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Collaborative Learning by Teaching: A Pedagogy between Learner-Centered and Learner-Driven

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Received: 16 January 2019; Accepted: 20 February 2019; Published: 22 February 2019

Abstract: Learner-centered and learner-driven pedagogy have long been advocated by many educators and scholars who focus on sustainable education. This study proposes a pedagogical approach called collaborative learning by teaching (CLBT), which is both learner-centered and learner-driven. This study aims to explore and analyze the student perceptions of CLBT by conducting a field experiment in a Chinese public university. The quantitative results show that student perceptions were comprised of three dimensions: perceptions of CLBT, perceptions of teamwork, and perceptions of mobile learning. The male students had significantly more positive perceptions of CLBT and mobile learning compared to the female students. The qualitative findings indicate that although students have some difficulties with self-discipline, they gain much in active learning capabilities and teamwork skills. The relationship between CLBT and sustainability competence should be further studied in the future.

Keywords: collaborative learning by teaching; blended learning; sustainability education; active learning; instructional pedagogy

1. Introduction

Learner-centered and learner-driven pedagogical approaches are widely perceived as ways to address the challenges of achieving sustainable education [1,2]. Since most sustainability issues are complex and uncertain, addressing these issues requires developing high-level sustainable competence, such as critical thinking, collaboration competence, etc. [3–5]. Both learner-centered and learner-driven learning approaches are based on constructivist learning theory, which was proposed by Jean Piaget for whom learning was an active process where learners must actively construct their knowledge through prior knowledge and experiences [3,6].

Learner-centered learning, also known as student-centered education, refers to teaching methods that shift the teaching focus from the teachers to the students for the purpose of cultivating the learners' autonomy and independence by giving them the responsibility and initiative for the learning procedure [3]. However, learner-driven approaches further intend to put the learners in the driver's seat, which entails planning, monitoring, and reflecting during the learning process [7]. In comparison, learner-driven strategies are especially important in sustainable education because the learner-driven pedagogy, which is a more divergent and marginal pedagogy compared to learner-centered pedagogy [3], is seen as an appropriate tool for developing sustainability competencies [8–11].

Teaching others is said to be a powerful way to learn and helpful in accomplishing the high-level learning objectives of Bloom's taxonomy, such as synthesizing, evaluating, and creating, which reflect

sustainable competence [12,13]. There are four main ways to learn: listening, speaking, teaching, and questioning. Listening and speaking correspond to the low-level objectives of Bloom's taxonomy, while teaching and questioning correspond to Bloom's high-level objectives [14]. Many researchers have explored learning by teaching (LBT) with contemporary educational practices [12–17]. Bargh and Schul [12] broke down the LBT process into three distinct stages of teaching: preparing to teach, explaining to others, and interacting with others. They also observed a teaching expectancy effect, namely that studying with the expectation of later teaching may play an essential role in determining the overall effects of learning by teaching. That is, the prospect of teaching others may help students select the most important material from a lesson, and to organize it into a meaningful representation. Based on the learning expectancy effect, Fiorella and Mayer [13,14] examined the roles of preparing to teach and actually teaching (i.e., explaining to others) on immediate and long-term learning. Their findings suggest that students who teach the content of a lesson develop a deeper and more persistent understanding of the material than those who solely prepare to teach. Park and Kim [17] proposed a web-based tutoring environment, the Virtual Tutee System (VTS), to improve the learning of college students by having them teach others, and found a significant improvement in students' emotional engagement in reading after using the VTS.

Teaching is clearly a complex task for students, so LBT should be explored from a collaborative perspective. Teaching is a process that involves the internalization of knowledge and its externalization, which also involves self-learning ability and computer display skills. In a limited time, it is difficult for one student to complete a subject task alone, so the quality of teaching cannot be guaranteed. According to Paas and Sweller [18], distributing the cognitive load among group members can expand the working memory of individuals for completing complex cognitive tasks. Kirschner, Paas, and Kirschner [19,20] concluded that a group of collaborating individuals learns more efficiently than individuals learning alone when facing highly complex tasks. Furthermore, collaborative learning helps to foster sustainable consciousness and critical thinking, which are core competence requirements for sustainable development [5]. Therefore, it is necessary to combine collaborative learning with learning by teaching, and to investigate collaborative learning by teaching (CLBT) in higher education.

