am not sure	I don't care
	50%	40%	0%	0%	10%

4.3.2.2 Comparison among Participants with Different Academic Achievement Levels

Students of different academic levels made relatively different choices in terms of their partners. Participants' answers to question 2 and 3 showed that LAAs paid more attention to "academic achievement" and were therefore more willing to collaborate with higher-level partners. In contrast, HAAs were more concerned with "character", given that their academic achievement level is already at the top of the entire class, it is unreasonable to expect a much more competent partner, therefore their emphasis was on personality. MAAs considered "character" and "academic achievement" to be of equal importance.

By comparing participants' answers to questions 3 and 4, it is found that the ideal partner's level expected by HAAs and LAAs was roughly the same as that of their actual partners. Interestingly, for MAAs, the level of an ideal partner seemed to be a little lower than that in the actual situation, because 60% of MAAs thought that the level of current partners is higher than themselves, while

only 40% hoped to collaborate with higher-level partners (See Appendix G, Table 6 for more details).

4.3.2.3 Comparison between Participants from Homogeneous and Heterogeneous groups

Students who participated in homogeneous groups were more likely to select "academic achievement" as the basis for grouping, and they paid little attention to their partner's character. In contrast, students who participated in heterogeneous groups were more concerned with their partner's character. (See Appendix G, Table 7 for more details).

4.3.4 The Interaction

Interaction is an important variable in collaborative learning. Understanding the intricacies of the interaction process and studying secondary variables will enable us to figure out how interaction affects the learning outcomes of collaborative learning. Using multiple data sets obtained from classroom observation, survey and interview, this paper explores the degree of engagement of students in collaborative learning and to what extent positive interdependence has been generated. Furthermore, various aspects of interaction are discussed, such as the quality of discussion, the solution adopted when disputes occur in the discussion, and collaborative learning time and its atmosphere. Finally, the influence of both cognitive conflict and scaffolding behaviour in interaction is explored. One theoretical interest of this study is to discover which out of scaffolding behaviour and cognitive conflict is more conducive to students' learning. Another question of concern is whether providing scaffolding support to one's less competent peer is potentially detrimental to HAAs. The analysis of quantitative data earlier in this chapter demonstrated that the HAAs who collaborated with less competent peers in heterogeneous groups in fact made the most significant progress. However, the survey found that these students also displayed the most negative feelings toward their academic achievement. In order to obtain an in-depth understanding of this contradiction, the participants' perceptions of scaffolding behaviour and cognitive conflict are collated and analyzed.

4.3.4.1 Level of Engagement and Positive Interdependence

Level of engagement and positive interdependence are closely related and are both vital factors in

interactions that promote positive learning outcomes. Table 4.20 showed the results of the analysis on the "engagement" section of the survey. The result of questions 1 and 2 showed that overall, students have a positive attitude toward their engagement in interaction as well as their partners', and this is consistent with the classroom observation. The analysis of the classroom observation notes evidenced that at the beginning of collaborative learning, some students displayed a lack of familiarity with this learning method and couple this with a lack of familiarity with their partners, the resulting consequence was low participation. However, after one or two classes, students became more familiar with their partners as well as this new learning strategy, therefore their participation increased. Most collaborative groups achieved a state of high concentration whereby intense discussion ensued. This is captured by the following observation note:

> It has been two weeks and the interaction between group members is becoming increasingly heated and frequent…Gradually, I found that the students realized the importance of discussing, expressing, listening, arguing and even compromising in order to achieve mutual learning goals. My encouragement may also have played a role…They are increasingly keen on discussions as well as being good at them…In today's discussion, group C was in high spirits and the students looked excited and joyful…

The improvement in engagement level correlates with the sense of interdependence that is established between group members. The results of questions 3-5 indicated that participants became aware that they were in a learning community and were striving for mutual learning goals, therefore they began to become sensitive to each other's learning and to some extent created a sense of responsibility for their partner's learning and ultimately were willing to care for and support their partner's learning.

Outlining a typical group's behaviour is useful for illustrating the above phenomenon. In this group, student A, was notable as his learning attitude was transformed after collaborative learning. Prior to this study, A was not a hardworking student, he sometimes failed to finish his homework, his learning motivation was low and he was easily distracted in a traditional classroom setting, thereby resulting in his low academic achievement in physics. However, after a period of exposure

to collaborative learning, a significant change took place. I was pleasantly surprised to find out that he began to engage more in interaction, he continuously and actively asked questions to his partner and displayed great enthusiasm for explanations and discussion, therefore acting entirely different from his original state. One interviewee, student B, happened to be A's partner and he stated that initially, A did not initiate any active collaboration, instead choosing to secretly play games in class. In order to change this adverse situation, B consciously adopted the following strategies: First, he took note of the mistakes in A's homework in order to attract A's attention. Secondly, he took the initiative to ask A questions and subsequently allow A to explain his ideas, and then B would ask follow-up questions and encourage A's responses, with these practices all gradually increasing A's participation. B's self-description is consistent with the classroom observation and there is a record in the field notes about their group:

> Today, I asked the whole class which group would like to report the result of the discussion. B immediately raised his hand but stood up and said mischievously: "let my partner A answer it." A stood up, albeit reluctantly, but gave a very clear and logical answer. It was very different from his old self!

In the second college entrance examination, B's score increased by 3 points, and he was satisfied with his collaborative learning experience. Upon being informed that A also made progress, B stated in a tongue-in-cheek fashion that it is himself that should be credited for that! Ultimately, the stimulation of his partner's learning enthusiasm and making mutual progress brought A a great sense of accomplishment.

The participants' sense of responsibility can also be attributed to mutual learning goals. As an example, interviewee C collaborated with a lower-level partner and he understood that in order to achieve the best learning outcome, the discussion must be effective and that can only be achieved when group members are truly devoted to achieving their mutual goal. Therefore, he was very sensitive to his partner's learning and offered support in order to enhance his partner's learning ability, with the quality of their discussion continually improving. In the end, this interviewee made significant progress, with his partner also making considerable progress in the second college entrance examination. Therefore, this interviewee's sense of responsibility is related to his

learning goal.

Table 4.20 Perception of engagement of all participants (n=66)

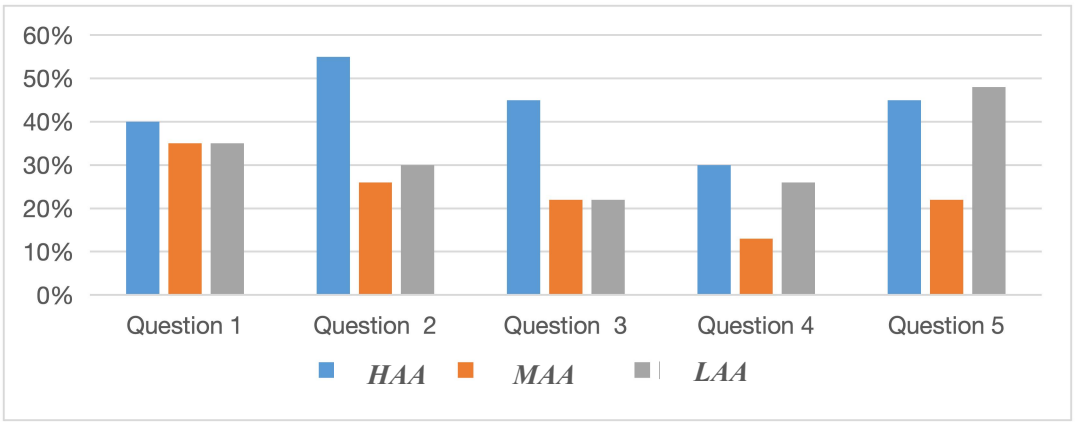
Question	Options and the corresponding choice proportions				
1、I participated in collaborative discussions actively	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	36%	64%	0%	0%	0%
Value	4.36				
2、My partner participated in collaborative discussions actively	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	36%	61%	3%	0%	0%
Value	4.33				
3、During collaborative learning, completing the learning task together is our mutual goal	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	29%	61%	8%	2%	0%
Value	4.17				
4、I am also concerned about my partner's learning, and I would like to offer help though reminding, asking questions and encouraging	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	23%	56%	17%	4%	0%
Value	3.98				
5、When my partner made progress in his (her) learning, I feel happy for him (her)	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	38%	52%	10%	0%	0%
Value	4.28				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

As shown in Fig 4.5, among all three academic levels, HAAs scored higher on questions concerning the level of engagement and also positive interdependence, with their choice of "strongly agreed" being the highest. In contrast, MAAs scored relatively lower, therefore indicating a lower degree of engagement and interdependence (See Appendix G, Table 8 for more details). The previous analysis found that HAAs made the highest degree of progress, followed by LAAs, and MAAs got relatively the least progress. From the literature review, active engagement facilitates the achievement of mutual goals in collaborative learning (Nokes-Malach, Richey and Gadgil, 2015) and positive interdependence also helps students be motivated to interact and learn together and thus further affect the learning results (Johnson and Johnson, 2005). Therefore, the results of data analysis may suggest that there does exist a positive correlation between active

engagement (as well as positive interdependence) and achievement progress.

Fig 4.5 The proportion of students choosing "strongly agree" in questions 1-5 (the "engagement" part) of each academic achievement level (HAA: n=20; MAA: n=23; LAA: n=23)

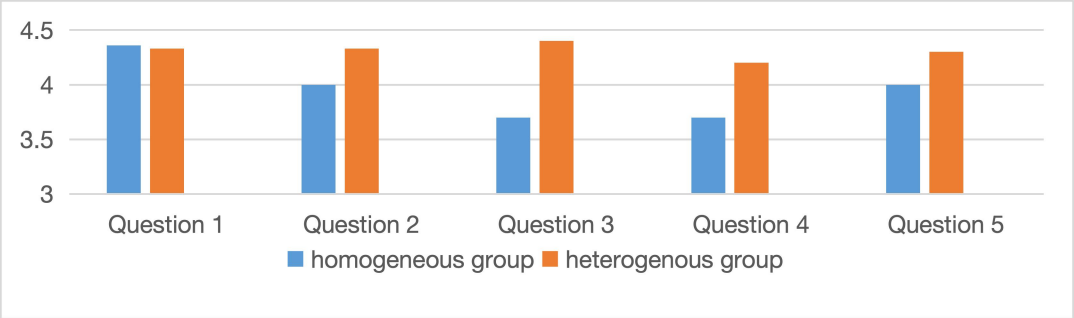


Note: the horizontal axis represents the question number; the vertical axis represents the respondents' choices proportion.

Due to the relatively low interdependence and degree of engagement among MAAs, this study divided them into homogeneous and heterogeneous groups and found interesting results displayed in Fig 4.6. Out of the five questions posed, except for the very similar results found in question 1, students who participated in homogeneous groups generally take a more positive view (See Appendix G, Table 9 for more details). This fact indicates that for MAAs, collaborating with partners of a similar level tends to stimulate a stronger collective consciousness. This correlates with conclusions found in the literature, namely that MAAs are more suitable for homogeneous groups. One MAA who participated in a homogeneous group collaboration described,

> There was a tacit understanding between the two of us. Our learning efficiency was very high during the discussion.

Fig 4.6 Comparison of the score of questions 1-5 (the "engagement" part) among MAAs in both heterogeneous and homogeneous groups (homogeneous groups: n=12; heterogeneous groups: n=11)



Note: the horizontal axis represents the question number; the vertical axis represents the score converted from the proportion of the respondents' choices in the Likert scale (each option is assigned a score from 5 to 1).

However, the survey is non-anonymous, and it is impossible to completely rule out the phenomenon that some students intentionally made false choices in order to meet the researcher's expectations. Therefore, it is necessary to triangulate the responses with data collected through classroom observation. For instance, one student selected the option "I participated in collaborative discussions actively" in the survey, yet the classroom observation recorded very contradictory behaviours, with his group at times remaining silent and its members instead studying their own homework or test papers rather than communicating. However, one member of this group happened to be an interviewee and her description painted a rather different story. She stated that at the beginning of each collaboration, both group members will require sufficient time to contemplate the problems on their own, otherwise, they cannot conclude which problems are in most need of redress. On occasion, although the mistakes or problems seem evident, participants will still embark upon their own process of problem-solving individually, and subsequently encounter issues that cannot be resolved independently, and only then will they collaborate purposefully and effectively. Consequently, their group often initiates discussion at a later point compared to the other groups, thereby giving the impression of low engagement, yet when the remaining groups had finished their discussion, their group was in the middle of an intense debate. This example demonstrates that only through considerate and thorough data triangulation can we understand students' behaviour in collaborative learning.

4.3.4.2 Quality of Discussion

Questions 1-4 in the "interaction" part of the survey mainly investigated the quality of the discussion. The analysis of data showed that overall, participants consider the collaborative

discussion of high quality. As displayed in Table 4.21, most students registered satisfaction in the survey regarding the quality of discussion, as they felt they were able to describe their ideas clearly and logically as well as provide detailed explanations.

Table 4.21 Perception of quality of discussion of all participants (n=66)

Question	Options and the corresponding choice proportions				
1、I can express myself clearly and logically during collaborative learning	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	11%	59%	30%	0%	0%
value	3.81				
2、My partner can express him or herself clearly and logically during collaborative learning	strongly agree	agree	undecided	disagree	strongly disagree
	24%	66%	8%	2%	0%
value	4.12				
3、During collaborative learning, I always explain in detail if necessary	strongly agree	agree	undecided	disagree	strongly disagree
	30%	52%	16%	2%	0%
value	4.1				
4、During collaborative learning, My partner always explains in detail if necessary	strongly agree	agree	undecided	disagree	strongly disagree
	35%	50%	9%	1%	0%
value	4.04				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

Actually, in collaborative learning, the quality of discussion may go through a process of continuous improvement. Firstly, students may find problems that were ignored through their own effort. When students solve problems independently, they tend to use intuition rather than strong logic, yet when they elaborate on their thoughts through communication, they will be more likely to detect the existing problem by applying logic and identifying gaps in the problem equation and figuring them out carefully. One interviewee confirmed this when he stated:

> At one point in the discussion, I suddenly realized that yesterday when I was tackling this problem, there was a logical problem, so I rethought it immediately and used a mathematical proof to complete the missing part of the logical chain. When I returned to the discussion, I found my mind was clearer and I explained it in a clear way.

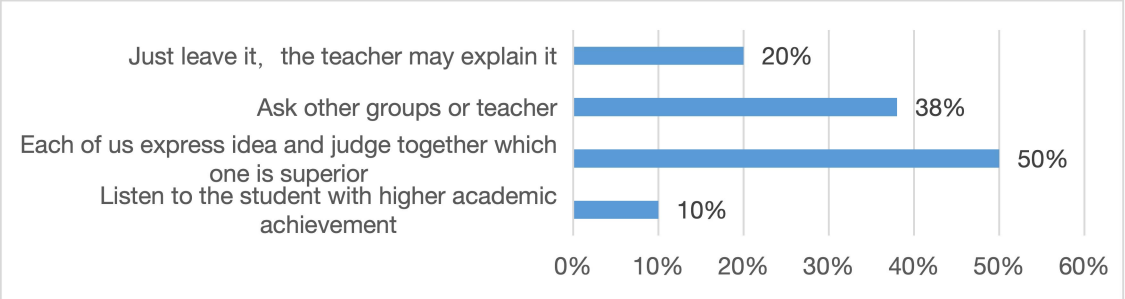
Secondly, students can receive inspiration from their partners during discussions. This is backed up by one interviewee who stated:

> When I was expressing my thoughts, my partner often identified some problems that were overlooked by myself, he asked questions that forced me to think about the problem again, which made my explanations in the interaction clearer.

It was found through the interviews that some students who chose the option of "the quality of discussion is not high" in the survey were in fact referring to the early stages of collaborative learning. Further along in the process, the students' thinking matured, and they were able to express ideas with confidence, and subsequently the quality of discussion gradually improved.

As shown in Fig 4.7, when disputes occurred during collaboration, students were most likely to "express each one's own opinions, judge together and listen to the more reasonable idea", and secondly "ask other groups or the teacher", thus mirroring the findings of the classroom observation. During collaborative learning, I observed the class in close proximity, and when groups asked me questions about problems that their discussions could not resolve, I provided guiding hints or thought-provoking questions rather than offering direct answers, with the aim being to enable groups to continue to discuss and solve problems by themselves. Among the five students who chose to "listen to the opinions of students with higher academic achievement", two were HAAs and three were LAAs, with no MAAs choosing this option. It may indicate that MAAs are relatively more independent and willing to rely on their own opinions.

Fig 4.7 The proportion of students choosing each option in question 5 "If there is a dispute over a particular question, we are most likely to" (n=66)



The quality of discussion is higher among HAAs as they reported higher scores in the questions dedicated to the quality of discussion, with their choice of "strongly agree" also being the highest

among all three levels. Moreover, LAAs took second place whilst MAAs were the lowest, thus evidencing that students' views on the quality of discussion may have a positive correlation to their academic level. In addition, both HAAs and LAAs deemed that their partners gave more detailed explanations than themselves, yet MAAs reported the opposite views. In the interviews, those who cited difficulties they experienced in discussions, including problems in logic and expression, are mostly MAAs and LAAs, however many of them added that after consciously practising for several classes, the quality of discussion improved. In contrast, most HAAs are found to be confident in their logic and expression in the discussion (See Appendix G, Table 10 for more details).

