Peer-Formulated Assignment Method for Experimental Projects in CS courses

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***Abstract*—New assignment methods are needed for motivating students to carry out experimental projects in computer science (CS) courses. This paper describes a study that uses the peer-formulated assignment method to improve assignment efficiency in CS experimental projects. This method requires each student or group to come up with a problem and then pick another problem from other students to solve. This exchange of problem and solution helps motivate students and leads to their enjoyable learning. Under the guidance of an instructor, students can be inspired with great interest, enhance their practical abilities, and cultivate themselves with an innovative spirit. The role of instructor is not weakened but rather becomes more important. The instructor plays a critical role in assessment. A comprehensive project consists of many design stages, which require the involvement of the instructor. This method has been applied in two CS experimental courses with comprehensive projects, namely, software engineering (SE) and digital system design (DSD). The results show that approximately a 19% improvement in passing rate and a 35% improvement in student perceptions (grade above Good) for SE course. Similar positive results can also be found for DSD course. The survey results also show that most of the students were interested in their assignment, with 81.5% positive and 14.8% no opinion. In conclusion, the peer-formulated assignment method can improve the performance of the students and has achieved a favorable level of acceptance among students.**

***Keywords*-peer-formulated assignments; undergraduate; computer science education; experimental course**

I. INTRODUCTION

Educators widely use experiment assignments to assist students in mastering knowledge of computer science (CS) courses. Experiment assignments can improve the knowledge conversion efficiency of students from acquisition to practical application, but how to improve assignment efficiency requires further investigation. Although traditionally formulated assignment designs are sound and practical, new approaches must be developed to increase assignment efficiency. Student feedback reports that traditional assignments are often mismatched against student interests [10].

How to improve student motivation has been extensively studied. Game-based learning is introduced to attract students attention, and this approach helps them review the knowledge they have just acquired [1, 9, 11]. Apart from games, game development tools can be used for studying relevant topics within CS courses (i.e., game development-based learning) [16]. Researchers assess the motivational factors of course assignments such as building a web site or programming personal robots [14, 15]. Certain learning methods allow students to choose course assignments [3, 7]. Although these approaches improve students' performance in course assignments, instructors plays a dominant role, which may still lead to mismatches against student interests. These assignments are often provided by instructors or textbooks, but students usually possess varied academic interests and ambitions, which differ from those of instructors.

To address aforementioned problems, we introduce the peer-formulated assignment method for conducting comprehensive experimental projects in CS courses. In the proposed assignment method, students can generate and choose problems freely. The main idea is the problem and solution exchange among students. Under the guidance of a course instructor, each student or group is encouraged to propose a problem and choose another problem from other students.

Several studies focus on allowing student creativity in assignments [2, 8, 13]. These works use "contributing student approach" in which students can generate questions and value the contributions of others. A number of software tools support the implementation of generating questions [4, 12, 17]. For example, PeerWise [4] is an online multiple-choice-question (MCQ) tool wherein students write questions, and these questions can be answered by other students. Students can also evaluate the contributions. This system has been used in several CS courses, such as introductory programming [5, 6]. Results obtained from this approach are encouraging, as students become motivated learners.

In this paper, we develop a peer-formulated assignment method for conducting the experimental project in CS course. Different from previous MCQ implementations, this method accommodates the unique condition of conducting a comprehensive projects. We focus on CS courses with a comprehensive project for four reasons. (1) Unlike courses, such as introductory programming, students experience difficulties in coming up with problems for comprehensive projects. (2) A comprehensive project consists of many design stages, which require an instructor to be involved in each stage. (3) The role of instructor should be reconsidered to help students to complete the entire procedure given the complexity of "question" and "answer" in the projects. (4) The score criterion should be reconsidered to be more flexible and stimulating. After taking all these problems into account, we apply the method to two CS experimental courses with comprehensive projects, namely, software engineering (SE) and digital system design (DSD). The results