Although Confucius said that teaching and learning improve each other, few empirical studies on LBT have been implemented in Chinese higher education until now [15,16]. Considering the potential importance of collaborative learning by teaching students to aid in developing their high-level learning abilities and sustainable competence, especially for students in higher education, it is necessary for us to propose CLBT and fill this gap. In order to explore and analyze student perceptions of CLBT and the composition of their perceptions, the main contents and contributions of this article are as follows:

- Propose and design a CLBT pedagogy.
- Conduct a field experiment on CLBT in a Chinese public university.
- Explore and analyze student perceptions of CLBT using qualitative and quantitative methods.

2. Related Pedagogical Approaches

With the development of computer technology and the internet, combining teaching methods and technology has become an inevitable trend in higher education [21]. So far, many scholars have found that blended and flipped pedagogies can help to achieve better academic performance and promote learning motivation, learning attitudes, and interactions [21–23]. Therefore, in order to promote student ability to achieve better learning performance and better experiences, the CLBT approach combines the concepts of blended learning and the flipped classroom in this article.

2.1. Blended Learning and the Flipped Classroom

There are numerous definitions of blended learning. Many scholars define blended classrooms as a combination of online learning and offline classrooms, with different learning ratios assigned [24,25]. However, this study uses the following definition: blended learning combines different delivery

media to promote meaningful and motivating learning. QQ (instant messaging software developed by China Tencent), blogs, instant messaging, social networking, and software applications are examples of tools that instructors can adopt to incorporate online opportunities in classes [24]. Bonk and Graham [25] describe the growing interest in blended learning by addressing the changing roles played by learners in the learning process. This transformation occurs as the learners' status changes from passive receivers of knowledge to active knowledge constructors. Vo, Zhu, and Diep [26] confirmed the effect of blended learning on student performance in a higher education setting, especially for science, technology, engineering, and mathematics (STEM) disciplines. The prevalence of mobile utilities enables learning to occur anywhere, and the pedagogical approach of blended learning is becoming available to Chinese higher education students.

A flipped classroom is an instructional strategy and a type of blended learning that reverses the traditional learning environment by delivering instructional content, often online, outside of the classroom. It moves activities, including those that may have traditionally been considered homework, into the classroom. The flipped classroom is still primarily a student-centered and active pedagogical method [27]. In the flipped classroom, a significant portion of the class time is used for practice, application exercises, group discussion, and extending knowledge to improve students' deep learning, knowledge, understanding, and generative processes. In recent years, the flipped classroom method has been applied in many disciplines and different grades of teaching practice, such as medical classrooms, language learning, and natural science. Several researchers and educators [28–30] have adopted flipped classroom methods in their research or classrooms, and found that students have positive experiences or advantages in STEM disciplines [31].

2.2. Collaborative Learning by Teaching

Collaborative learning (CL) is considered a promising educational approach from the perspectives of both cognitive load [32] and constructivist learning. According to the cognitive load theory, the collective working memory effect enables collaborating learners to gain from each other's working memory capacity during learning. Additionally, group or collaborative learning has been recognized as an alternative way of overcoming individual working memory limitations [18]. Kirschner, Paas, and Kirschner [19] also argue that learning individually becomes less effective and efficient than learning in a group as task complexity increases. Kirschner et al. [20] explain the higher efficiency of collaborative learning in terms of both cognitive and affective factors while engaged in high-complexity cognitive tasks. People may feel more confident regarding highly complex tasks when working in groups compared to working alone because they can use the processing capacity, expertise, and knowledge of others and because the high cognitive load can be distributed among group members.

Learning by teaching (LBT) has a cognitive theoretical foundation. According to the cognitive theory of multimedia learning [33], meaningful learning depends on the learner's ability to select the most relevant information from a lesson, organize it into a meaningful cognitive representation, and combine it with their prior knowledge. According to cognitive load theory [34], learners have a very limited processing capacity they can use to engage in cognitive processing for learning. Preparing to teach and explaining to others corresponds to the cognitive processes of selecting, organizing, and integrating, and represents the generative process, which can improve deep learning and understanding.