Further analysis (See Appendix G, Table 11 for more details) revealed that no matter what level the students are, those who participated in homogeneous groups reported higher scores on all questions relating to the quality of discussion. With only one exception, LAAs who participated in heterogeneous groups scored higher for the second question, thus they indicated that their partners' communication quality was higher. The above results may lead to the conclusion that participants, especially HAAs and MAAss, are more satisfied with the quality of discussion in homogeneous groups.

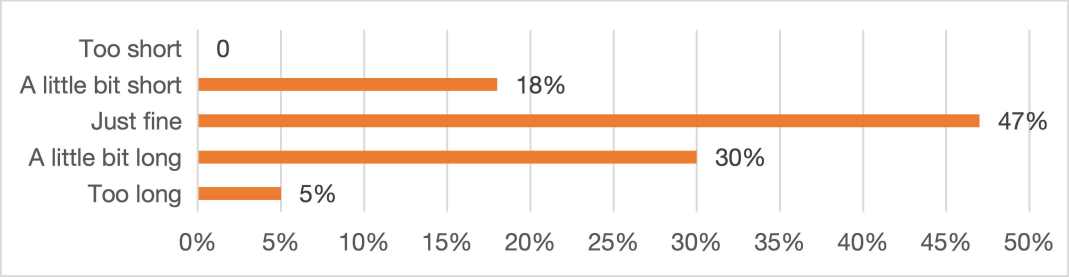
4.3.4.3 Time for Collaborative Learning

Question 9 in the "interaction" part of the survey concerns the time allocated to collaboration, Fig 4.8 indicates that almost half of the students felt that the time allowed for completing collaborative tasks was appropriate. The remaining half offered varying opinions, therefore demonstrating that different students have different needs with this contradiction being particularly evident in a large class. Specifically, both high and LAAs registered a score of around three, signifying that they believe the time is quite appropriate. However, MAAs reported a significantly higher score of nearly 4, thereby confirming that they considered the allocated time to be a little too long (See Appendix G, Table 12 for more details). This may be related to their lower degree of engagement and lower sense of interdependence (as illustrated in 4.3.4.1).

Based on classroom observation, the perception of the length of time is related to the task at hand. On one occasion, as the discussion task, namely homework revision, was relatively simple, I

found that many groups reached a "silent" state prior to the end of the allocated time, with group members moving on to other assignments, therefore evidencing that the time allowed was excessive for them. On another occasion, due to the homework being rather challenging, each group was still involved in heated discussions at the time of the class ending. In addition, the perception of the length of time is also related to the specific background of each group, with several groups that performed more actively usually feeling that the preset time was too short. Nevertheless, it was found that in one heterogeneous group, the more competent partner consistently offered explanations whilst her partner rarely asked questions in response. These kinds of interactions typically last for a short time, and in some sense, it cannot reasonably be considered a real collaboration. Given the complexity of conducting collaborative learning in a large class, I often make minor adjustments to the time allowed for collaboration in accordance with specific tasks, yet it is nonetheless difficult to fully satisfy the needs of every participant. The question remains as to how to ensure that collaborative learning in large classes can go forward more flexibly so as to meet the needs of different participants.

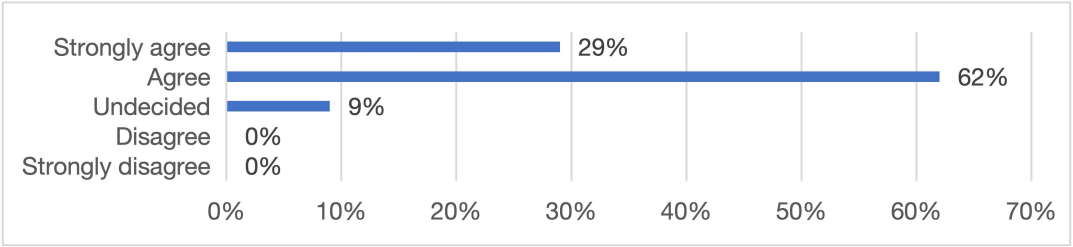
Fig 4.8 The proportion of students choosing each option in question "time for collaboration" (n=66)



4.3.4.4 Atmosphere in Collaborative Learning

Question 10 in the "interaction" part of the survey concerns the atmosphere in collaboration. As shown in Fig 4.9, most students reported that the atmosphere of collaboration was positive.

Fig 4.9 The proportion of students choosing each option in question "our group has a good atmosphere in collaboration" (n=66)



4.3.4.5 Cognitive Conflict and Scaffolding Behaviour in Interaction

According to the constructive learning theory, there exists both scaffolding behaviours and cognitive conflicts in interaction. Both cognitive conflict and scaffolding help are considered to be essential in children's development. Therefore, in the"interaction" section of the survey, questions 6 and 7 evaluate how positive their influence is on students' development and question 8 investigates the negative influence of immature ideas from one's partner. As displayed in Table 4.22, we can see that students generally consider these two of equal importance for their learning. As to whether one can be disrupted by misconceptions imparted by less competent partners, students' responses vary. However, the overall score is less than 3 points, thus indicating that there is no clear proneness toward interference.

Table 4.22 Perception of cognitive conflict and scaffolding behaviour of all participants (n=66)

Question	Options and the corresponding choice proportions				
6、More often, it is the difference or even conflict in opinions that promote us to think more deeply	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	34%	60%	6%	0%	0%
Value	4.28				
7、More often, it is my partner's explanation or scaffolding that makes me think more deeply	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	33%	65%	0%	2%	0%
Value	4.29				
8、My partners' immature ideas or mistakes can easily confuse me	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	1%	18%	36%	39%	6%
Value	2.69				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

The perception of students among different academic levels and group compositions is further compared. For different academic levels, HAAs believed that scaffolding behaviours played a

more significant role in collaborative learning compared to cognitive conflict, whilst MAAs attached more importance to cognitive conflicts, and for LAAs, scaffolding behaviour and cognitive conflict are deemed to be of equal importance. Nevertheless, the difference is trivial (See Appendix G, Table 13 for more details).

Moreover, HAAs and MAAs generally believed that immature ideas proposed by one's partner had no apparent negative impact. In contrast, LAAs demonstrated an obviously much higher concern about it. This is likely attributable to LAAs being more likely to accept or be influenced by their partner's ideas while HAAs and MAAs are more capable of judging for themselves and thinking independently. As illustrated earlier in the quantitative data section of this chapter, HAAs who participated in heterogeneous groups made the greatest progress in the second college entrance examination, therefore confirming that there is no obvious evidence to prove the existence of the negative influence from the less competent peers, or the potential of a drop in academic achievement in this study, no matter from the viewpoint of actual learning results or students' personal feelings.

For students across different group compositions, both cognitive conflicts and scaffolding behaviours exist no matter whether they are in homogeneous or heterogeneous groups. Notably, this result contradicts the conclusions reached in the relevant literature. This local study reveals more complexities concerning the idea that "homogeneous groups are more likely to arouse cognitive conflicts as group members are of equal level, and heterogeneous groups are more likely to stimulate scaffolding behaviours as members are asymmetric in ability" (See Appendix G, Table 14 for more details).

4.3.5 Overall Attitudes Toward Collaborative Learning

This study introduces collaborative learning as a new teaching pedagogy and learning strategy at the second round review stage in senior high school physics classes. This is an innovation in local education, with both the researcher and the students being inexperienced in its methods. Due to them being front-line participants in collaborative learning, students' attitudes and suggestions toward collaborative learning and their experience and understanding of its strengths and

weaknesses can equip researchers with an in-depth understanding of the effects of collaborative learning implementation and how it can be improved in the future.

4.3.5.1 Participants' Attitudes Toward Collaborative Learning

In the "Overall attitudes toward collaborative learning" section of the survey, question 1 investigates students' evaluation of their experience and question 4 aims to understand students' expectations for future collaborative learning. The survey data (shown in Table 4.20) indicates that most students were satisfied with their experience in this study and significantly they showed a willingness to participate in collaborative learning in the future.

Table 4.23 Overall attitudes towards collaborative learning of all participants (n=66)

Question	Options and the corresponding choice proportions				
1、I enjoyed this collaborative learning experience	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	21%	67%	11%	1%	0%
Value	4.08				
4、I would like to experience collaborative learning in the future	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
	21%	68%	11%	0%	0%
Value	4.1				

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

Among all three academic levels, HAAs recorded the highest score for both these questions while LAAs had the lowest, and MAAs were in between. Understanding the positive relationship between students' choices in question 1 and 4 is straightforward, as the more positive the experience of students in previous learning, the higher their expectations for the future will be. This result indicates that HAAs have the most positive attitude toward collaborative learning as well as the highest expectations for future participation in collaborative learning (See Appendix G, Table 15 for more details).

There is no substantial difference between homogeneous and heterogeneous groups in terms of their attitudes toward collaborative learning (See Appendix G, Table 16 for more details). However, a more thorough analysis (See Appendix G, Table 17 for more details) finds that HAAs

were more positive towards collaborative experience when in homogeneous groups, while LAAs felt similarly in heterogeneous groups. Moreover, this finding is consistent with the result of "the influence on academic achievement" in the early part of the survey, namely HAAs deem that they have made more progress in homogeneous groups, while LAAs believe they have made more progress in heterogeneous groups. This also confirms that the factor that participants value the most is the influence of collaborative learning experience on academic performance. Whether this influence is positive or not will directly impact their evaluation of collaborative learning as a teaching method and learning strategy.

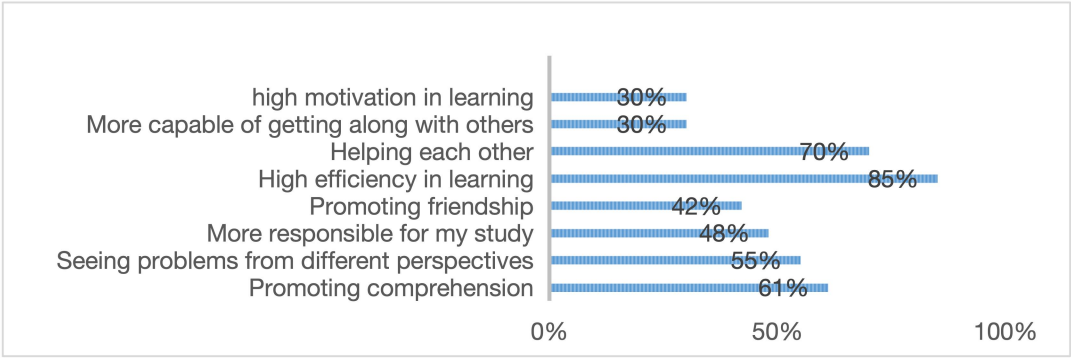
The interviews deepened the understanding of the participants' attitudes. For most interviewees, this was their first experience of authentic collaborative learning. Despite the fact that some had similar experiences, such as jigsaw tasks in junior high school, this study's duration is significantly longer, therefore their attitude towards it was entirely different as they had to take responsibility for their own learning as well as their partners. In the early stages of collaborative learning, they struggled to adapt accordingly due to how accustomed they were to lecture-style teaching. Some interviewees mentioned their pre-existing belief that the only thing one needed to do in the past was to remain in their seat and passively listen to the teacher, with one's mind being akin to a metal can that awaits the teacher filling it in. Evidently, these behaviours are ill-suited in collaborative learning where participants must be energized and willing to take the initiative in proposing the questions worth answering, establishing harmonious relationships, expressing one's opinions clearly and logically, appreciating other perspectives, and finding superior solutions in the face of contradictions. Nonetheless, students may feel pressurized initially, but after completing several classes, they should begin to realize the benefits, namely a clearer and sharper mindset, a stronger learning initiative, and improved interpersonal relationships. Additionally, they even found the class considerably more engaging. Furthermore, most interviewees asserted that collaborative learning is clearly beneficial for learning, and they wish to participate in collaborative learning again in the future.

4.3.5.2 Advantages of collaborative learning

As outlined in Fig 4.10, concerning the advantages of collaborative learning, the option selected

the most in the survey was "high efficiency in learning", with the remaining choices ranked as follows: “helping each other in learning”, “promoting comprehension”, “seeing problems from different perspectives”, “more responsible for my study”, “promoting friendship”, “more capable of getting along with others” and "high motivation". These results indicate that most students consider collaborative learning to be directly helpful for improving their problem-solving ability whilst also having a relatively indirect influence on communicative skills, way of thinking, learning efficiency, and motivation.

Fig 4.10 Proportion of Participants’ choice of the "advantage of collaborative learning" (multiple-choice question) (n=66)



Among participants across all three levels, the most commonly chosen option is "high efficiency in learning" (See Appendix G, Table 18 for more details). The in-depth interviews helped to reveal the reasoning behind this choice. Firstly, students are more active and exhibit higher concentration in collaborative learning. This contrasts with traditional lecture-style classes where students are generally in a state of passive learning with their minds tending to wander off-topic. However, during group discussions in collaborative learning, they took the initiative and became more active, with one interviewee describing their minds as being "sharpened". Collaborative discussion also helps to promote a more careful and thorough way of thinking by allowing students to uncover each detail through problem-solving, thereby rendering their ideas more precise and clearer. Moreover, one interviewee recalled that at first, when his partner posed a question to him in relation to one problem, he was not always capable of remembering how he solved it, therefore was unable to offer a clear and logical explanation, even though he had completed it only yesterday. Consequently, this led to the unpleasant feeling of wasting his partner’s time and ultimately delaying the group’s progress. In order to avoid that feeling, he made changes as

described through the following:

> I developed a new habit, that is, to make notes of my own ideas when solving each problem or option. The original intention was to facilitate the discussion and save me from being embarrassed, but it is surprising that by consciously recording the thinking process, my thinking became much clearer.

Furthermore, another student expressed a similar viewpoint. He felt that heated discussions have a proclivity to help expose the lack of precision in his thinking and encouraged him to think more seriously and with more discernment. In addition, collaborative learning affords students the opportunity to ask questions over the course of a significant length of time, whereas in a traditional classroom, if a student is having difficulty understanding something, he may not ask questions immediately in order to avoid embarrassment. As time goes by, he will likely forget the problem at hand, thus leaving a gap in his knowledge. Alternatively, in collaborative discussion, if one encounters an incomprehension, one can ask questions immediately and the partner can potentially provide answers directly, or they can clarify and exchange their thoughts amongst each other. This results in more effective learning. Finally, each student has ample opportunity to encounter a wider range of problems, as one interviewee described:

> We can discuss my problems as well as my partners', and that helps cover a wider range of knowledge, especially some blind spots that I usually neglect.

All reasons outlined above result in learning becoming more effective. The second most selected option differed among students across different academic levels. For HAAs, it was to "think from multiple perspectives", whilst for MAAs, it was to "enhance friendship" and lastly for LAAs, it was to "help each other". This difference in choice may reflect the different needs of students at different levels. HAAs considered the most crucial factor to be enhancing the flexibility and diversity of one's thinking. For MAAs, they deem it a significant achievement to enhance friendships in collaboration, and for LAAs, utilizing opportunities to offer and receive help is even more important.

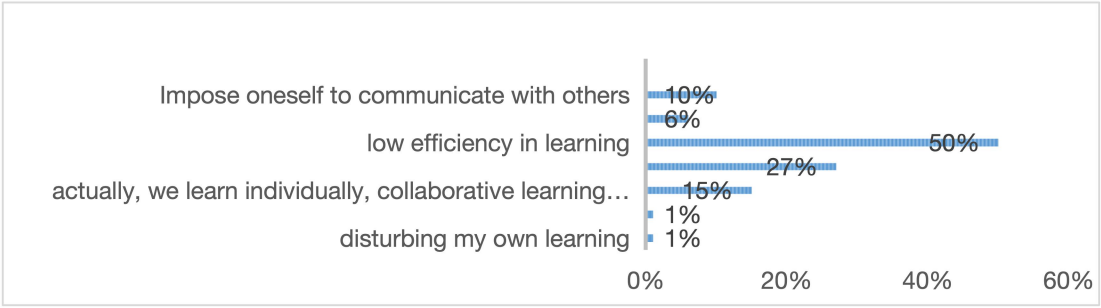
Across different group compositions, homogeneous groups scored higher for almost every option

(See Appendix G, Table 19 for more details). In particular, for the option "more responsible for my study", homogeneous groups registered a significantly higher score compared to heterogeneous groups.

4.3.5.3 Disadvantages of Collaborative Learning

In terms of the disadvantages of collaborative learning, as indicated in Fig 4.11, the option selected the most was "low efficiency in learning", followed by "easily distracted", and then “actually, we learn individually, collaborative learning becomes merely a formality”. When different academic levels and group compositions are evaluated, it was established that there is no significant difference between students of different levels, however, the percentage of students selecting "impose to communicate with others" was also notably higher within homogeneous groups (See Appendix G, Table 20 and Table 21 for more details).