In summary, considering the limited capacity of individuals and the benefits of collaborative learning for complex tasks, the CLBT approach is more realistic and feasible for present undergraduates compared to LBT alone. In addition, with the prevalence of computers, mobile devices, and online learning resources, it is possible and necessary to combine them with the concepts of the flipped classroom, blended learning, and mobile learning [17,30,35].

3. Methodology for Pedagogical Implementation

This study conducted a field experiment involving 102 undergraduates in a Chinese public university. Both quantitative and qualitative data were collected and analyzed by the researchers. These included student questionnaires and final written group reports. Both teachers and students participated in the formative assessment.

3.1. Pedagogical Design

Due to the characteristics of the computer concepts course, most students had basic computer knowledge. It was feasible for students to fulfill their teaching tasks in groups, with the support of the teacher and internet resources. In this study, the teacher became a facilitator or director, with the students as doers or actors. Students were asked at the beginning of the course to select and join one of the following groups: hardware, software, operating system, network, web, or multimedia. Each group contained 5 to 6 members, and was required to give one 90-minute class presentation on the group's selected theme. The presentation was comprised of a quick test, review, key point representation, knowledge extension, group discussion, and group talent show. The course encouraged students to adopt creative pedagogical methods, and required them to use multimedia materials such as video and PowerPoint slides. Each group was required to communicate with the teacher and make preparations at least two weeks before their presentation. The process of group division, content discussion, and class time arrangement was reported to the teacher during the preparation phase. To give students sufficient time to make their preparations, learning materials were delivered one week before the class presentation through the QQ group. The students were required to hand in the final report and peer assessment. Formative assessment was employed during the entire process. The teacher scored the group of students, accounting for 70 percent of the total score, based on three dimensions: collection, selection, and distribution of multimedia materials before class, arrangement and performance in class, and the final written report after class. The group members rated their classmates based on the quick test and performance in class, accounting for 15 percent of the total score. Figure 1 shows the detailed pedagogical design for each group.

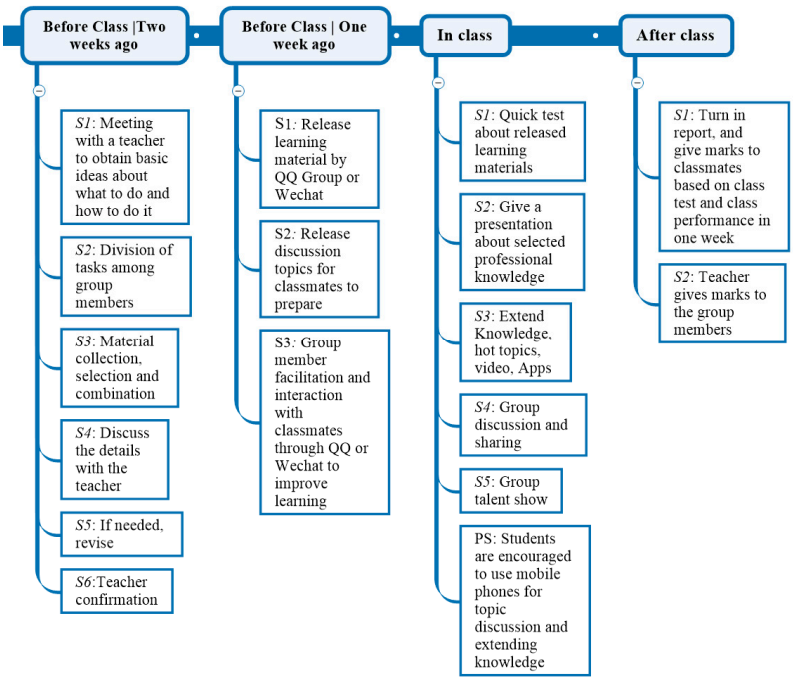

Figure 1. Collaborative learning by teaching (CLBT) pedagogical design for each group. *SX* represents Step *X*, e.g., *S1* = Step one, *S2* = Step two.

In conclusion, the concepts of the flipped classroom, blended learning, and mobile learning were combined into the process of collaborative learning by teaching. The digital learning materials were distributed through the internet before class, enabling students to prepare for the class in advance using mobile devices or computers, which left more class time available for group discussions and effective knowledge construction and expansion.

3.2. Participants and Context

The experiment was performed in a computer concept course at the International College of a public university in China. In Chinese public universities, lecturing is the main pedagogical approach adopted by teachers. The participants were a cohort of 102 undergraduate students in three Grade 1 classes majoring in international financial management. As the three classes belonged to the same major, students from different classes had the opportunity to communicate with each other. At the beginning of the course, all the students were asked whether they were willing to try a creative learner-centered learning method after a teacher described the whole process, and they agreed to participate. Then, every student in each class chose to participate in one of the following six groups: hardware, software, operating system, network, web, or multimedia. Each group contained 5–6 members, and was required to give one 90-minute class presentation based on the teacher's pedagogical framework. After all the groups had finished teaching, assessing, and reporting, a questionnaire with both closed and open questions was distributed to the 102 students in the three classes to investigate their perceptions of the whole process.

3.3. Measurement

The student perception of CLTB questionnaire was modified according to the perception scale in the flexible learning and flipped class [36] and the student survey of the flipped classroom course design and the usage of active learning strategies [37]. The items on mobile learning were modified based on the mobile-based instrument [38]. In addition, since in China most classes from primary school to university are taught by teachers lecturing, learner-centered and learner-driven teaching methods are new and innovative for both students and teachers. Therefore, the questionnaire contained some items to compare CLBT and traditional teaching methods, and some items asking whether CLBT met the requirements of the International College. After analysis by two researchers, the initial student perception of CLTB questionnaire was composed of 40 closed and 2 open questions. The demographic details, such as gender, class, and group, were included at the beginning, and the open questions were asked to collect students' difficulties and suggestions for future studies. Two researchers and several students assured the content validity. A five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree was used.

3.4. Data Analysis Method

This study adopted both quantitative and qualitative analysis methods. The software SPSS 24 was used for the quantitative analysis; it used exploratory factor analysis (EFA) to investigate student perceptions after the course and identified gender differences using the independent sample t-test method with group descriptive statistics. EFA is a statistical method adopted to examine the covariance relationships among a large number of observed items and to derive latent factors to explain these relationships [39]. Meaningful components of the student perception of collaborative learning by teaching were identified by principal component factor extraction with a varimax rotation. Qualitative analysis included open questions answered by individual students and a final group report. The research findings were validated and verified by triangulation using several types of data from multiple sources. The following section describes the findings of the exploratory factor analysis, group descriptive statistics, independent sample t-test analysis classified by gender, and qualitative data analysis.

4. Results

As Table 1 shows, 102 students completed the survey with 75 (74%) females and 27 (26%) males.

Table 1. Response gender ratio of post-test survey.

Sum = 102	Post-Test
Female	75 (74%)
Male	27 (26%)
Total	102 (100%)

4.1. Composition of Student Perceptions

As Table 2 shows, the KMO value was 0.924, while the p-value of Bartlett's test was 0.000, indicating that the correlations between items were adequate for the EFA. The principal component analysis showed three components with eigenvalues of over 1.0, explaining 74.5% of the total variance.

Table 2. KMO test and Bartlett's test of perception.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.924
Bartlett's Test of Sphericity	Approx. Chi-Square	3308.228
	Df	406
	Sig.	0.000

According to Kaiser's criterion, three dimensions were extracted by factor analysis: learning by teaching classroom perception (LBTCP), teamwork perception (TP), and mobile learning perception (MLP). Table 3 shows the mean and standard deviation (SD) of each item. As shown in the table, all extracted items were greater than 0.6, indicating that the risk indicators fit well with the factor solution, and should be retained in the analysis. Cronbach's alpha coefficients of the three perception dimensions were greater than 0.94, indicating adequate internal consistency and reliability. Students' overall perception was ideal. The factor items means of teamwork and mobile learning ranged from 3.90 to 4.08, indicating that collaborative learning by teaching in the current study improved the development of student capability in teamwork and mobile learning.