Fig 4.11 Proportion of participants’ choice of the "disadvantage of collaborative learning" (multiple-choice question) (n=66)



In this section, peculiar contradictions arise. “Low efficiency” was the option selected the most as the biggest disadvantage of collaborative learning. However, as illustrated earlier, its "high efficiency in learning" was the most chosen option, with 85% of participants choosing this as the biggest advantage of collaborative learning. Obviously, some students must have chosen both "high efficiency" and "low efficiency". The reasoning behind this contradictory choice will be explored in Chapter 5.

Furthermore, the interviews led to other weaknesses being proposed. One of these concerns is the dependence of collaborative learning outcomes on one’s collaborative partner. Students clearly believe that their learning outcomes are heavily influenced by their partners, thus if group members are unable to establish a certain degree of friendship and subsequently effectively

communicate, collaboration may not be sufficiently effective, and it even has the potential to negatively influence learning outcomes. In addition, the high expectancy of higher-level partners is commonplace with some students expressing their dissatisfaction with their lower-level partners, and consequently their negative attitude towards the entire collaborative learning experience. One interviewee supported this viewpoint when stating:

> The effect of collaborative learning depends on the relationship between you and your partner. It's a matter of two people. It's not something you can do unilaterally...

A further disadvantage lies in collaborative tasks. On most occasions, the collaborative learning task is homework revision, with each group allowed to choose problems to discuss in accordance with their own learning situation. Furthermore, classroom observation found that students tend to be more interested in and spend most of the allocated time on, challenging problems. As a result, some basic problems are often overlooked due to time constraints. However, in terms of the college entrance examination, the proportion of basic problems to be solved is in fact higher than that of difficult ones. Ultimately, this disequilibrium in time allocation may lead to an inconsistency between students' feelings and their actual academic performance. Specifically, This may result in some students feeling satisfied with their experience due to the sense of achievement gained from solving difficult problems, yet their academic achievement may not have improved significantly, or even regressed, due to their neglect of more basic problems.

4.3.5.4 Suggestions for Improving Collaborative Learning

The survey collected suggestions from students on improving the effectiveness of collaborative learning, and approximately half of the students responded to this open-ended question. Some suggestions are contradictory, such as increasing and decreasing collaborative time, reflecting the diverse learning needs of learners. Others are highly insightful and merit considerations in the future, such as combining personal learning with collaborative learning (as will be further illustrated in 5.11). Certain suggestions, such as allowing students to choose their own partners, warrant further exploration through interviews to understand potential dissatisfaction with partners or experiences. Overall, the students' suggestions can be mainly categorized into three types. The first is related to group composition, such as increasing the number of group members, regularly

changing partners, and allowing students to choose their own group members. The second is about the strategies of collaborative learning, such as setting more thought-provoking tasks, assigning tasks within the group, allowing cross-group discussions, organizing competitions between groups, and combining individual learning with collaborative learning. The third is about the role of the teacher: assigning post-class collaborative tasks, flexibly adjusting collaborative learning time, surveying which topics need further explanation after collaborative learning, and increasing the time for lecturing.

4.4 Conclusion

An analysis of the generated data, such as college entrance examination scores, survey data, interview transcripts, and classroom observation notes finds that it is possible that collaborative learning has a positive influence on academic achievement, science learning and interpersonal skills.

Statistical analysis revealed that there is a significant positive correlation between participation in collaborative learning and progress in academic performance in the second college entrance examination. It is also found that participating in heterogeneous groups showed more significant progress compared to homogeneous groups. Out of all three academic levels, HAAs achieved the greatest progress in this study. Moreover, among each academic level, students who participated in heterogeneous groups made more significant progress, in comparison to those who participated in homogeneous groups. In particular, among all 6 types, combining academic level and group composition (namely high in homogeneous, high in heterogeneous, medium in homogeneous, medium in heterogeneous, low in homogeneous, low in heterogeneous), HAAs in heterogeneous groups made the greatest progress with an exceptional 7.9 points' progress in average score. Furthermore, statistical analysis revealed a statistically significant result that HAAs who participated in heterogeneous groups achieved more obvious progress compared to those who participated in homogeneous groups. However, survey data showed that the former's satisfaction with their academic progress was the lowest among all types of students. In contrast, the latter showed significantly higher satisfaction, although their actual performance had almost no progress. The above phenomenon reflects the difference between learners' subjective feelings and objective

learning results. For LAAs, they preferred participating in heterogeneous groups, thereby correlating with their actual performance. Nonetheless, HAAs did not consider the immature ideas of their lower-level partners to have a detrimental impact on them. Therefore, whether objectively or subjectively, for HAAs, this study has not established the potential for a drop in academic performance.

Collaborative learning is also found to be beneficial for science learning. In this context, students claimed to have made clear progress in aspects directly related to collaborative tasks, such as homework revision and problem-solving. They also cited progress in skills such as " thinking from multiple angles " and "logical reasoning".

Students tend to perceive their collaborative partner as one of the most influential factors for learning outcomes, with the focus being on their partners' academic level. Higher-level partners are often depicted as de facto teachers that can offer scaffolding support and detailed explanations. Furthermore, collaborating with equal-level partners often leads to cognitive conflict whilst also stimulating a more thorough understanding through one's reflection on the coordinated thinking of the group. Therefore, the concealed reasoning behind students' preference for their partner's academic level could potentially be the students' views of the role that scaffolding behaviour and cognitive conflict play in learning. In particular, HAAs believed the former to be more important, with MAAs preferring the latter, whilst LAAs considered these two to be of equal importance. Notably, both scaffolding behaviour and cognitive conflict emerged in almost equal proportion within both homogeneous and heterogeneous groups, with this being somewhat different from the viewpoints expressed in the literature. Given that both scaffolding help and cognitive conflict are beneficial for learning, it may be more beneficial if a balance between these two benefits is reached. Therefore, an ideal partner is one of a slightly higher level than oneself. Moreover, HAAs tend to take their partners' character into account. Lastly, an easy-going and communicative partner may lead to a more positive attitude toward collaborative learning.

Collaborative learning also had a positive influence on students' interpersonal abilities. Through collaborative learning, students' oral expression, listening and multi-dimensional thinking skills have improved. They have also learned how to resolve conflicts in communication and enhanced

their awareness and frequency of social communication.

Interaction is the most critical intermediate variable in collaborative learning and all aspects of it were analyzed. The level of engagement in interaction was found to be relatively high. To some extent, positive interdependence emerged once students began to perceive their collaborative group as a learning community and subsequently cared for their partner's learning. Among the three academic levels, HAAs' engagement is the highest whilst medium students' was the lowest. Another finding was that the quality of discussion in interaction experienced a process of continuous progress and students were generally satisfied with it. Upon encountering disputes, students were determined to discuss and ultimately reach mutual conclusions, and that can be viewed as proof of their collaborative ability. However, students registered diverse opinions regarding the time allocated for collaborative learning. Both HAAs and LAAs considered the time allowed for collaborative learning to be appropriate, but some MAAs regarded it to be too long.

The advantage of collaborative learning lies in "high efficiency in learning", "promoting comprehension", "helping each other in learning", "promoting friendship", "seeing problems from different perspectives" and so on, while the disadvantage includes "low efficiency in learning", "easily distracted" and so on. However, the fact that 85% of participants chose "high efficiency in learning" and 50% chose "low efficiency in learning" indicates that the overlapping part may hold some complex feelings to express and that will be discussed in Chapter 5.

Overall, students conveyed satisfaction with their collaborative learning experience, and approved of collaborative learning as a learning strategy and a teaching pedagogy, while they also displayed their willingness to participate in collaborative learning in the future.

Chapter 5: Discussion

5.1 Introduction

The previous chapter answers the research questions posed in this study through data analysis. Firstly, there is a distinct possibility that collaborative learning helps participants to achieve improved scores in the Second College entrance examination, with the average score improving more significantly compared to non-participants. When different academic levels and group compositions are evaluated, it is established that HAAs made the clearest progress among all three levels, and being in a heterogeneous group may be more advantageous when compared to homogeneous groups. Across all six types of participants, HAAs participating in heterogeneous groups achieved the most significant progress in academic achievement. However, participants with the most progress, namely an improvement of over 10 points in the second college entrance examination, do not necessarily belong to this category. In reality, they come from all three levels, and both heterogeneous and homogeneous groups. This begs the question as to what factors are directly leading to the huge improvement for some individuals.

When investigating how influential the experience of collaborative learning is, students claimed that it is beneficial for developing problem-solving ability, multi-dimensional-thinking, and logical ability, therefore rendering it conducive to science learning.

This study also demonstrated that students tend to believe that their collaborative partner is a crucial factor that affects learning outcomes, with students being most concerned about the academic level of their partners. The majority wish to collaborate with higher-level partners, with the rest preferring partners of a similar level. Moreover, friendship and the partner's personality are also matters of concern. This mindset presents a compelling question that will be explored later in this chapter, namely, "What makes an ideal partner in students' minds?"

In addition, although it is not ideal to collaborate with lower-level partners, most middle and HAAs who participated in heterogeneous groups do not believe that lower ability partners exert

detrimental impacts on their learning, and this is consistent with objective facts. Questions remain as to why this negative effect existed in some studies (Tudge, 1992), but not in this study. Furthermore, it is worthwhile considering which factors may result in the emergence of such negative effects, and what ideas may this result generate in terms of understanding the complexity of ZPD.

Constructive learning theory proposes that scaffolding-help occurs mainly in heterogeneous groups, while cognitive conflict occurs mainly in homogeneous groups. However, this study found a considerable number of cognitive conflicts in heterogeneous groups in addition to scaffolding help. Likewise, there exists both cognitive conflict and scaffolding help in homogeneous groups. Furthermore, no matter whether students are in homogeneous or heterogeneous groups, they all believe that cognitive conflict and scaffolding help are of equally importance. The reasoning behind these viewpoints, which are contrary to the widely accepted theory, are worth exploring.

There are also two further contradictions worthy of discussion. The first emerges from the comparison of sub research question 1, which focuses on objective data, and sub research question 2, which is concerned about students' subjective views. Despite HAAs who participated in heterogeneous groups attaining the most significant progress, their subjective attitude towards their learning results is the least positive among all the types of students. The second comes from students' contradictory answers in the survey. For the questions on the advantages of collaborative learning, "high efficiency in learning" is the most frequently selected option, with 85% of students selecting this option. Among the disadvantages of collaborative learning that were identified, "low efficiency in learning" is the most frequently selected option, with 50% of students choosing this option. Interestingly, some students chose both "high efficiency" and "low efficiency", and the reasons behind these contradictions are worth investigating.

This chapter will further explore the above issues that emerged in the process of the localization of collaborative learning. Moreover, it will discuss the contradictions between the subjective feelings and the objective performance of HAAs, the ideal partner from students' perspective, issues of learning efficiency, patterns of collaborative learning, students' suggestions, as well as the

potential factors behind performance progress, to ultimately provide insight into the localization of collaborative learning. It will also reflect on the possibility of retrogression in students' academic achievement, and the ambiguity in the definitions of "homogeneous" and "heterogeneous", with the aim being to contribute to the theory of collaborative learning.

5.2 Contradiction between HAAs' Actual Achievement and Subjective Feeling

The data analysis in Chapter 4 revealed that students across all three levels accomplished progress in the second college entrance examination, with HAAs making the most apparent progress. The new college entrance examination in Zhejiang province employs a standard scoring system where one's score is assigned in accordance with one's ranking amongst all the examinees (Chen, 2016). Overall, it is more challenging for HAAs to make progress as they face the stiffest competition. Therefore, this study finds that implementing collaborative learning at the second round review stage may be of considerable significance to HAAs.

When delving deeper into the influence of group composition on HAAs, different researchers propose different views in the literature. Some stressed that HAAs are capable of making significant progress in both heterogeneous and homogeneous groups (Saleh, lazonder and Jong, 2005) and their academic development is not dependent on the level of their peers (Carter and Jones, 1994), whilst some exhibit concern about the possibility of regression instigated partially by less competent partners (Mercer and Littleton, 2007; Tudge, 1992). Unexpectedly, this study found different results, namely that across all six types of students (HAA in heterogeneous group, HAA in homogeneous, MAA in heterogeneous, MAA in homogeneous, LAA in heterogeneous, and LAA in homogeneous), HAAs participating in heterogeneous groups who collaborated with a less competent partner made the clearest progress, 7.9 points, while those who participated in homogeneous groups made the least progress (0 point). For HAAs, whether they participate in homogeneous or heterogeneous groups shows statistically significant differences in their progress.

When researching into students' subjective feeling, it is established that despite attaining the most

progress, HAAs in heterogeneous groups hold the most negative views about their performance. In sharp contrast, despite achieving the least progress among all six types, HAAs in homogeneous groups register the most positive subjective feelings.

The phenomenon of HAAs' subjective feelings being clearly contrary to their actual performance is worth exploring. First, it is worth noting that the progress of HAAs in heterogeneous groups is logical. Some researchers have asserted that providing elaborated explanations helps promote academic progress, and those who offer detailed explanations receive more benefits in terms of improving their ability (Slavin, 1987; Webb, 2009). When HAAs collaborate with LAA peers, they have the opportunity to express more opinions and demonstrate more helping behaviors (Carter and Jones, 1994). Similar phenomena were observed in the classroom observations and interviews conducted in this study. HAAs tend to take on the role of explainers more frequently, providing tailored explanations based on their peers' actual difficulties and needs. This prompts the HAAs to construct a more refined conceptual framework, something that cannot be achieved when collaborating with peers of similar ability levels (Webb, 2009). This may explain the remarkable progress made by HAAs in heterogeneous groups. Moreover, as Carter and Jones (1994) found in their research, heterogeneous grouping in scientific disciplines is beneficial for LAAs without being detrimental to their high-level partners. In fact, this study found no evidence suggesting that LAA partners cause misunderstandings harmful to HAAs' learning (more details will be provided in section 5.7). However, considering the small sample size of only 11 HAAs participating in heterogeneous groups and the unique background of this study, gaining a deep understanding of the phenomenon might be even more complicated. Webb, Nemer and Zuniga (2002) argued that the performance of HAAs in heterogeneous groups varies; they may perform well in some heterogeneous groups but struggle in others and the quality of group function is a predictive factor for the performance of HAAs, which can be a direction for future research.

Concerning the negative feelings of HAAs when in heterogeneous group, this may be attributable to students' existing prejudices against collaborative learning. In interviews, some HAAs opined that while receiving help is beneficial for one's learning, offering help to others may be an

inefficient use of their time. Moreover, the immature ideas emanating from their lower-level partner do make them question their original thoughts, and as a result they must spend extra time and energy assessing or correcting their original ideas. One participant epitomizes this viewpoint when stating that,

> "the main job of a HAA is helping his or her partner while him or herself does not improve, thus participating in collaborative learning is about pure dedication".

Reasoning such as this is why 85% of high-level participants wish to collaborate with partners of the same, or an even higher, level in this study. Also, this viewpoint illustrates why they do not appreciate collaborating with lower-level partners in heterogeneous groups.

However, the reality may be that the HAAs' knowledge reconstruction after the cognitive conflict is stimulated by their less competent partners, or they develop cognitively through providing explanations to their partners, with both leading to an improvement in their ability and performance. On the contrary, when HAAs collaborate with partners of an equal level, the similarities in their knowledge structures may cause a decline in collaborative motivation, with less chance of encountering diverse perspectives, and a lack of opportunities to strengthen one's knowledge system through interpretation. HAAs were positive about their partners being at the same level as the ability gap between such partners and a genuine teacher is as small as is feasibly possible. In this instance, the belief was that this type of partnership would guarantee positive learning effects, however less progress than they had assumed was actually attained.

To some extent, the result of this study eliminates the misunderstanding displayed by HAAs who participated in collaborative learning in heterogeneous groups. Despite the small sample size, this study demonstrates that collaboration between HAAs and LAAs can possibly be beneficial to the former's learning as well as to the latter's. Collaboration of this type can also enhance the confidence and enthusiasm of HAAs who participate in heterogeneous groups, thereby promoting improved learning effects. For educators, recognizing the reasons behind these contradictory outcomes can help form an in-depth understanding of collaborative learning.

5.3 Issues around Efficiency and Effectiveness

Many researchers have established the effectiveness of collaborative learning in the context of academic achievement, communicative ability and students' attitudes (Hattie, 2009; Lou, Bernard and Abrami, 2006), with similar results being found in this study. However, when researching participants' subjective feelings, the effectiveness of collaborative learning was called into question. In the survey, regarding the disadvantages of collaborative learning, the option chosen the most was "low efficiency in learning". Moreover, in the interview, students displayed a high degree of concern around the efficiency of collaborative learning. Some students believe that collaborative learning is only effective when partners propose different methods of analysis or different dimensions of thought. Some students venture that collaborative learning is only efficient when higher-level partners offer detailed explanations. Furthermore, there are also a percentage of students who are more inclined toward individual thinking, and even after discussion they feel it is necessary to spend time on individual thinking in order to fully understand what was discussed.