Table 3. Factor loadings, reliability, and item mean (SD).

Item/Factor	LBTCP	TP	MLP	Cronbach's Alpha	Mean (SD)
The collaborative learning by teaching (CLBT) classroom fits my learning needs.	0.820			0.967	3.44 (1.03)
CLBT makes the class more active than traditional teaching methods.	0.815				3.58 (0.96)
Adopting CLBT to teach computer concepts is effective.	0.813				3.64 (0.95)
I prefer CLBT to the traditional teaching method.	0.804				3.56 (0.98)
Using CLBT lets us learn abundant computer-related content.	0.786				3.75 (0.93)
I am happy to join in CLBT.	0.770				3.62 (0.99)
CLBT fits the requirements of process assessment of the International College.	0.751				3.72 (0.92)
CLBT is an exciting experience for me.	0.739				3.49 (0.97)
CLBT helps develop a student's critical thinking ability.	0.695				3.78 (0.88)
I hope more courses will use CLBT.	0.680				3.67 (0.98)
CLBT helps develop a student's time management capabilities.	0.676				3.81 (0.89)
CLBT helps students to develop responsibility for their own learning.	0.659				3.81 (0.89)
CLBT helps students develop active learning capabilities.	0.638				3.84 (0.85)

Table 3. *Cont.*

Item/Factor	LBTCP	TP	MLP	Cronbach's Alpha	Mean (SD)
Group cooperation has cultivated our consciousness and methods of overall arrangement and division of labor.		0.851		0.955	4.01 (0.80)
Group cooperation has increased team cohesiveness.		0.848			3.95 (0.79)
Group cooperation has increased the sense of teamwork.		0.836			3.90 (0.80)
Group cooperation fostered the development of communication capabilities.		0.822			3.94 (0.84)
Group cooperation has improved affection among team members.		0.799			3.96 (0.83)
Group cooperation has developed our active learning capability.		0.639			4.05 (0.85)
Group cooperation has developed our creative awareness.		0.629			3.92 (0.89)
Group cooperation has developed our problem-solving capability.		0.604			3.94 (0.85)
Sharing learning materials through the QQ group is convenient for me.			0.805	0.943	4.06 (0.87)
Use of mobile phones helps me with my studies.			0.777		3.99 (0.91)
Using QQ to distribute the learning materials is helpful for my active learning before class.			0.738		4.08 (0.89)
Using the QQ group to release learning materials is helpful for remembering learning materials.			0.723		3.99 (0.85)
Using QQ or Wechat to distribute learning materials is useful for fragment learning.			0.657		4.05 (0.84)
Learning using mobile phones promotes learning flexibility.			0.651		3.93 (0.89)
Using mobile phones to search for unknown knowledge helps the development of active learning.			0.650		4.04 (0.84)
Using mobile phones to search for unknown knowledge helps the development of learning interest.			0.601		4.08 (0.83)

Note. LBTCP: Learning by teaching classroom perception. TP: Teamwork perception. MLP: Mobile learning perception.

4.2. Gender Difference in Perceptions

Since CLTB involves collaborative learning and mobile learning, it is necessary to examine the gender differences in student perceptions after the course. Table 4 lists the group statistics of each perception dimension. The mean of teamwork perception (TP) for female students was 3.9167 and the male students' mean of TP was 4.0787, indicating that students thought that the group cooperation helped them in many aspects, such as active learning and cooperating with others. The mean of mobile learning perception (MLP) ranged from 4.023 to 4.037, indicating that students found that using mobile phones was very helpful and feasible in supporting their studies.

Table 4. Group statistics.

	Gender	Number	Mean	Std. Deviation	Std. Error Mean
LBTCP	0	75	3.6195	0.67368	0.07779
	1	27	3.8120	1.06659	0.20527
TP	0	75	3.9167	0.58930	0.06805
	1	27	4.0787	1.01678	0.19568
MLP	0	75	4.0233	0.58222	0.06723
	1	27	4.0370	1.05088	0.20224

Note. LBTCP: Learning by teaching classroom perception. TP: Teamwork perception. MLP: Mobile learning perception.

The gender difference of each perception dimension was examined using an independent sample t-test. Table 5 shows the independent sample t-test results. The p-values of LBTCP and MLP were 0.031 and 0.005, respectively, which were less than 0.05, indicating significant differences between female and male students in LBTCP and MLP. Male students had significantly higher perception than female students of collaborative learning by teaching classroom and mobile learning, indicating that male students were more willing to accept challenges and open minded to learner-centered and learner-driven instructional approaches, and were willing to apply mobile technology, such as QQ and Wechat, in their daily learning.

Table 5. Independent-sample t-test results.

Perception	Mean	SD	F	t-stat	Sig.
LBTCP	−0.19248	0.17837	4.766	1.079	0.031
TP	−0.16204	0.16274	2.557	−0.996	0.113
MLP	−0.01370	0.16461	8.378	−0.083	0.005

4.3. Qualitative Findings

The qualitative findings mainly come from the open-ended questions and the groups' final reports. This section will describe the students' self-reported gains, difficulties, and suggestions.

4.3.1. Main Gains

As shown in Table 6, among the six final group reports, two thirds of the groups reported that they had improved their active learning capability and teamwork capability. Some groups mentioned that they had some unexpected achievements, such as learning special skills about proxy software and developing friendship between group members. For example, one student said: "During the process of material searching, I gained special skills about proxy software; it is a good thing because the YouTube website has many useful learning resources." Another student said: "Teaching enables me to think more about the cognitive process; learning while thinking makes the knowledge learned more useful and practical." These unexpected gains provide positive evidence for inquiry-based learning [40,41].

Table 6. Main gains in group reports.

Main Gains	Materials/References	Original Text (Some Examples)
Active learning	4/6	- In this process, I not only developed my active learning capability, but also promoted my PowerPoint slide skills. - In my opinion, the success of CLBT lies in whether the teacher is willing to give up the traditional teacher-centered pedagogical approach and habits, and let students handle some teaching tasks to stimulate their learning enthusiasm. - Teaching in class has significantly improved our active learning capability.
Teamwork capability	4/6	- Preparing the class took us almost two weeks; our group members worked together and helped each other, promoting our teamwork capabilities. - Our group cohesion was great; almost all tasks were fulfilled collaboratively; through this process, we have developed a sense of belonging, and I know more about myself with more self-acceptance.
Unexpected achievement	3/6	- During the process of material searching, I gained special skills about proxy software; it is a good thing because the YouTube website has many useful learning resources. - Teaching enables me to think more about the cognitive process; learning while thinking makes the knowledge learned more useful and practical.

4.3.2. Difficulties and Suggestions

As shown in Table 7, in response to the first question "how many materials have you reviewed before class?", the largest number was 39 students accounting for 44%; they responded that they had reviewed 70–85% of the learning materials, and 25 (28%) students reported that they had read more than 85% of the materials, which was encouraging news for teachers. Additionally, 11 (12%) students

had read about 50–70% of the materials, and 14 (16%) students had read less than 50% of the materials. The quality of the in-class learning of the students who failed to complete the preview task was hard to guarantee. Consequently, the study needed to explore the reasons why these students did not read all of the materials, and discover what difficulties they encountered.

Table 7. Students' responses to open-ended questions.

Item	Phase	Content	Frequency
Task completion	Before class	less than 50%	14 (16%)
		≥85% and <100%	25 (28%)
		≥70% and <85%	39 (44%)
		≥50% and <70%	11 (12%)
Difficulties	Before class	English words and phrases	29
		Time limitation	2
		Knowledge is too professional	23
		Material complexity	23
		Lack of enthusiasm and self-management	4
Suggestions	Before class	Need for supervision	4
		Term translation	11
		More teacher intervention	9
		Multimedia learning materials	25
	In class	Teacher intervention	31
		Various interactions	31
		Depth and width of learning content	15
	Future advice	Assessment method	3
		Combination with traditional pedagogical approach	12

As shown in Table 7 and Figure 2, all of the difficulties reported by students occurred in the "before class" phase. The difficulty faced by the largest number of students was with words and phrases, reported by 29 students (36%). Even though every student had an English–Chinese dictionary, it remained an unexpectedly significant obstacle to effective study. The second and third difficulties were related to the learning materials delivered before class: 23 students reported difficulties with the abstract and professional computer knowledge, and 23 students reported that the learning materials were too complex and the key points were obscure. Additionally, four students reported a lack of learning enthusiasm and self-management, and difficulty focusing on studying without supervision. All of the reported difficulties provide some clues for future modification and expose the problems of Chinese students.