It is reasonable for students to be concerned about classroom efficiency especially as at the second-review stage, time is considered to be of the essence. However, considering that the participants in fact made exceptional progress in the second college entrance examination when compared to non-participants, the sentiment of "inefficiency" registered is somewhat surprising. Another outcome that contrasts sharply is that many more students selected "effective" as the biggest advantage of collaborative learning. Therefore, the question of whether collaborative learning is efficient or inefficient must be analyzed, and what this contradiction conveys.

The in-depth exploration enabled by the interviews shone a light on further issues to be considered. It is found that the notion of "efficiency" as understood by some students should be defined as the number of problems solved during a class. During collaborative learning, each student not only confronts his own problems, but also those of his partner's, therefore the number of problems they encounter increases. In contrast, as one interviewee stressed, due to the extra time required for communication and to understand one's partner's opinion, the number of problems capable of being solved in a collaborative class is less than in a traditional class. During discussion, in order

to achieve mutual goals, students debate each other, and mistakes are commonplace prior to finally reaching a mutual conclusion, and they must explain their pre-existing knowledge to their partners, with all these actions inevitably consuming more time and effort. Ultimately, this contrast gives some students a feeling of low efficiency.

However, one interviewee pointed out that "efficiency" does not equal "effect", and less problems being solved does not therefore mean less learning has taken place. In fact, new ideas voiced by one's partners, such as new perspectives and new methods, or details that have been overlooked, can all help broaden one's horizon, stimulate reflection and enhance one's thinking. In that case, despite it taking more time and energy compared to a traditional class, it is worthwhile. In other words, although the "efficiency" is reduced, the effect is improved, as this interviewee described, "extra time and effort are meaningful, not wasteful". Another interviewee stresses that collaborative learning can improve one's enthusiasm for learning while enhancing their sense of responsibility, which in turn is conducive to the improvement of efficiency. There was also one interviewee who used the relevant saying "illusion of low efficiency" to describe the phenomenon of a HAA offering elaborated explanations to his lower-level partner, therefore feeling like he is wasting time, yet he is unaware that due to the explanation effect, he is attaining stronger logic, clearer thinking and stronger problem-solving ability.

Nonetheless, inefficiencies do exist. Wismath and Orr (2015) pointed out that students tend to be distracted and find it hard to maintain motivation during group work. Indeed, in the classroom observation and the interviews in this study, phenomena including absent-mindedness, switching topics, and chatting are mentioned by interviewees. Hsiung (2012) also asserted that in group-work, students must confront the dual tasks of problem-solving and communication, and this is prone to generating attention conflict. Furthermore, this type of attention conflict will manifest itself in low efficiency in the early stages of collaborative learning. However, through increasing familiarity with this learning method, attention conflict will be lessened, and learning efficiency will be improved. In this study, many interviewees alluded to the existence of an adaptive process.

This study also discovered more factors increasing inefficiency, namely inappropriate tasks leading to low motivation, and subsequently low efficiency. An example of this is where one day's homework is relatively simple, therefore both students in a group find it straightforward to solve, and then they begin to chat about their social lives. Moreover, some students claimed that their motivation and quality of discussion were easily influenced by their moods, with one interviewee stating: “If one day I did poorly in an exam, thus I was in a bad mood, I will not feel like discussing at all. When my partner raises questions, I just answer the questions perfunctorily without deep thinking.” This is evidence of such situations existing in real-life classes.

Therefore, the fact that students selected "effective" as collaborative learning’s main advantage and "low efficiency" as collaborative learning’s biggest disadvantage is not wholly contradictory, but alternatively it reflects students’ different experience and perspectives. In future implementation of collaborative learning, it may be beneficial to discuss the concept of efficiency with students, therefore enhancing their confidence in collaborative learning and promoting its positive impacts on their learning outcomes. Concerning the phenomena of low efficiency that do exist, methods aimed at minimizing factors leading to low efficiency must be established, thereby ensuring collaborative learning is more effective in the future.

5.4 Ideal Partner

This study discovered the finding that students believed that collaborative partners are important, and they have expectations of certain characteristics of their ideal partner. This leads to the question of what the ideal partner looks like.

The survey data showed that over half of participants opted to collaborate with more capable partners. Making this choice is endorsed by much of the literature which asserts that collaborating with higher-level partners can produce scaffolding help, which in turn is conducive to learning (Hattie, 2009; Howe et al., 1992; Lou, Bernard and Abrami, 2006). In this study, students display clear concern and an expectation for scaffolding help. Moreover, the interviews aid in the development of a deeper understanding of students’ choices. One finding is that students seek a

higher ability partner, or a so-called "little teacher", due to the accompanying scaffolding behaviour that mirrors what they may receive in a traditional class. Nevertheless, the difference is that such a class consists of only one student who receives all the attention and support of the "little teacher". One student epitomizes this viewpoint when stating:

> “Because this study takes place at the review stage of senior three, I have time constraints. A higher ability partner can offer me direct helps similar to that of a teacher, and that can surely improve my ability rapidly”.

Furthermore, another interviewee voice a similar opinion when stating:

> “When I solve problems alone, I sometimes reach a dead end and can't find my way out. In these situations, I need a partner with higher ability to clarify the existing problem, so I can escape this dead end.”

However, the experience of collaborative learning equips students with a more multidimensional understanding of interactions between partners. The survey established that students believe that both cognitive conflict and scaffolding help are vital in the development of thought. The interviews saw some students emphasizing the positive influence of cognitive conflict, or to be more specific, the benefits to their learning of the co-construction and self-reflection that took place after the cognitive conflict. In addition, when two students of similar abilities come to a disagreement, neither are capable of firmly offering a decisive opinion. Subsequently, in order to solve the problem, they may debate each other and continuously coordinate until they reach an agreement and achieve a higher level of cognition, with this process benefiting both parties.

Based on their understanding of the benefits of scaffolding help and cognitive conflict in learning, students reflected upon both the strengths and weaknesses of both a more competent, and an equal-level partner. One interviewee provided detailed reasoning that reflected some students' ideas to some extent. He opined that when collaborating with a partner of similar ability, one could solve problems through co-construction that was stimulated by cognitive conflict, and that could instill a sense of conquering the unknown or climbing a tall "mountain" together with a

friend. This indirect journey can support authentic improvement in ability as well as self-efficacy, with this being deemed the first type of benefit. Nonetheless, if the "mountain" is insurmountable and the problems requiring a solution are beyond one's existing ability, partners of equal ability are incapable of offering a more developed perspective, thereby causing the entire group to stagnate. In such situations, a more competent partner may lead the group to a breakthrough, thereby reaching the top of the "mountain", with this being considered the second type of benefit as it is akin to the guidance imparted by a teacher. In summary, it is preferable to work with an equal partner when climbing moderate "mountains", but a more competent partner is desirable when a genuine challenge emerges. In order to benefit from a combination of these two benefits, several interviewees asserted that an ideal partner is one with slightly higher ability.

Interestingly, partners with significantly higher ability are not necessarily the most popular ones, with some interviewees stating that such partners may solve problems individually without any collaboration, and this is not conducive to one's development. To that effect, collaborating with higher-level partners is in fact not beneficial for learning in all situations. Some researchers found that a high-level partner who cannot explain the correct methodology yet dominates decision-making has negative effects rather than positive (Messer, Joiner, Norgate, Light and Littleton, 1992). In the interview, it is observed that despite students desiring high-level partners, they are unwilling to be dominated as they wish to take the initiative for their learning and subsequently participate in the decision-making process. Furthermore, there is evidence that joint decision-making improves the performance of all group members (Blaye et al., 1991; Howe et al., 1990; Howe et al., 1992). Another concern is that a partner of an excessively high level may cause psychological stress leading to low enthusiasm in collaboration, with some interviewees admitting that they felt embarrassed to ask their partners what they considered to be too many questions.

In addition to academic achievement level, students also attached importance to other factors, such as friendship-making and group size. A phenomenon in the class of adjoining groups spontaneously initiating discussions amongst themselves emerged, thereby forming four-person groups. In light of this unique behaviour, students from the groups concerned were interviewed. One interviewee from a homogeneous group stated that he was satisfied overall with his partner

yet he still sought guidance from a more competent one, and fortunately there was a HAA in the adjoining group who could satisfy his needs. Moreover, another interviewee pointed out that her closest friend happened to be in the adjoining group and therefore a four-person group emerged somewhat naturally. Lastly, some interviewees felt that a larger group comprised of more participants is more likely to arouse multi-dimensional thinking and insights.

5.5 Patterns of Collaborative Learning

In the early stages of this study, due to the participants' lack of experience of collaborative learning (even if group members had attended similar activities, they did not in fact experience positive interdependence, such as mutual learning goals), a settling-in period for most groups was necessary. In that period, students may experience unfavorable states, such as shyness, absent-mindedness, and low efficiency in collaboration, whilst some are still more willing to turn to the teacher rather than discussing with their partner. However, in the end nearly every group formed a unique collaborative pattern that usually persisted for the remainder of this study.

From both the classroom observation and the interviews, four patterns were established. Firstly, pattern 1 involved both group members raising questions and offering explanations, enlightening each other and discussing matters together. This pattern can be labeled a bi-directional pattern. One interviewee described their group discussions as usually ensuing in the following way: when discussion of a difficult problem has been initiated, one group member will explain his thinking first and then will seek confirmation that his partner understands the idea, then it is his partner's turn to offer his view on the same problem. If the group comes across conflicting ideas, they engage in discussion until the problem is solved and all doubts are eliminated.

This group formed a close partnership and a strong relationship of interdependence, and on one occasion after collaboration, the teacher requested this group to explain their answer to a problem in front of the class, namely an electromagnetism problem about a rectangle coil traveling through a magnetic field. Subsequently, the two students approached the blackboard and then initially drew a schematic diagram together, with one student explaining the first part, namely the situation

of the coil entering the magnetic field, and his partner then elaborated on the second part, namely the situation of the coil leaving the magnetic field. Notably, when one spoke, their partner would interject with a supplementary explanation or a minor correction, and vice versa. These two students displayed an evident and harmonic bi-directional pattern.

Secondly, pattern 2 entailed a more fixed role differentiation, with one group member (usually the more competent one) acting akin to a teacher or an interpreter, while the other (usually the less competent one) performs the role of a student, or a receiver, thus demonstrating a single-directional pattern. Thirdly, pattern 3 is also a mixed pattern in which the previous two patterns are evident, and with a similar ratio. Lastly, pattern 4 involved a four-person group pattern, namely two collaborative groups spontaneously holding discussions for a variety of reasons, such as friendship or the desire for a more competent partner, with this deemed to stimulate multiple perspectives. After the settling-in period, most groups operated in a fixed pattern, thereby enabling the collaborative learning to be more efficient as group members are able to swiftly achieve their highest efficiency state. One interview sums this up when stating: “it feels really good, although the whole classroom is filled with noise, I can only hear myself and my partner discussing”.

Some researchers suggest that homogeneous groups are highly likely to trigger cognitive conflicts, whilst heterogeneous groups are more likely to produce scaffolding support (Kruger,1993; Shayer, 2003). Taking this into account, there should mainly be bi-directional patterns in homogeneous groups and single-directional patterns in heterogeneous groups. However, according to both the interviewee’s descriptions and the notes from classroom observation, the findings of this study contradict this theory. In homogeneous groups, aside from bi-directional patterns, there also existed mixed patterns that included single-directional pattern. In heterogeneous groups, a similar phenomenon transpired as a single-directional pattern and a mixed pattern were both presented. The cause of the above phenomena may relate to the unique background of this study and the definitions of homogeneous and heterogeneous employed. Further details will be provided in section 5.7.

5.6 Factors Relating to Significant Improvement of Academic Achievement

As illustrated in Chapter 4, collaborative learning is beneficial for students' academic achievement. Across students of all academic achievement levels and group compositions, HAAs in heterogeneous groups progressed the most with regard to average score. Nonetheless, not all HAAs in heterogeneous groups achieved progress. On top of that, there are four students who made exceptional progress in the second college entrance examination, yet none of them were HAAs in heterogeneous groups. In reality, they were of differing academic achievement levels and participated in both heterogeneous and homogeneous groups. For groups, the initial academic level and group composition are evidently variables that influence the effects of collaborative learning. However, for individuals, there are other variables at play that jointly influence the learning effects.

This study investigated many other factors that potentially affect the results of collaborative learning, such as partner's level and the pattern of collaboration, with these factors jointly influencing a specific student's performance. Therefore, it may be beneficial to gain an in-depth understanding of one specific student's collaborative experience, with a view to figuring out whether there are common factors that may relate to the emergence of students' significant academic achievement. As a result, these four students were selected as interviewees, with other interviewees consisting of four students whose progress remained static, and finally four students' whose achievements regressed.

This analysis mainly utilizes the in-depth and rich information gained from the interviews. The interview transcripts were analyzed studiously several times with the objective being to ascertain whether there is a direct relationship between any particular factor and the change in academic achievement, or whether the students who have made progress have any common characteristics.

Firstly, students tend to wish to collaborate with partners of a higher level than themselves, and they subconsciously believe that high-level partners are useful for their learning. However, this

study found that the academic level of one's partner's do not necessarily correlate with the progress of one's performance. Specifically, out of the four students who made significant progress, two collaborated with LAAs, one with a MAA partner, and one with a HAA partner. Out of the four students who regressed, two collaborated with HAA partners, one with a MAA partner, and one with a HAA partner. Therefore, if you collaborate with a LAA, you still have the potential for improvement, and if you work with a HAA, you still must counter the risk of falling behind. Moreover, the degree of satisfaction with one's partner can influence the level of engagement and ultimately the degree of satisfaction with one's overall collaborative experience, but it is not directly related to one's improvement in academic performance. Among the interviewees who progressed significantly, only one was satisfied with his partner, with two of them dissatisfied with their partners, and the other one holding a neutral opinion.

Secondly, the group composition and the pattern of collaborative learning have no demonstrable direct relationship with the improvement of performance. No matter whether it is among students who have made significant progress, or those whose grades have not changed or declined, there are both students from heterogeneous groups as well as homogeneous groups present.

Furthermore, there is also no predictable relationship between change of achievement and the pattern of collaborative learning. Among the four students who made significant progress, two experienced mixed patterns, one a bi-directional pattern, and the other a single-directional pattern. Among the four students whose academic achievement remained almost identical, one experienced a mixed pattern, one a bi-directional pattern, and the other two single-directional patterns. Among the four students whose grades declined, two experienced mixed patterns and two bi-directional patterns.

Finally, the efforts that individuals consciously and continuously make in adjusting their manner of communication and negotiation, in order to make collaborative learning more and more effective, may help improve their overall performance. Moreover, four interviewers who made significant progress all reached the firm conclusion that collaborative learning differs considerably from the individual learning that they are accustomed to, and that interaction between two students

equates to more than merely speaking. Using their own experience in collaborative learning, they contemplated the advantages and disadvantages of both individual learning and collaborative learning. It is particularly noteworthy that all of them developed their own unique way of collaborating in line with the characteristics of both themselves and their partners.

Student A employed a combination of independent thinking and collaborative learning, and preferred to communicate with his partner by noting down his thought process. With regard to the latter, he believed this clarified his expression and increased the quality of discussion. For instance, when interviewed, he reported that:

> I believe that communication and (independent) thinking need to go hand in hand. It is not advisable to communicate without first thinking about a question. When I encounter obstacles or blocked thoughts during my own thinking process, I choose to communicate. I think the focus should be on my own thinking (communication serves thinking), and my own thoughts are quite important. Communication is a way to learn from others' strengths and improve upon one's weaknesses.

In the survey, student B referred to her peer as a "philosopher". During the interview, she explained the reason, saying, "He's too immersed in his own self-talk... His thoughts are agile, but he often speaks in a jumping manner." She also expressed dissatisfaction with her partner, saying, "Sometimes it's quite helpless..." However, she felt compelled to halt her partner's tendency to stray off-topic during the collaboration, often actively leading the discussion by proposing certain topics or asking leading questions, as she said, "Usually, I will stop him and keep asking him questions..."

Student C placed a high value on considering the ideas of his partner and actively compared them with his own. During the interview, he made numerous similar statements, such as: "I thought, actually, sometimes her method was better than mine. Mine was a more clumsy approach, while she sometimes used a more...how to say...a more efficient method." He believed that comparing methods with his peer broadened his horizons and improved his ability. When he encountered conflicting views, he tended to spend time evaluating both his own perspective and that of his

partners and this ultimately made his thinking clearer. Furthermore, he generally felt that the time allocated for collaborative learning was insufficient. He emphasized that detailed discussions required considerable time, but discovering a superior problem-solving method made “spending the time undoubtedly worth it”.