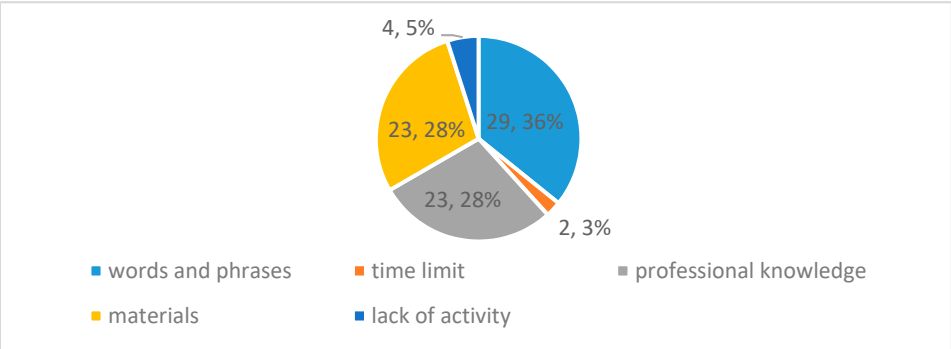

Figure 2. Difficulty distributions.

Student suggestions for future pedagogical improvements were organized into three groups according to learning phase: before class, in class, and after class. As shown in Table 7, 'teacher' was mentioned nine and 31 times (40 times in total, 39.2%) in the column about advice for before class and in class improvements, respectively, indicating that the teacher's authority and professionalism were rooted deeply in the Chinese students' minds. Although the teacher confirmed the learning content, and the students gained much from collaborative learning by teaching, some students still hoped that the teacher could participate further. Although effective supervision of the preview process in the before class phase was only explicitly mentioned by four students, it should be a focus of attention because it is consistent with the difficulty associated with a lack of learning enthusiasm and self-management reported by some students in this phase. This phenomenon is now quite common among college students in China, and should receive more attention in future instructional design.

To encourage classroom participation and activity, suggestions for improving in class interaction procedures, such as adding a small test, and adopting creative pedagogical forms with more discussion and interaction, were mentioned 31 times (30.4%), reflecting the students' need for further expression of learning passion in class. Concerning the aspect of future modifications, 12 students (11.8%) suggested combination of the traditional teacher-centered pedagogical approach with creative learner-centered instruction, which is in accordance with the teacher's perception. Accordingly, the teacher's role should be further investigated and defined in future studies.

5. Discussion and Limitations

The results indicate that most students have a positive attitude towards CLBT. Student perceptions were composed of three factors: perception of collaborative learning by teaching classroom, perception of teamwork, and perception of mobile learning. The mean of team work perception and mobile perception was close to 4, indicating that the students had a positive perception of team work and mobile learning. The positive findings of team perception are in line with Roach [42], who reported that students could benefit a lot from group discussion in a flipped classroom. The positive findings about mobile perception are consistent with previous studies [43,44] but inconsistent with Molina et al. [45]. In Lin's study, most students reported positive perceptions toward the usage of mobile interactive learning and the diagnosis system, but Molina concluded that mobile phones were not suitable to access and visualize learning materials, as they imposed an additional cognitive load. Future studies should further investigate students' perceptions about collaborative learning and mobile learning.

The independent sample t-test analysis results revealed that the male students had significantly higher positive perceptions than female students did regarding collaborative learning by teaching and mobile learning. This result is consistent with the results of Wang et al. [46], who recommend that teachers should target male students to play the lead role during the active mobile learning process in future studies because they show significantly higher behavioral intention to use mobile learning than females. This result is inconsistent with the findings of Reychav et al. [47]; in their investigation into the relationship between gender and mobile technology use, they concluded that females benefit from group learning and features provided by mobile technologies by asking questions and soliciting input actively. The reason for the discrepancy may lie in the cultural differences between countries [48,49]. For example, in a comparative study of internet use between China and the US, Chinese females were the least intense users [50]. Chinese women were also found to use the internet less frequently when studying gender and cultural differences in internet use between China and the UK [51].

Concerning qualitative analysis, students reported their difficulties, gains, and suggestions. The main gains included active learning capability, teamwork capability, and unexpected inquiry skills, such as using proxy software in their final reports. These self-reported gains were positive advantages of this study and could be investigated further in future studies. During the process of collaborative learning by teaching, students went through three distinct stages of teaching: preparing to teach, explaining to others, and interacting with others [9], which provided students with a chance to practice their active learning capability, teamwork capability, and inquiry skills. As students had knowledge

and effective self-management difficulties before class, more teacher intervention and supervision were mentioned many times, which reflected the teacher's authority and professionalism in students' minds, and that the teacher's role should be explored in the future.

Based on the comparison between the learner-centered and the learner-driven approach, it can be inferred that CLBT is a pedagogical approach which lies between learner-centered and learner-driven pedagogy [1,2]. The CLBT approach also has characteristics of the learner-centered approach and the learner-driven approach, which are suitable for designing sustainability courses [3]. Based on Herranen's results, the characteristics of CLBT belonging to learner-driven pedagogy includes three aspects: the nature of CLBT, meaningfulness, and pedagogical support. From the pedagogical perspective, CLBT is divergent to some degree; for example, learners decide what is interesting and useful for them, and the facilitator creates learning environments, which enable and stimulate learners to learn and act for sustainability.

This study has several limitations that could be addressed in future studies. First, the quantitative findings of the perception items and their implications discussed in this article were based on one study with 102 students from three classes in China. For better generalization, the survey should include more experiments in different disciplines and universities over a wider area. Second, this study lacked further exploration of the relationship between the pre-test and post-test variables and the comparison of student performance after the experiment. Third, as this was a field study, some variables could not be controlled. The class arrangements, including time, place, and personnel were based on the university's requirements, and teachers had little freedom and limited time to supervise the whole pedagogical process in detail.

6. Conclusions and Future Works

This study proposed a pedagogical approach called collaborative learning by teaching which is between learner-centered and learner-driven education. The experiment was conducted on freshmen at a public university in China, and the student perceptions of CLBT were explored and analyzed using qualitative and quantitative methods. The field experiment lasted for one semester and the results indicate that students had positive perceptions about teamwork and mobile learning during the CLBT process; the independent sample t-test results demonstrate that male students had significantly higher positive perceptions of learning by teaching and mobile teaching than female students. According to the qualitative analysis, although students had some difficulties with self-discipline, they gained much in the development of active learning capabilities and teamwork skills; some students who lacked self-management or learning enthusiasm expressed their need for more supervision from the environment and teacher.

Overall CLBT is an active pedagogy between learner-centered and learner-driven. In CLBT, although the themes, the core objectives of the course, and the main content framework were designed by teachers, each group of students had the right to choose their theme, and then decide the depth and breadth of the content according to their interests and judgment. Throughout the process, teachers acted as facilitators by enabling and stimulating learners to learn and teach. Future studies are recommended to conduct experiments to verify the effectiveness of CLBT in terms of improving student academic achievement and related sustainability competences [4], such as critical thinking, collaboration competence, etc., which are listed in Table 3. Second, gender disparity should be further considered and utilized in the grouping process. In addition, since the teacher's authority and professionalism are rooted deeply in students' minds, the teacher's role during CLBT should be explored and clearly defined.

Author Contributions: Conceptualization, X.D.Z. and C.-L.C.; methodology, X.D.Z.; validation, X.D.Z. and L.-H.C.; investigation, X.D.Z.; data analysis, X.D.Z.; writing—original draft preparation, X.D.Z.; writing—review and editing, X.D.Z.; supervision, L.-H.C. and C.-L.C.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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