Student D was particularly unusual as he displayed good problem-solving (especially in difficult problems) ability yet many gaps in his basic knowledge. During the interview, he implicitly expressed regret that his partner’s ability was not as high as he would have liked, nonetheless he He further outlined how he consciously led the discussion by initially guiding his partner through posing fundamental questions and offering scaffolding support in order to enable his partner to develop a better understanding of a particular problem, and then they held a discussion on common ground. He described this process as follows:

> I would ask him, 'Let's first identify the crucial points of this question. Where should we start? Once we've agreed on a starting point, what do you suggest we do next?' He would propose an approach, and I would evaluate and help him, when I agree (with his approach), I will say, 'You've made a valid point.'

Due to his partner’s thought process being rather different from his, cognitive conflicts were often stimulated. Moreover, he believed that this method would enable both himself and his partner to reap the most rewards. He humorously compared their collaboration to a race, saying, "Imagine both of us running. I allow him to take the lead because he runs slower than me. I catch up to him, and together, we both run, making our team faster." He displayed strong responsibility for both his and his partner’s learning as well as pursuing efficiency. Lastly, he also ruminated on collaborative learning as a new teaching pedagogy and advanced many suggestions in the survey.

Thus the four students who made exceptional progress were all keenly aware of the difference between collaborative learning and individual learning, paying particular attention to their different learning effects and taking the initiative to find the most suitable way of collaborating. Furthermore, they actively developed and implemented what they judged to be the most effective

strategy of collaboration in accordance with the actual situation of themselves and their partners. It is worth nothing that as only four students in this study demonstrated notably improved academic performance, despite all of them being interviewed. The limitation of the sample size necessitates a cautious attitude towards the reliability of this conclusion. However, the fact that none of the four interviewees who regressed in the second college entrance examination explicitly mentioned their unique way of collaboration, nor did they perceive collaborative learning as a novel pedagogical strategy or learning method, may offer some indirect support to the aforementioned conclusion.

Another notable contrast is that while the majority of the four students who achieved outstanding progress were not particularly satisfied with their partners, the four students who regressed were all satisfied with their partners. It may be possible that satisfaction between partners can enable smooth collaboration, but it may also allow for a lack of motivation to explore more effective ways of collaborating.

The above analysis suggests that collaborative learning alone does not guarantee the improvement of academic performance. Individuals also need to identify and consciously apply effective learning strategies that match their own specific situation.

5.7 Exploration into the Theory of Collaborative Learning

5.7.1 Possibility of Retrogression in Academic Achievement

In a heterogeneous pair, the higher-level student is like "a novice teacher" who can offer scaffolding support and allow their partner to make improvements in their academic achievement. However, collaboration is a concept involving both parties and its influence on the higher-level students must also be fully accounted for. Some researchers stressed the multiple potential in students' development process (Mercer, 2010; Tudge, 1992). When insufficiently developed opinions from their lower ability partners are voiced, HAAs may feel disoriented and subsequently reconstruct their knowledge system in an incorrect fashion, and that may result in a drop in academic performance in cognition and a decline in ability. Therefore, "ZPD" is considered to be a

circular area that is centered on the current academic achievement level of students and the development process may contain both the possibility of progress as well as retrogression. Given that the potential for retrogression does exist, ethical problems for HAAs in participating in heterogeneous collaboration will present themselves, especially at the final stage of college entrance examination.

Nevertheless, no clear evidence of retrogression in students' academic achievement was discovered in this study. In contrast, HAAs, especially those who participated in heterogeneous groups with lower-level partners, achieved the most progress in the second college entrance examination out of all types of students. In addition, the opinions of HAAs were collated in the survey via questions such as "will the immature ideas of your partner cause you confusion?" Overall, data analysis revealed that HAAs did not believe they would be negatively affected by their partners' immature thinking. Furthermore, the fact that none of the HAAs raised such concerns throughout the entire study is also evidence that they were not perturbed by the possibility of their partners causing them confusion.

Studies of students who are at different stages may of course arrive at different conclusions. Overall, heterogeneous collaboration is beneficial to both the less and the more competent partners, not only to one of the parties (Howe et al., 1992; Mugny and Doise 1978). Moreover, Vygotsky's social-cultural theory concentrates on explaining the progress of the former, while the progress of the latter is often explained by the self-expansion effect (Dillenbourg et al., 1995). In terms of the drop in academic performance of HAAs that does present itself on occasion, it often takes place when a diffident HAA collaborates with a confident LAA without feedback from teachers (Tudge, 1992). This may provide us with some insight as to why the HAAs in this study do not experience such issues.

Firstly, the participants in this study were all from a prestigious high school, with the overall academic performance of the school ranked top in the city, therefore they have confidence in their ability. Importantly, this study is carried out at the second round review stage, and by this point participants have learned all the senior high school physics curriculum, and also experienced the

first-round review, hence they generally have a strong ability in physics. For HAAs, even if gaps remain in their knowledge systems, or they lack capability when it comes to solving really difficult problems, when encountering incorrect ideas, they are able to identify existing mistakes and subsequently formulate correct answers, utilizing their partner's immature ideas as a starting point. Therefore, this study establishes that students' development process, as well as their academic achievement, displays a trend of consistent progress in collaborative classes. This finding may be encouraging to teachers who wish to employ collaborative learning at the second round review stage, as the threat of a drop in academic performance to HAAs in heterogeneous groups is rather remote, with the more likely case being that they will make exceptional progress.

5.7.2 Complexity in Homogeneous and Heterogeneous Groups

According to constructive learning theory, cognitive conflict is more likely to occur in homogeneous groups, while scaffolding support is more likely to occur in heterogeneous groups (Dillenbourg et al., 1995). Whilst both having a positive impact on students' development in their thought process, and improvement in academic achievement, a debate still rages about which is more conducive to students' learning, and which group composition is superior. In this study, as illustrated in chapter 4, the intriguing phenomenon of reconciliation emerged. Moreover, in homogeneous groups, there also existed scaffolding support, while in heterogeneous groups there also existed cognitive conflict. Additionally, in each group composition, the proportion of cognitive conflicts and scaffolding supports is almost identical, contradicting previous research findings.

A homogeneous group generally refers to a group composed of equal ability students. In this instance, equal ability means the general intelligence or development level. However, in order to stimulate the occurrence of cognitive conflict, different views must be voiced, which often implies that there are different levels of knowledge and ability present. In fact, one can argue that it is impossible to achieve complete homogeneity as even if the overall academic achievement level of group members is approximately the same, their specific knowledge structure may differ, therefore each member may be suited to solving different problems. Based on the classroom

observation, one of the group members may have a more mature understanding of a specific topic and is consequently able to provide scaffolding support to their partner. In that case, the homogeneous group acts more like a heterogeneous group.

Regarding heterogeneous groups, there are many definitions of heterogeneity, namely having different knowledge, different expressions, and different reasoning mechanisms (Bird, 1993). Even if academic achievement level is the only facet considered, the boundaries between homogeneous and heterogeneous groups are not apparent. In the city where this study was conducted, there are clear differences in ability among students across different senior high schools. Even in the same school, significant differences in ability are likely to present themselves between different classes as when students enter high school, first they attend an exam and are then arranged into different classes according to their grades, with the difference in average score between an excellent class and an average one being considerable, whilst the differences between students in the same class is relatively minor. In this study, students in the same collaborative group are from the same class. Despite their academic achievement level being stratified in accordance with the first college entrance examination, the difference between the group is in fact insignificant, and when compared to students in other classes or even other schools, they may be viewed as having almost the same academic achievement level. In other words, to some extent, the collaborative groups in this study can all be deemed homogeneous groups, thus the existence of cognitive conflicts in heterogeneous groups is reasonable.

Given that the boundary between homogeneous and heterogeneous groups in this study is not evident, it is difficult to define whether a particular group is homogeneous or heterogeneous accurately. Sometimes, the nature of the groups may change when confronting different tasks. As an example, one student in a homogeneous pair was very intelligent and adept at solving difficult problems. Nonetheless, he was not a rigorous learner and had gaps in his knowledge system, therefore rendering his overall performance similar to his partner. When tackling difficult problems, he usually acts as an interpreter and offers scaffolding support to his partner. In these moments, the nature of the group is heterogeneous. However, when facing more manageable

problems, he often offers conflicting opinions to his partners and tends to solve problems through a more equal discussion, thereby returning the nature of the group to homogeneous.

The characteristics of the patterns of collaborative learning supported the above discussion. As illustrated in Chapter 4, a single-directional pattern (a fixed role differentiation emerged when the interpreter supplied the listener with scaffolding support, or when he explained the problems directly, something that is more likely in heterogeneous groups) emerged in some homogeneous groups, and also a bi-directional pattern (where group members are of equal status, tasks are often completed through discussion, with cognitive conflicts being stimulated, with this is more likely to take place in homogeneous groups) in some heterogeneous groups. In addition, there existed mixed patterns, (both single-directional and bi-directional patterns in coexistence) thereby evidencing that the power relationship between group members is transformed by different situations.

At a more foundational level, the above discussion indicated that there is ambiguity and relativity in the definitions of homogeneous and heterogeneous. On one hand, this complexity may be related to the nature of classes in Chinese senior high schools, whilst on the other hand it also originates from the framework of this study. Rogoff and Mistry (1990) stressed that tutoring and scaffolding support are necessary in acquiring new knowledge, and while collaboration between partners of equal ability is deemed more conducive to concept reconstruction, his scope of consideration did not include a particular period in time, namely the second round review stage in senior high school in China. Perhaps it is a fitting moment to discard the comparison of homogeneity and heterogeneity (or cognitive conflict and scaffolding help) in terms of which is superior. What is more important is to consider the situation where learning takes place and choose the appropriate form of collaboration. Besides, in order to respect the complexity of educational situations, an understanding of the specific characteristics of each student's knowledge structure is desirable, and subsequently attention must be paid to what form of interaction occurs among group members when confronting different tasks, and how this interaction affects students' learning outcomes.

5.8 Conclusion

This study is a real-life case of the localization of collaborative learning at the second round review stage in senior high school physics classes in China. It provides insights into both practice and theory. In practice, through collating students' views on all aspects of collaborative learning, in combination with their scores in the second college entrance examination, this study provides evidence that enables an understanding of the impact of collaborative learning on both students' science learning and their academic performance in the second college entrance examination in other similar educational situations. Moreover, in theory, this study explored the potential of a drop in academic performance in participants' development process, it also established ambiguity in the concepts of heterogeneous and homogeneous, thereby enriching the understanding of collaborative learning.

The first purpose of this study is to ascertain the degree to which collaborative learning facilitates students' preparation for the second college entrance examination, with the result being a positive one. Compared to traditional lecturing classes, collaborative learning helps improve students' performance more significantly. The progress of high-ability students is the most evident among all three academic achievement levels, while the progress of students participating in heterogeneous groups is higher than those participating in homogeneous groups. Specifically, high-ability students who participated in heterogeneous groups achieved the greatest progress out of all the types of students (all three academic achievement levels across both group compositions, equaling a total of six types). Nevertheless, they displayed the worst subjective feelings towards their learning.

This contradiction may correlate with a fundamental misunderstanding of collaborative learning. Collaborative learning is rarely employed as a pedagogical strategy in the second round review class of senior high school physics classes in China, mainly due to both teachers and students lacking sufficient understanding of collaborative learning. Furthermore, there are common misunderstandings, such as high-ability students being the best partners, and collaborative learning being useless for high-ability students. However, this study evidenced that high-ability

students can also attain significant progress through offering scaffolding support or elaborating on the explanations they provide. Therefore, this study helps to dispel the concerns of both teachers and students, especially high-ability students, who participate in collaborative learning.

Even though students generally wish to collaborate with higher-level partners, experiencing collaborative learning enabled students to discover advantages in collaborating with equal-ability partners. In fact, students' views of their peers tend to be influenced by their understanding of scaffolding support and cognitive conflict. Peers with equal ability are capable of stimulating cognitive conflict, and thereafter co-construction, whilst peers with higher ability are able to directly provide scaffolding help or detailed explanations. Ultimately, combining both these advantages is most beneficial, hence an ideal partner is one with slightly higher ability.

The students' views on whether collaborative learning is efficient or inefficient also resulted in contradictions. Overall, students state that one of the major disadvantages of collaborative learning is "low efficiency", yet one of its major advantages is "high efficiency". In fact, this may be attributable to students having a different understanding of "efficiency". Moreover, low efficiency may indicate that a lesser quantity of problems has been solved, while high efficiency may equate to more in-depth thinking and better learning outcomes achieved through discussion. Therefore, the "illusion of inefficiency" may in truth be efficiency. Nonetheless, it is undeniable that there are inefficiencies related to time allocation, the nature of tasks and students' tendency to stray off-topic.

Concerning the reasons for the outstanding improvement in academic achievement, none of the factors (namely an individual's academic achievement level, group composition, partner's academic achievement level, satisfaction with partners, and pattern of collaborative learning) that this study focused on initially were in the end directly related to it. Through in-depth analysis, it is established that each of the four students who attained remarkable progress in the second college entrance examination took great care to develop the most suitable method according to their specific situations, therefore demonstrating their awareness of appling effective learning strategies that match their own specific situation.

Learners' suggestions for improving collaborative learning include exchanging partners regularly and allocating time more flexibly for collaborating. In this localized study, the two-way influence between the educational study and the participants is observable, as the latter can propose suggestions based on their experience and these are useful for future studies.

The second purpose of this study is to evaluate the theory of collaborative learning in the process of localization. One matter of particular interest is the potential of a drop in academic performance in students' development process. However, it is not found that collaborating with lower-level partners leads to a drop in academic performance or even stagnation in academic development. From one perspective, not discovering the "potential possibility of a drop in academic performance" is itself a meaningful discovery, because it demonstrates that ZPD should be considered a complex concept that is highly dependent on the educational context.

In addition, relativity and ambiguity are present in the concepts of homogeneous and heterogeneous employed in this study. The survey data indicates that the scaffolding support that should appear in heterogeneous groups also appeared in homogeneous ones. Moreover, the cognitive conflict that usually emerges in homogeneous groups also emerged in heterogeneous groups. Further evidence comes in the shape of the pattern of the collaborative groups as both single-directional patterns and bi-directional patterns were apparent in homogeneous as well as heterogeneous groups. The four noticeable patterns were the single directional pattern (whereby communication tends to be one-way, with interpreters supplying listeners with scaffolding support or offering detailed explanations), bi-directional patterns (whereby communication is mostly two-way, and co-construction after cognitive conflict often occurs), and a mixed pattern combining the above two patterns, and lastly a four-person group pattern.

This ambiguity may be attributable to the class division system in Chinese high schools, with students' ability being relatively concentrated in any given class. In some sense, the heterogeneous groups in this study can also be considered homogeneous ones. Another relevant factor may be the unique background of this study, namely the second round review stage in senior three. At this particular stage, most students are equipped with a relatively high level of ability, yet they have a

tendency to display different ways of thinking or ability levels when completing different tasks. As a result, in some tasks, heterogeneous groups may act like homogeneous groups, and vice versa.

5.9 Implications for Science Learning

The findings of this study may provide the following implications for improving teaching and learning in science classes.

Collaborative learning can be considered a beneficial pedagogy and incorporated into traditional classes. There are multiple reasons for this. First of all, this study found that collaborative learning is conducive to improving academic performance in physics, which is in accordance with other studies on physics (Astra, Wahyuni and Nasbey, 2015; Ho and Boo, 2007), as well as those on other scientific subjects (Omeodu, 2020). Moreover, Andrews, Sekyere and Bugarcic (2020) pointed out that collaborative learning helps learners obtain a deeper understanding of scientific concepts. From the interviews in this study, it was discovered that collaborative partners can bring new perspectives or challenge existing perceptions, thus helping learners clarify and form a more sophisticated understanding of scientific concepts. The analysis of the survey and interview also found that collaborative learning can improve learners' ability in logical reasoning and multi-angle thinking. When learners analyze and challenge their partner's ideas, their critical thinking can gradually be improved. Huda and Rohaeti (2021) and Suyanti and Nasutio (2015) hold similar opinions and further proposed that if collaborative learning is integrated into inquiry learning in science, it is even more particularly helpful for cultivating reasoning ability and critical thinking. Besides, Omeodu (2020) believed that compared with traditional teaching, collaborative learning can improve class engagement and the findings of this study supported this viewpoint. In collaborative groups, students are willing to share, discuss and solve problems through their own efforts, and gradually form positive interdependence among group members and personal accountability for their own learning. In addition, this study found that collaborative learning can enhance students' interpersonal skills, such as clear and logical expression, and the ability to listen to, compare and understand others' ideas (Panggabean, Irfandi and Sinuraya, 2017), and that is

consistent with China's college entrance examination reform. What's more, Slavin (2005) believed that collaborative learning can improve self-confidence. This study found that when learners respect and evaluate each other's weaknesses and strengths in a collaborative group, they develop a sense of security and self-confidence, and generate courage to face challenges and willingness to collaborate with others.

In order to stimulate better learning outcomes, it is advisable to establish heterogeneous groups when implementing collaborative learning. According to the findings of this study, there is a significant difference in the degree of academic progress between participants in heterogeneous groups and those in homogeneous groups. The preference for heterogeneous groups does not mean that scaffolding behaviour is superior to cognitive conflict. According to constructive learning theory, cognitive conflict is more likely to occur in homogeneous groups, while scaffolding support is more likely to occur in heterogeneous groups (Dillenbourg et al., 1995). However, in this study, combining classroom observation and survey data, it was found that both cognitive conflict and scaffolding behaviours existed in both homogeneous and heterogeneous groups, and students believed that they played an equivalent role in the development of thinking. To explain the above phenomena, this study discussed the ambiguity in the concepts of heterogeneous and homogeneous. It is undeniable that both cognitive conflict and scaffolding behaviours have positive impacts on learning outcomes, but this study is not yet able to explain why heterogeneous groups are superior to homogeneous groups in terms of academic achievement. There may be more factors that need further research. It should also be noted that when constructing heterogeneous groups, teachers should not only consider academic achievement level but also individual characteristics. For example, pairing high-learning-motivation students with low-learning-motivation students, or expressive students with introverted students may promote better collaborative effects (Xu, 2022).

HAAs should be encouraged to participate in collaborative learning, especially with lower-level peers. In this study, the academic progress of HAAs was higher than that of students of other levels. Some researchers hold different views on the impact of collaborative learning on HAAs. For example, Majoka et al., (2007) and Kagan (1994) found that LAAs benefited most because

they received more help from higher-level partners' scaffolding behaviours. In contrast, HAAs could be held back because of their effort to help others or being disturbed by immature ideas from lower-ability partners (Slavin, 1996; Tudge, 1992). The results of this study challenged the above viewpoint, as there was no clear evidence to suggest the existence of this "hold back" effect. In this study, HAAs, especially those who participated in heterogeneous groups with lower-level partners, achieved the most significant improvement in academic performance (although overall, students who participated in heterogeneous groups showed statistically significant higher levels of progress than those who participated in homogeneous groups, further analysis of students at each academic achievement levels revealed that, in fact, only HAAs showed statistically significant differences in their performance between heterogeneous and homogeneous groups). Therefore, collaboration between HAAs and lower-level partners could be potentially beneficial for the former. One possible explanation comes from Eshetu, Gebeyehu and Alemu (2017) as they believed that those who offer more elaborated explanations definitely benefited more. In this study, HAAs usually play the role of scaffolder and explainer, and their frequent offer of elaborated explanations may serve as an explanation for their remarkable progress. However, this study also found that, subjectively, HAAs prefer to collaborate with equal-level students rather than lower-level partners, and this psychological tendency affected their feelings about the learning outcomes. Although there is no evidence that negative feelings will reduce the learning effect, it may still cause some resistance to the promotion of collaborative learning, because HAAs may not be willing to participate in heterogeneous groups. Therefore, it is necessary to adopt appropriate methods to publicize the findings of this study and improve the confidence of HAAs in participating in heterogeneous groups.

Finally, this study found the impact of students' awareness and ability to apply effective learning strategies that match their own specific situation on learning outcomes among students with outstanding academic progress. Inspired by this, when carrying out collaborative learning, teachers should organize collaborative groups to reflect, evaluate and adjust collaborative learning strategies. In order to further improve the quality of collaborative discussion and the effect of collaborative learning, students need to find the most suitable pattern of collaboration based on both their own and their peers' specific situations (such as combining personal thinking with

collaborative discussion), identify existing problems (such as lack of logical discussion, drifting discussion topics, passively waiting for peer explanations, etc.) and develop appropriate solutions (Wang and Chen, 2015).

5.10 Contributions and Limitations

The background of this study is China's college entrance examination reform which created challenges for front-line teachers as they must work out how to provide more effective assistance for students at the second round review stage, thereby supporting the improvement in their academic achievement as well as enhancing their scientific learning ability and ultimately providing comprehensive support for their future development. Collaborative learning seems to be a reasonable idea. To some extent, this study helps dispel the notion that employing collaborative learning in Chinese high school classrooms is unsuitable, and provides new ideas for its localized practice, for example, desk-mate collaboration may be effective for conducting collaborative learning in large classes. Furthermore, collaborative learning may be beneficial to HAAs, and the combination of collaborative learning and teacher-lecturing is adaptable. Despite obtaining some results that align with existing literature, such as the benefits of collaborative learning in improving academic performance and enhancing communication skills, this study also identifies discrepancies. Specifically, it highlights the contradictions between the subjective feelings and the objective performance of HAAs and the ambiguity in the definitions of homogeneity and heterogeneity. These may be related to the characteristics of the participants in this study and the particular framework of this study, thereby reflecting the complexity of the educational world. Meanwhile, they also demonstrate the value of this localized study.

However, this study also has some limitations. One is the number of participants. Due to my real-life situation, I was only able to implement collaborative learning in the two classes that I taught, with the total number of students being 70. After dividing the students into three academic levels, there were only slightly more than 20 students in each level. Once both the academic level and group composition are considered, of which there are six different types, each grouping has only just over 10 students. Consequently, obtaining statistically significant results for this study is relatively challenging. Secondly, this study was conducted in a real-life school environment

without establishing experimental, and control groups. Given that the average score of each class varied, there is no common basis for comparison between classes. Ultimately, the same level of progress may have different implications for different classes. Considering the above factors, this study exercises caution in drawing conclusions directly from the quantitative data. Rather, one primary purpose of this study is to understand the impact of collaborative learning through the learners' views. As a result, it relies on both quantitative and qualitative analysis. The study posed open questions in the survey, conducted semi-structured interviews, and it also triangulated quantitative data with qualitative data in order to support the conclusion. As a practitioner-researcher, I performed the role of the teacher, the interviewer and the researcher simultaneously, with this unequal power relationship potentially affecting the reliability of students' answers in the interviews. In order to enable students to describe their experiences and express their views as honestly as possible, the interview only presupposed a few topics using keywords. During the interviews, I encouraged students to express their inner thoughts in depth with sincerity and I avoided offering excessive guidance. To some extent, these measures ensure the authenticity of the interviews, but future research might address some of the limitations of this study.

5.11 Future Research

In the survey, open-ended questions were used to collect suggestions from students on improving collaborative learning (see Appendix A and section 4.3.5 for details). Later in the interview, the final topic was overall perception and suggestions toward collaborative learning (see section 3.4.5 and Appendix D for details), with one student expressing a particularly thoughtful suggestion that collaborative learning should be suitably combined with individual work, as collaborative learning on its own is limited in its capacity to achieve optimal results. Wismath and Orr (2015)'s study on the combination of individual thinking and collaborative learning provided some insights on this point, suggesting that it is very important that teachers allow and encourage independent thinking in collaborative learning, rather than forcing students to engage in discussion from start to finish. The establishment of a model that successfully combines traditional teaching and learning

methods (teacher lecturing and individual independent thinking) with collaborative learning is a very worthwhile objective.

Secondly, the analysis of the students who achieved outstanding progress indicates that collaborative learning may not be effective in all contexts or scenarios, and the awareness and ability to apply effective learning strategies may also contribute to the improvement of academic achievement. In the future, the cultivation of students' ability to apply effective learning strategies must be advanced, in doing so making collaborative learning more effective.

In addition, this study found that students generally recognized the importance of both scaffolding and constructive cognitive conflict for learning. The fact that there existed scaffolding in homogeneous groups and cognitive conflicts in heterogeneous groups also supported the view of ambiguity in the definition of homogeneity and heterogeneity. However, it is undeniable that all three levels of students in this study, especially the HAAs, have made more obvious progress in heterogeneous groups. What other factors were also affecting the learning outcomes? Perhaps it was the detailed explanation given in the collaborative discussion, or the positive engagement and interdependence (although data analysis showed that they may be positively related to students' progress in academic performance, the exploration in this study is far from enough). More studies can be conducted in the future.

Finally, I am keen to conduct action research to explore my own teaching in the future by identifying and forming meaningful research questions in real-life educational contexts, developing preliminary strategies through reading relevant literature and discussions with others, and then carrying out a pedagogical practice in my own classroom. I will observe the progress of the practice, use flexible methods to delve into it, and seek to understand the real learning experiences of the students. In a sense, this study can also be seen as the first stage of an action research, by reflecting on and modifying strategies, and so a further round of practice can be conducted, resulting in a spiraling increase in the effectiveness of the teaching and learning strategies.

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Appendix A: Survey (English Version)

Survey on collaborative learning

Dear student:

This survey concerns your thought and feeling about the collaborative learning experience during last two months. Feel free to answer these questions frankly. All contents you answer will be confidential. Record your responses by checking on blank that corresponds to your thought and feeling correctly.

Thanks for your participation and contribution to this research!

About your collaborative partner

1、What do you think is the rationale of the collaborative group

a、personality　b、academic performance　c、friendship　d、random　e、I am not sure

2、What do you prefer to be the rationale of the collaborative group

a、personality　b、academic performance　c、friendship　d、random　e、I am not sure

3、I prefer my partner to be

a、with higher learning ability　b、with similar learning ability　c、with lower learning ability　d、I am not sure

e、I don't care

4、I think my current partner is

a、with higher learning ability　b、with similar learning ability　c、with lower learning ability　d、I am not sure

e、I don't care

About collaborative learning effects

1、Through collaborative learning, I think my academic performance has

1	2	3	4	5
improved a lot	slightly improved	unchanged	slightly regressed	regressed a lot

2、Through collaborative learning, I think your partner's academic performance has

1	2	3	4	5

improved a lot slightly improved unchanged slightly regressed regressed a lot

3、Through collaborative learning, I can understand problems in my homework (exams) more clearly and deeply

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

4、Through collaborative learning, my homework correction is more effective

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

5、After class, my awareness and frequency of using discussions to solve problems have increased

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

6、As a whole, my interaction with others has increased

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

7、After collaborative learning, I feel more confident and willing to communicate with others

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

8、In addition to academic performance, I think I have also made progress in

□ expressing □ interpersonal interaction □ability to listen and accept different ideas

□ logical reasoning □thinking from multiple angles □ability to help the others

Others：_____ , _____ , _____

Engagement

1、I participated in collaborative discussions actively

1	2	3	4	5

strongly agree	agree	undecided	disagree	strongly disagree

2、My partner participated in collaborative discussions actively

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

3、During collaborative learning, completing the learning task together is our mutual goal

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

4、 I am also concerned about my partner's learning, and I would like to offer help though reminding, asking questions and encouraging

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

4、When my partner made progress in his (her) learning, I feel happy for him (her)

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

Interaction

1、I can express myself clearly and logically during collaborative learning

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

2、My partner can express him or her self clearly and logically during collaborative learning

1	2	3	4	5
strongly agree	agree	undecided	disagree	strongly disagree

3、During collaborative learning, I always explain in details if necessary

1	2	3	4	5

strongly agree agree undecided disagree strongly disagree

4、During collaborative learning, My partner always explain in details if necessary

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

5、If there is a dispute or conflict over a particular question, we are most likely to

a、listen to the student with higher achievement

b、each of us express idea and judge together which one is superior

c、ask other groups or teacher

d、just leave it， the teacher may explain it

6、More often, it is difference or even conflict in opinions that promote us to think more deeply

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

7、More often, it is my partner's explain or scaffolding that make me think more deeply

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

8、My partners' immature idea or mistakes can easily confuse me

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

9、For me, the time for collaborative learning in class is

1 2 3 4 5

too long just fine too short

10、Overall, our group has a good atmosphere during collaborative learning

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

Overall attitudes toward collaborative learning

1、 I enjoyed this collaborative learning experience.

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

2、In my perspective, the advantage of collaborative learning lie in

□promoting comprehension □seeing problems from different perspectives;

□more responsible for my study □promoting friendship □high efficiency in learning

□helping each other □more capable of getting along with others □high motivation

Others:_____

3、In my perspective, the disadvantage of collaborative learning lie in

□disturbing my own learning □low motivation □low efficiency in learning

□actually, we learn individually, collaborative learning becomes merely a formality

□being distracted easily □easily triggered contradiction

Others:_____

4、I would like to experience collaborative learning in the future

1 2 3 4 5

strongly agree agree undecided disagree strongly disagree

5、I think I did well in_____, _____, _____

I think my partner did well in_____, _____, _____

Overall, I think our group did well in_____, _____

6、I think I can improve in_____, _____

I think my partner can improve in _____, _____

Overall, I think our group can improve in_____, _____

7、The most impressive thing or detail during collaborative learning is:

_____

_____

8、I think collaborative learning can also be used in（Please describe the specific content or scene）：

_____

_____

7、Additional ideas to improve collaborative learning（Your suggestion is very important to the improvement of cooperative learning）：

_____

_____

 Please be sure that you have answered all the questions and thanks again for your participation and contribution!

Name: _____

(For the researcher's reference only. Your name will not appear in the research report.)

Appendix B: Participant Consent Form (English Version)

Project title Collaborative learning in high school physics class

Researcher's name Echo Zhang

Supervisor's name Professor B Adamson

- I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree to take part.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- I understand that the interview/data collection [*omit as appropriate*].

  will be recorded/filmed [*omit as appropriate*].
- I understand that data will be stored in accordance with data protection laws.
- I understand that I may contact the researcher or supervisor if I require more information about the research, and that I may contact the Research Ethics Sub-Committee of the University of Nottingham, Ningbo if I wish to make a complaint related to my involvement in the research.

Signed …… (participant)

Print name …… Date ……

Contact details

Researcher: zx17845@nottingham.edu.cn

Supervisor: Bob.Adamson@nottingham.edu.cn

UNNC Research Ethics Sub-Committee Coordinator:

Joanna.Huang@nottingham.edu.cn

Appendix C: Participant Information Sheet (English Version)

Implementing Collaborative Learning in Second Round Review Stage in Senior High School Physics Class

Dear Participant,

Thank you for participating in my doctoral research project at the University of Nottingham in Ningbo. The topic is to implement collaborative learning in second round review stage in senior high school physics class. The choice of the topic is mainly based on the actual problems in our classroom. In a few months, we are facing the second college entrance examination. In the past, our classes mainly adopted the strategy of teacher-lecturing to elaborate on problems existing in our learning. However, in the second round review stage, although everyone's overall ability has improved, the knowledge gaps of each student are more dispersed. It is difficult for the teachers to cover all the problems and meet the different needs of all students. In other words, the original pedagogical strategy is no longer suitable for the current stage. In order to help you better prepare for the second college-entrance-examination and improve the efficiency of the class, we will incorporate collaborative learning tasks in the second round review stage. In each class, there will be a collaborative task developed according to the teaching plan, which will take about 15-20 minutes, and the main content will be homework revision or problem-solving.

Here are some more points: First, to ensure the coverage of knowledge, in addition to collaborative learning, the lecturing method is still adopted. I will explain the difficulties and key points in your learning as a supplement to the group discussion. Besides, we will carry out pair-collaboration and most students will have new partners. Please try to accept new ideas, complete tasks together and reach mutual goals. In addition, pay attention to the communicative skills. For example, respect our peers, learn to listen, understand the thinking process of others, express logically and clearly, and do not be emotional when there are disputes and etc.

In order to understand the impact of collaborative learning on the second college entrance examination and physics learning, there will be a survey for all students and an interview for some students after the second college entrance examination. Both the survey and interview are voluntary, and the time, place and procedure will be informed in advance. You can withdraw from the survey or interview at any time. All personal information will be strictly kept confidential and pseudonyms will be used in the report.

This research has been reviewed by the Ethics Committee of the UNNC, and guided by my supervisor. If you have any questions during the whole process, please contact me or my supervisor in time.

Researcher: zx17845@nottingham.edu.cn

Supervisor: Bob.Adamson@nottingham.edu.cn

UNNC Research Ethics Sub-Committee Coordinator: Joanna.Huang@nottingham.edu.cn

Appendix D: Interview Protocol

1. Purpose

To deeply understand the impact of collaborative learning on participants and students' perceptions on collaborative learning.

2.Interview method

Semi-structured face-to-face interview

3. Interviewees

12 participants

4.Interview process

4.1 Signing the informed consent form

Introduce the purpose and process of the interview (including the use of a recording pen), as well as the rights of the interviewee. The interviewee carefully read and sign the informed consent form. Sample conversation:

In the past several months, we adopted the collaborative learning method in the second round review stage. Today's interview is based on the questionnaire you have done and will take about 20-30 minutes. The interview aims to understand your experience and feelings in the whole process and your perception of this learning method. This interview is completely voluntary. If you feel uncomfortable during the interview, you can choose to quit at any time, or refuse to discuss an issue; you also have the right to initiate a new topic. In order to ensure the accuracy of data recording, we will use a recording pen to record the whole process. The transcript will be sent to you for confirmation. All data (including your personal information) will be strictly kept confidential and used only for the purpose of educational research. If you are willing to conduct the following interview, please read this informed consent form carefully and sign your name here.

4.2 Principles of setting interview questions

The setting of interview questions is in accordance with the questionnaire . Generally, the first topic is about one's partner, and then goes on to learning effects. The next topic is in-depth understanding of collaborative learning experience (including engagement and process of interaction process), and the last one is the overall perception and suggestions.

The specific wording of interview questions is flexible. In order to create a relaxed atmosphere and facilitate the understanding of the real feelings of the interviewees, the interview is conducted in a natural way. In specific, it avoid rigid and fixed questions and use appropriate wording to naturally guide the conversation to the next topic.

The order of interview questions is also flexible. If the interviewee deviates from the original discussion during the conversation, the interviewer should show respect and listen patiently, and lead back to the original discussion direction at an appropriate time, to make sure that the whole interview can cover all the scheduled topics.

4.3 Interview topics and sample questions

Topic 1. the partners

Sample questions:

- What do you think of your partner during collaborative learning?
- What do you think of his/her learning ability, personality, etc.?
- Have you collaborated with him/her before?
- What is an ideal partner in your perspective?

Topic 2. the effect of collaborative learning

Sample questions:

- Talk about the effect of collaborative learning.
- What do you think of the results of the second college entrance examination?
- How effective are homework correction and problem-solving in class?
- Are there any other changes? For example, the ability of expressing yourself and scientific reasoning?

Topic 3. Collaborative learning experience

Sample questions:

- Please describe the process (or your experience) of the collaborative learning in your group.
- Do you and your partner actively participate in collaborative learning?
- How do you carry out the discussion?
- Are the discussions detailed and logical?
- Have you experienced cognitive conflict/peer inspiration and guidance?
- How do they influence you?
- Can you give an example in detail?
- What do you think of the length of time for collaborative learning?

Topic 4. Advantages and disadvantages of collaborative learning and suggestions for future implementation

Sample questions:

- Talk about your overall feeling of using collaborative learning in the second round review stage.
- What do you think are its advantages and disadvantages?
- On the whole, do you think it is helpful to you?
- Are you willing to participate in collaborative learning in the future?
- Is there anything particularly impressive about collaborative learning?

Appendix E: Sample Transcript of an Interview (Chinese Version)

5 月 17 日下午 4 点 20 分（A 为访谈者，B 为访谈对象）

A：那我们要么从你的合作伙伴谈起好不好?

B：其实我跟我们班很多男生都不是很熟，就很怕分到一个不好说话的人，结果后来分到的同伴就觉得他应该性格还好，然后后来合作讨论的时候也还好吧，现在跟他关系也比以前熟了一点。

A：那你觉得他在成绩啊性格啊各方面怎么样?

B：嗯成绩的话我一直觉得他还是头脑很灵光的，就看到很多题目我觉得他就想得还是很快的，做题速度也很快，嗯虽然有时候他会有做错（笑）。然后性格的话，感觉还是挺好的。

A：这个过程当中就是你们的合作讨论形式是怎么样的？能不能描述一下?

B：就是一开始的时候互相讲话就是比如说讲完后如果可能有一点不是很理解的地方也不会再提问，但是后面还是会提问的，就是因为刚开始感觉就会有点不好意思嘛。

A：那提问的时候他给你的解释详不详细啊?

B：嗯……其实他解释还是比较就是可能是思维比较快吧，有时候他给我讲的话我还要想一想才会“哦，原来是这样 ”。

A：如果万一你没有理解呢?

B：没有理解我到后面还是有时候会再问。

A：哦，我记得有一次我就站在你们旁边，然后呢你有一段话我是听到的，大概就是，你问他一个什么问题，然后呢他就给你一个答案，没有详细的解释，然后呢你的反应是“哦”。（笑）就是说你告诉我答案了，我也不进一步向你问一个解释了，这是不是可能你们刚刚开始合作的一个情况？到后来还是这样吗?

B：其实到后来也就是比如说最后一道题目他也可能不会从一开头开始讲，就是比如说直接告诉我这个图形是怎么样的，就是比如说那个粒子运动的那个轨迹啊什么的，他就会觉得我是不是几何方面遇到了问题啊。

A：他讲他觉得的关键点，那也是他在针对你的一个情况，嗯那你觉得他解释的比较逻辑性强吗?

B：嗯……想想（思考中）嗯……逻辑性嘛，因为我感觉我很多时候就是一个点不是很理解，他也不会从头开始给我长篇大论地讲。

A：那他就将这个点都讲述得很清楚让你很信服吗?

B：嗯其实有时候是不能。

A：嗯那你怎么办呢那时候。

B：所以大多时候我可能还是会自己想想吧。

A：那也就是说你自己需要一个时间来内化。

B：就有时候人家讲给我，我就觉得这个时候我能认同，就是没有从心底里就自己想通的感觉。

A：嗯，那我可不可以理解为逻辑性还是可以的，就是说自己还需要一个反思的过程?

B：嗯。

A：嗯好，那从你的角度呢，他再比如说提出一个话题的时候你对他的一个解释是不是详细呢或者说你觉得你表达的时候有没有够清楚?

B：我觉得有时候他错的都是那种可能一不小心题目看错了，或者有个什么东西没有理解对，这个基本上就是我只要一说，或者一点给他几个字，他就“哦（理解状）”。嗯，然后后面其实不是有时候会发那个比较难的几道题就是讨论完成的时候，还是有时候会互相提出一下就是“会不会是这样呢？会不会是这样呢？”然后再一起想。

A：嗯就是两个人一起来讨论这个问题。我记得有一次大家都投入在讨论中了，然后呢你们两个人呢还在各做各的，到后来大家好像有点讨论得差不多了，你们那时却正讨论得很热烈。

B：因为一开始的时候我就是会想再确认一下自己是就是哪个地方没有想通，就是直接开始问我可能会一下子不知道要问什么，就是这样子。

A：也就是说讨论之前的话就是你也要自己先想一想，然后再开始讨论。

B：对。

A：嗯，嗯那就是有没有整个过程当中让你比较印象深刻的事情？

B：嗯……想想（思考）好像没有什么印象深刻的事情（笑）。

A：好的，那你能不能谈一谈，整个这种学习的方式跟那种传统的就是“我讲你们听”还是挺不一样的，那么就是这样的一个过程对你的整个影响，就比如说我第二次准备选考我的具体的解题能力或者说是我跟人的交流方式，各个方面，有什么样的帮助？

B：嗯，我觉得……传统的讲的话就是有时候可能就是这样写下来，中间有一个点可能不是很理解，然后比如说这个时候可能走神一下就会中间有一个点没有办法理解，然后到后面的内容就是虽然你看到了后面也能接受，但是就是因为你中间有个东西没有办法想通，整体要是下次看到我可能还是不会做。但是讨论的话就是相当于有时候你可以一边讨论一边想一想啊什么的，而且如果突然不会的话就可以马上发问，我就还是会更有空间一点吧好像。

A：就相当于把思考的过程给打开了。那么这是你觉得比较好的地方。

B：嗯还有就是上课如果我看到有一个地方不理解我也不会马上发问。

A：嗯嗯这是你觉得比较好的地方。嗯，那你觉得有没有还可以改进的？

B：嗯，可能我跟我的合作伙伴还不是很熟，我可能跟不是很熟的人我就会不好意思问，但如果跟王小欢（假名）一起的话，我肯定会直接问，她说完一遍后我会说“啊你说什么”，然后她会再给我说一遍。

A：那你如果我现在给你机会让你再选择一次的话，你会选什么样的呢？除了就是你想选熟悉一点的，对他的性格啊能力啊有什么想法吗？

B：嗯……可能我会喜欢讲题比较具体详细一点的吧。

A：就是可以给你解题更详细一点的。嗯那么你自己在讲的时候详细吗？

B：我觉得自己讲的时候还挺详细的。

A：嗯你好几次讲到熟悉不熟悉，是不是你觉得就是比较要好的同学在一起？

B：但是我又觉得要好的同学在一起上课可能会讲闲话。

A：那你觉得比方说从他的成绩啊水平来讲。

B：那我可能还是希望比我好一点的吧。

A：哦比你好一点的。

B：我刚刚想了一下老赵和老杨（假名），但是我不是很清楚，因为我跟老赵不是很熟，我也不知道他给人讲题的风格是怎么样的，但我感觉他应该看起来还是比较好的吧，很多男生有时候也会问他题目。

A：嗯就是老赵这样子的话，他讲题也讲得很清楚的，能给你讲得详细一点，跟他一起合作也是比较不错的，是吗？

B：嗯，不过我感觉老赵的性格好像比较高冷。

A：嗯所以你觉得跟性格也有关系。那你们除了就是相互比如说我给你解释你给我解释，有没有就是比如你也不是很确定他也不是很确定，两个人讨论啊讨论啊最后大家一起把这个问题给解决了，有没有这样的经历？

B：有。

A：你可以详细描述一下吗？

B：嗯就是有一次做一张就是整张讨论的那个最后一题，然后那个时候好像是第三小题比较难还是什么的，我们其实都没有什么方向，是动量定理或者是能量守恒，然后我们就是先开始我讲，会不会是这样的呢，他讲，会不会是这样的式子呢。其实那时候我们都不确定是不是对的，但是后来算着算着，他又给我讲一下他的，我就觉得诶好像很有道理，然后后来就达成了共识。

A：刚刚讲了两种情况，一种是像老赵（假名）水平很高的（伙伴），可能就没有这样一起来钻研的过程

了。一种是你实际有的讨论的经历。这两种你有什么样的偏向，分别有什么感觉吗?

B：那我好像还是觉得一起讨论比较好，如果他能力比我好很多，我可能自己要想比较久，确定哦这个真的想不出来才会问可能。

A：因为他一下子就会直接告诉你。

B：如果一下子我还没想清楚他就给我讲，这次能理解，下次还是可能忘记了或者还是不会做。

A：所以我能理解成你还是更加愿意经常也有自己的一个思考过程。

A：合作讨论的方式可以有待改进的地方？从你个人的角度。

B：（思考良久）感觉没什么想改进的。

A：那么你觉得以后在什么情况下你还想经历这种方式呢?

B：可能就是接触一个新东西的时候，大家可以一起想一想。

A：你想想看还有什么需要补充的地方吗?

B：嗯……那我觉得人际交往这方面，我觉得我现在人际交往应该好一些。。。

B：到最后肯定比刚开始熟悉很多。

A：还有什么要补充的吗?

B：嗯没什么想补充的了。

A：嗯那我们先到这里好了。

Appendix F: Sample Transcript of an Interview (English Version)

May 17 4:20 PM (A is the interviewer, B is the interviewee)

A：Shall we start with your partner?

B： In fact, I am not familiar with many boys. I am afraid of being assigned to a partner who is not easy to communicate with. In the end, I was assigned to C. I think he has a good personality. Later, when I discussed with him, I felt good. Now I am a little familiar with him.

A：What do you think of his performance, personality and other aspects?

B：Well, I always think that he is smart. I think he can think and solve problems quickly, although sometimes he will make mistakes (laugh). And his character is very kind.

A：In this process, what is the pattern of the collaborative discussion like in your group? Can you describe it?

B： We will express opinions to each other first. If I don't understand something, I won't ask questions at the beginning, but after we get familiar with each other, I will still ask questions because I feel a little embarrassed at the beginning.

A：Did C give you a detailed explanation?

B：Hmm... In fact, he may be thinking fast. Sometimes I have to think about what he said to me before "Oh, so it is".

A: What if you don't understand?

B: I sometimes ask again.

A： Oh, I remember standing next to you once, and then I heard a conversation from you. Probably, you ask C a question, and then C gives you an answer without a detailed explanation, and then your response is "oh". (Laughter) It seems that you only want the answer but not any further explanation. Is this the situation when you just started to cooperate? Or did it happen later?

B：In fact, later on, he may not start from the beginning, for example, (he will) tell me directly how the figure is, or the trajectory of the particle, and he will think that I have a problem with geometry.

A： Well, do you think his explanation is logical?

B：Hum... Hum... As for logic, because I feel that sometimes I just don't understand a certain point , and he doesn't need to start from the beginning and tell me a long story.

A： So did he make it very clear and convinced you?

B： Well, actually sometimes he can't.

A： Well, what do you do then?

B： So most of the time I may still need to think about it myself.

A： That means you need a period of time to internalize.

B： Sometimes I feel that I can agree with what others have told me, but I don't have the feeling of understanding from the bottom of my heart.

A： Well, does it mean that the logic of the partner is still fine, but you still need a process of reflection?

B： Yes.

A： Well, what about you, did you give him a detailed explanation when he raises a topic, or do you think your expression is clear enough?

B：I think sometimes the reason why he is wrong is that he may make mistakes in reviewing the questions, or there is something that is not understood correctly. Basically, once I say it or give him a few words, he will "oh (understanding)". Later, when we were asked to discuss and sole some difficult questions, we will ask each other,

"Can this be the case? Can this be the case?" Then we will discuss a certain situation together.

A： I remember that once most groups were all positively engaged in the discussion, and then you two were still doing your own work separately. However, later on, when most groups were nearly finished, your group was in a state or heated discussion.

B：Because at the beginning, I just want to reconfirm where I haven't figured out

If I start the cooperative discussion directly, I may not know what to say at once. That's it.

A: That is to say, before the discussion, you should think for yourself first, and then start the discussion.

B: Yes.

A： What impressed you most during the whole process?

B： Hmm... There seems to be nothing impressive (laugh).

A： Collaborative learning is quite different from the traditional class. So what is the impact of this process on you, for example, for the preparation for the second exam, problem-solving ability or the way you communicate with others?

B： Well, I think... in the traditional classroom, if you are distracted, you will miss some points. Although you can understand the following content, the missing point will lead to the fact that the next time you encounter a similar problem, you still cannot solve it.

A： Cooperative learning can open the process of thinking without missing any points. So this is an advantage for you.

B： Besides, I won't ask questions immediately if I don't understand something in class.

A： Well, then what do you think can be improved?

B: Well, maybe I'm still not very familiar with my partner. I may be embarrassed to ask someone I don't know very well, but if I'm with Mary (pseudonym, her best friend), I will ask directly.

A： If I gave you the chance to choose again, what kind of partner would you choose? Do you have any ideas about his character and ability?

B： Hmm... Maybe I will like a partner who explains more in detail.

A： Well, Did you explain in details?

B： I think my explanation was quite detailed.

A： Well, you talked about the familiarity between peers several times? Do you think that it's better to collaborate with your best friends?

B： But I also think that close friends may chat.

A： Then what about the academic achievement level?

B： I hope (to collaborate with) someone who is better than me.

A： Hmm...better than y

B： I just thought about Jacky and Richard (pseudonym, two high ability boys), but I'm not sure, because I'm not very familiar with Jacky, and I don't know his style of interpreting problems, but I think he looks good, and many boys sometimes ask him questions.

A： Well, like Jacky, he explained clearly, you feel it's good to work with him, isn't it?

B： Yes, but I think Jacky is not easy to get along with.

A： So you think it has something to do with character. Do you have such experience that both of you are not sure about a certain problem, you two discuss and finally solve the problem together?

B： Yes.

A： Can you describe it in details?

B： Well, once we encountered a difficult problem and didn't have any idea at the beginning, whether to use the theorem of momentum or the conservation of energy. Then we adopted this strategy: first, I said, would it be like

this, and then he said, would it be like this. In fact, at that time, we were not sure whether it was right or not, but after a few rounds, he proposed his (idea), and I felt that it seemed very reasonable, and then we reached a consensus.

A： We just talked about two situations. One is with a high level (partner) like Jacky (pseudonym). Maybe there will be no discussion (he will guide you directly and explain to you). One is your actual experience. What is your preference?

B: I still think it is better to discuss (with equal ability partner) together. If he is much better than me, I may have to think about it for a long time. I will only ask after I am sure that I can't figure it out by myself.

A: Because he'll tell you all at once.

B: If he explains it to me directly before I think it clearly, even if I can understand it this time, I may forget or uncapable of doing it next time.

A： So I can understand that you are more willing to have your own thinking process.

A： what do you think of the disadvantage of collaborative learning, do you have any suggestions?

B: (thinking for a long time) I don't feel much to improve.

A: So when do you think you will want to experience collaborative learning again?

B: Maybe when learning something new, it is better to thinktogether.

A: Is there anything else to add?

B: Hmm... I think I should be better at interpersonal communication now...

B: It must be much more familiar than at the beginning.

A: Anything else?

B: Nothing.

A: Well, let's stop it here.

Appendix G: Tables of Survey Analysis

Note: value is converted from respondents' choices proportion in the Likert scale, where each option is assigned a score from 5 to 1.

Table 1 Comparison of perception of "learning outcomes" between participants in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question1	Improved a lot	40%	33%
	Slightly improved	60%	67%
	Unchanged		
	Slightly regressed		
	Regressed a lot		
	Value	4.39	4.33
Question2	Improved a lot	33%	39%
	Slightly improved	61%	61%
	Unchanged	6%	
	Slightly regressed		
	Regressed a lot		
	Value	4.27	4.39
Question3	Strongly agree	21%	36%
	Agree	61%	61%
	Undecided	12	3%
	Disagree	6%	
	Strongly disagree		
	Value	4	4.3
Question4	Strongly agree	15%	30%
	Agree	64%	49%
	Undecided	18%	15%
	Disagree	3%	6%
	Strongly disagree	3.9	4
	Value	4	4

Table 2 Comparison of perception of "learning outcomes" among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Improved a lot			17%
	Slightly improved	70%	78%	70%
	Unchanged	15%	22%	13%
	Slightly regressed	10%		
	Regressed a lot	5%		
	value	3.5	3.78	4.04
Question2	Improved a lot	15%		18%
	Slightly improved	60%	78%	52%
	Unchanged	25%	22%	30%

	Slightly regressed			
	Regressed a lot			
	value	3.9	3.78	3.88
Question3	Strongly agree	40%	13%	26%
	Agree	60%	70%	70%
	Undecided		17%	4%
	Disagree			
	Strongly disagree			
	value	4.4	3.96	4.22
Question4	Strongly agree	45%	17%	26%
	Agree	50%	74%	70%
	Undecided	5%	9%	4%
	Disagree			
	Strongly disagree			
	value	4.4	4.08	4.22

Table 3 Comparison of perception of "interpersonal factors" among participants in different levels

Achievement level		HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question5	Strongly agree	25%	9%	9%
	Agree	40%	57%	52%
	Undecided	30%	30%	30%
	Disagree	5%	4%	9%
	Strongly disagree			
	Value	3.8	3.71	3.61
Question6	Strongly agree	25%	4%	4%
	Agree	50%	74%	48%
	Undecided	20%	22%	44%
	Disagree	5%		4%
	Strongly disagree			
	Value	3.95	3.82	3.52
Question7	Strongly agree		13%	17%
	Agree	40%	26%	22%
	Undecided	45%	48%	44%
	Disagree	15%	13%	17%
	Strongly disagree			
	Value	3.25	3.39	3.39

Table 4 Comparison of perception of "interpersonal factors" between participants in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question5	Strongly agree	9%	18%

	Agree	52%	49%
	Undecided	36%	24%
	Disagree	3%	9%
	Strongly disagree		
	Value	3.65	3.75
Question6	Strongly agree	12%	9%
	Agree	55%	61%
	Undecided	27%	30%
	Disagree	6%	
	Strongly disagree		
	Value	3.72	3.79
Question7	Strongly agree	9%	12%
	Agree	27%	30%
	Undecided	46%	46%
	Disagree	18%	12
	Strongly disagree		
	Value	3.27	3.42

Table 5 Comparison between homogeneous and heterogeneous groups among participants in each level

	Value	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question7	Heterogeneous group	3.27	3.35	3.17
	Homogeneous group	3.22	3.39	3.58

Table 6 Comparison of perception of "partner" among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Character	25%	13%	8%
	Academic achievement	35%	48%	33%
	Friendship	5%	4%	8%
	Random	50%	26%	30%
	I am not sure		9%	21%
Question2	Character	30%	35%	20%
	Academic achievement	25%	35%	36%
	Friendship	20%	13%	24%
	Random	25%	13%	16%
	I am not sure	5%	4%	4%
Question3	With higher academic level	40%	40%	43%
	With similar academic level	45%	52%	39%
	With lower academic level	15%	8%	
	I am not sure			9%
	I don’t care			9%
Question4	With higher academic level	45%	60%	43%

	With similar academic level	45%	30%	43%
	With lower academic level			
	I am not sure			
	I don’t care	10%	10%	14%

Table 7 Comparison of perception of "partner" between participants in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question1	Character	19%	9%
	Academic achievement	31%	44%
	Friendship	3%	9%
	Random	39%	26%
	I am not sure	8%	12%
Question2	Character	38%	17%
	Academic achievement	30%	40%
	Friendship	10%	30%
	Random	22%	13%
	I am not sure		10%
Question3	With higher academic level	42%	36%
	With similar academic level	36%	55%
	With lower academic level	18%	6%
	I am not sure		
	I don’t care	4%	3%
Question4	With higher academic level	55%	42%
	With similar academic level	33%	48%
	With lower academic level		
	I am not sure		
	I don’t care	12%	10%

Table 8 Comparison of perception of " engagement " among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Strongly agree	40%	35%	35%
	Agree	60%	65%	65%
	Undecided			
	Disagree			
	Strongly disagree			
	Value	4.4	4.35	4.35
Question2	Strongly agree	55%	26%	30%
	Agree	45%	65%	70%
	Undecided		9%	
	Disagree			

	Strongly disagree			
	Value	4.55	4.17	4.3
Question3	Strongly agree	45%	22%	22%
	Agree	50%	65%	65%
	Undecided		13%	9%
	Disagree	5%		4%
	Strongly disagree			
	Value	4.35	4.09	4.05
Question4	Strongly agree	30%	13%	26%
	Agree	45%	70%	52%
	Undecided	20%	17%	13%
	Disagree	5%		9%
	Strongly disagree			
	Value	4	3.96	3.95
Question5	Strongly agree	45%	22%	48%
	Agree	40%	69%	43%
	Undecided	10%	9%	9%
	Disagree	5%		
	Strongly disagree			
	Value	4.25	4.13	4.39

Table 9 Comparison of perception of " engagement " of MAAs in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question1	Strongly agree	40%	33%
	Agree	60%	67%
	Undecided		
	Disagree		
	Strongly disagree		
	Value	4.36	4.33
Question2	Strongly agree	33%	39%
	Agree	61%	61%
	Undecided	6%	
	Disagree		
	Strongly disagree		
	Value	4	4.33
Question3	Strongly agree	21%	36%
	Agree	61%	61%
	Undecided	12	3%
	Disagree	6%	
	Strongly disagree		
	Value	3.7	4.4

Question4	Strongly agree	15%	30%
	Agree	64%	49%
	Undecided	18%	15%
	Disagree	3%	6%
	Strongly disagree	3.9	4
	Value	3.7	4.2
Question5	Strongly agree	36%	39%
	Agree	49%	55%
	Undecided	12%	6%
	Disagree	3%	
	Strongly disagree		
	Value	4	4.3

Table 10 Comparison of perception of "quality of discussion" among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Strongly agree	21%	9%	5%
	Agree	53%	65%	73%
	Undecided	26%	26%	22%
	Disagree			
	Strongly disagree			
	Value	3.95	3.83	3.66
Question2	Strongly agree	35%	9%	30%
	Agree	55%	78%	65%
	Undecided	10%	9%	5%
	Disagree		4%	
	Strongly disagree			
	Value	4.25	3.9	4.25
Question3	Strongly agree	40%	22%	30%
	Agree	45%	61%	48%
	Undecided	15%	13%	22%
	Disagree		4%	
	Strongly disagree			
	Value	4.25	4.01	4.08
Question4	Strongly agree	50%	26%	35%
	Agree	40%	57%	61%
	Undecided	5%	17%	4%
	Disagree	5%		
	Strongly disagree			
	Value	4.5	4.1	4.31

Table 11 Comparison between homogeneous and heterogeneous groups in each level

	Value	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Heterogeneous group	3.55	3.64	3.45
	Homogeneous group	4	4	3.83
Question2	Heterogeneous group	4	3.7	4.5
	Homogeneous group	4.6	4.1	4
Question3	Heterogeneous group	4.2	4	3.6
	Homogeneous group	4.3	4	4.5
Question4	Heterogeneous group	4	4	4.1
	Homogeneous group	4.8	4.2	4.5

Table 12 Comparison of perception of "time for collaboration" among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question9	too long	5%		9%
	A little bit long	25%	35%	26%
	just fine	50%	48%	48%
	A little bit short	20%	17%	17%
	Too short			
	value	3.15	3.85	3.27

Table 13 Comparison of perception of "cognitive conflict and scaffolding behavior" among participants in different levels

	Choice	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question6	Strongly agree	35%	26%	39%
	agree	55%	74%	57%
	undecided	10%		4%
	disagree			
	Strongly disagree			
	value	4.25	4.26	4.35
Question7	Strongly agree	50%	17%	35%
	agree	45%	83%	65%
	undecided			
	disagree	5%		
	Strongly disagree			
	value	4.4	4.17	4.35
Question8	Strongly agree			4%
	agree	10%	9%	30%
	undecided	35%	41%	35%
	disagree	50%	45%	22%
	Strongly disagree	5%	5%	9%
	value	2.5	2.43	4.4

Table 14 Perception of "cognitive conflict and scaffolding behavior" between participants in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question6	Strongly agree	30%	36%
	Agree	64%	61%
	Undecided	6%	3%
	Disagree		
	Strongly disagree		
	Value	4.2	4.3
Question7	Strongly agree	27%	39%
	Agree	70%	61%
	Undecided		
	Disagree	3%	
	Strongly disagree		
	Value	4.2	4.4
Question8	Strongly agree		3%
	Agree	19%	15%
	Undecided	34%	39%
	Disagree	38%	39%
	Strongly disagree	9%	3%
	Value	2.6	2.8

Table 15 Comparison of overall attitudes towards collaborative learning among participants in different levels

	Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Strongly agree	40%	9%	17%
	Agree	50%	87%	61%
	Undecided	5%	4%	22%
	Disagree	5%		
	Strongly disagree			
	Value	4.25	4.05	3.95
Question4	Strongly agree	35%	18%	13%
	Agree	60%	78%	65%
	Undecided	5%	4%	22%
	Disagree			
	Strongly disagree			
	Value	4.3	4.13	3.9

Table 16 Comparison of overall attitudes towards collaborative learning between participants in different groups

	Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Question1	Strongly agree	21%	21%
	Agree	67%	67%
	Undecided	9%	12%
	Disagree	3%	
	Strongly disagree		

	Value	4.1	4.1
Question4	Strongly agree	24%	18%
	Agree	67%	70%
	Undecided	9%	12%
	Disagree		
	Strongly disagree		
	Value	4.2	4.1

Table 17 Comparison between homogeneous and heterogeneous groups in each academic achievement level

	Score	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Question1	Heterogeneous group	4	3.9	4.3
	Homogeneous group	4.6	4.2	3.7
Question4	Heterogeneous group	4.18	4.18	4.09
	Homogeneous group	4.44	4.08	3.75

Table 18 Comparison of perception of "advantages of collaborative learning" among participants in different levels

Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
Promoting comprehension	65%	70%	39%
Seeing problems from different perspectives;	70%	52%	39%
More responsible for my study	25%	39%	30%
Promoting friendship	30%	52%	48%
High efficiency in learning	80%	96%	83%
Helping each other	60%	65%	65%
More capable of getting along with others	30%	30%	30%
High motivation in learning	30%	20%	10%
Ranking	52164 (78) 3	5162 (4) 378	5641 (2) 3 (7) 8

Table 19 Comparison of perception of "advantages of collaborative learning" between participants in different groups

Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
Promoting comprehension	55%	61%
Seeing problems from different perspectives;	52%	55%
More responsible for my study	15%	48%
Promoting friendship	45%	42%
High efficiency in learning	88%	85%
Helping each other	58%	70%
More capable of getting along with others	20%	30%
High motivation in learning	10%	30%

Table 20 Comparison of perception of "disadvantages of collaborative learning" among participants in different levels

Option	HAAs (n=20)	MAAs (n=23)	LAAs (n=23)
1、disturbing my own learning		4%	
2、low motivation	5%		
3、actually, we learn individually, collaborative learning becomes merely a formality	10%	17%	17%
4、being distracted easily	25%	26%	30%
5、low efficiency in learning	50%	44%	57%
6、easily triggered contradiction	5%	9%	4%
7、Impose oneself to communicate with others	10%	10%	10%
Ranking	543（7）2（6）	543761	54376

Table 21 Comparison of perception of "disadvantages of collaborative learning" between participants in different groups

Option	Heterogeneous groups (n=33)	Homogeneous groups (n=33)
1、Disturbing my own learning		3%
2、Low motivation	3%	
3、Actually, we learn individually, collaborative learning becomes merely a formality	12%	18%
4、Being distracted easily	30%	24%
5、Low efficiency in learning	45%	55%
6、Easily triggered contradiction	6%	6%
7、Impose oneself to communicate with others	3%	20%
Ranking		3%

Appendix H: Selection of Observation Notes

There were 32 physics classes in the whole process of this study, and there was a collaboration period in each class. The teacher observed the collaborative interaction process in a participatory way and recorded field notes. The selection of the points for observation is based on both the research question and the literature review. They include the level of engagement, intra-group relationship, quality of discussion, time of collaboration, body language, personal behavior and effect of interaction. The following excerpts include some notes from some classes. It should be noted that in the following notes, students' family names are presented and all are pseudonyms.

Selection of notes (Class 1)

Today, the overall participation in the discussion is not very high, and the frequency of group discussions is not high, either. The Yan and Zhe groups did not discuss at all, the two students were doing their own homework revision.

Later after class, Zhe talked to me, he said that his partner was an unfamiliar girl who belonged to different administrative classes and he hoped to find a new partner. I replaced him with An in a group.

Selection of notes (Class 3)

Today, during the collaboration period, Jia/Xue group showed very low engagement, possibly because both individuals were relatively introverted and are high in ability, as well as the unfamiliarity between girl and boy. About 60% of the group discussions were of quite high engagement. I noticed that Zhe looked out of the window during the collaboration period and put his hand underneath the desk. When I walked over, I found a Rubik's Cube in his hand. Zhe's partner An was doing his own work, and the two of them had occasional conversations.

Selection of notes (Class 5)

Today's task is to analyze the circuit structure in electromagnetic induction problems. The participation of Zhe and An's group in recent discussions has become increasingly high. Today, two heads often get very close to each other. During the class review session, I proposed a question relating to the task. An took the initiative to raise his hand, but after standing up, he mischievously said, 'Let my desk mate answer.'. Zhe hesitated and stood up, but the answer was very good. This is really different from his previous performance!

Selection of notes (Class 10)

Yesterday, Chong didn't do any homework at all. During today's discussion, his partner Chi did all the talking (explaining). However, Chi confused the average and effective values of the current, Chong didn't raise any objections but just lightly nodded his head.

The conversation between Xin and Hong group that attracts my interest. Xin pointed to a question in her homework and asked why the magnitude of photocurrent in the image varies from high to low. Hong said: Saturation current has been reached. Xin said, 'Oh.'. They went on to discuss another question.

Selection of notes (Class 14)

Gradually, I found that students are becoming more and more enthusiastic about discussion and the quality of discussion improved.

Today, the two members of the Zi/Jian group got their heads together and wrote on the same assignment with pens. The discussion was intense and the relationship in the discussion seems “bidirectional”. In the class review session, I picked Zi/Jian group to conduct a dynamic analysis of the conductor frame from entering the magnetic field to leaving the magnetic field in front of the whole class. They went to the blackboard together and discussed task allocation on-site. Zi/ introduced the phase when the wireframe enters the magnetic field, while Jian introduced the phase when it leaves. They analyze while creating a process diagram on the blackboard. What's even more interesting is that when Jian was speaking, Zi kept looking at him. After Jian finished speaking, Zi made some additions, and the collaborative atmosphere was very strong.

Selection of notes (Class 17)

Some groups exhibit a clear role differentiation, where one student primarily asks questions and waits for explanations (listener and receiver） and the other is responsible for answering questions (explain-provider). One typical example is Yang/Zhuo group, Yang has been explaining to Zhuo for quite a long time and then pondering after the explanation. His partner Zhuo has always been relatively passive, asking questions and listening to explanations. Is it because her achievement level is much lower than Wang's? Besides, the relationship in Fang /Chong group also seems to be "unidirectional" because, in recent classes, Chong is always helping Fang.

The group with significantly "indifferent" engagement today is Yin’s group. At first, the group members did not communicate with each other, but they passed on assignments and books to each other. Later, they discussed but the atmosphere was relatively cold throughout the process, and the frequency of dialogue was relatively low.

Selection of notes (Class 26)

1. Groups participated in inter-group discussions

Rui/Lin group and Zhe/An group held inter-group (four-person) discussions;

Chi/Chong and Si/Ke group held inter-group (four-person) discussions.

2. Groups with “active” engagement

Tian/Yu group; Qiu /Zhe group; Wen/Yue group; Zhang/Yu group;

3. Groups with significant improvement in engagement

Fang/Huang group (initially both group members were relatively introverted, but now the frequency of discussions is very high)

Qian/Zhang group (initially the boy and the girl were not familiar, but now the discussion of high quality);

Chen/Xue group also made progress in having more communication, indicating that introverted individuals can also achieve high engagement in discussion

4. Groups with “indifferent” engagement

Yan（boy）/ Yan（girl） group (almost no communication today, Yan （boy） chatted with other classmates; Yan （girl）had discussions with another group)

Does it mean that the partner is dissatisfied with each other, so they are looking for someone else to discuss?

Fang /Chong group (with very rare communication, Fang later looked out of the window)

Selection of notes (Class 30)

Today, as we approached the end of the collaboration period, the discussions were still heated, but when I announced the end of the collaboration period, all groups except for Xin/Hong group returned to silence. The Xin/Hong group showed relatively low engagement at the initial stage, but the two may have adapted to the form of collaboration with each other, and the frequency and quality of discussions have improved. Today (as well as in recent classes), their collaboration begins with individual thinking and after quite a while, they began to discuss and the atmosphere is heated. After class, it was observed that Xin/Hong group began to discuss another question. Obviously, today's time is not enough for them.