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Survey question	Positive	No Opinion	Negative
1. Do you think the project assignment in the textbook is interesting?	8 (7.2%)	27 (24.3%)	76 (68.5%)
2. Do you think the project assignment designed by instructor is interesting?	31 (27.9%)	35 (31.5%)	45 (40.5%)
3. Is there any change to the project assignment in recent years?	57 (51.4%)	28 (25.2%)	26 (23.4%)
4. Do you think the current project assignments are real problems?	37 (33.3%)	42 (37.8%)	32 (28.8%)
5. Do you want to participate in designing project assignment?	54 (48.6%)	34 (30.6%)	23 (20.7%)

Table I: Results of the questionnaire regarding traditional project assignment methods

show that approximately a 19% improvement in passing rate and a 35% improvement in student perceptions (grade above Good) for SE course. Similar positive results can also be found for DSD course. The survey results also show that most of the students were interested in their assignment, with 81.5% positive and 14.8% no opinion. In conclusion, the peer-formulated assignment method can improve the performance of the students and has achieved a favorable level of acceptance among students.

The rest of the paper is organized as follows. Section II describes the background and motivation of this paper. Section III introduces the peer-formulated assignment method. Section IV provides the case studies and Section V provides the implementation results. Section VI concludes this paper.

II. Motivation

Assignment is a crucial issue, especially for CS experimental courses. These courses are that learning and validating knowledge by means of experiments, such as SE with large-scale experimental projects. In this section, we describe several common methods of project assignment and their results in our university. Reviewing the existing methods motivates us to introduce a new project assignment method for improving assignment efficiency.

The assignment method for comprehensive CS course projects in our university takes two forms. One is selecting assignments directly from textbooks or reference materials, and the other is having an instructor prepare assignments according to classroom contents. Several problems can arise from these two methods. The first method makes each student do the same work for a single topic [3], thus limiting variety and possibly abetting indolent students to plagiarize. Instructors may be unable to distinguish which students truly master the knowledge when evaluating their results. Although the second method features advantages such as selectivity [7], actual application is restricted. When we asked students from our university and those visiting from other famous universities, they claimed that the problem pool of instructors often comes from their research projects. Even after fixing the problem pool and making few updates, the experiment areas remain limited to the instructors experiences. This limitation often make students perceive experiment as a burden, and they subsequently lose interest. One reason comes from the instructor. For example, the instructor often takes more than one course. They may also participate in some affairs of the society and universities, or even take times for further-education. Therefore, they may not have so much time to learn new things and figure out new problems. Another reason comes from students. If it is assumed that instructors are providing problems, they may not be willing to find, analyze and solve problems of no interest, so that they may not be able to enjoy the whole learning process.

Simple tracking results were used to assess the limitations of traditional project assignment methods. A questionnaire with five statements and one question asking for comment was devised (see Table I). The survey was distributed to CS undergraduate students enrolled in SE and DSD courses. To expand the investigation scope, we selected two batches of students. In total, 111 students were investigated, and completed responses were obtained, with a response rate of 100%. The survey included 107 copies of questionnaire and 4 copies of phone records. These four copies came from visiting students.

The average overall assessment by students for the first two questions shows a positive percentage rating of 17.6%; no opinion, 27.9%; negative, 54.5%. These results indicate that many students are dissatisfied with the assignments of experimental course in terms of creativity and personal interest. However, students still prefer to wait for the assigned problems and do not think about interesting problems due to their lack of initiative and requirements from instructors. In addition, 23.4% of students think that assignments exhibit little variation in their courses. This finding reflects that instructors do not frequently update the problem pool. Another problem is that 28.8% of students think these assignments are not actual problems, and thus they lack a sense of achievement. The last question primarily aims to learn about the willingness of students to participate in project assignment design. Overall, the result is positive despite certain negative points. This outcome indicates that a new assignment design should consider the willingness of students.

Students were also invited to write comments on the current project assignment design at the end of the questionnaire sheet. Nineteen comments were obtained, accounting for 17.1% of total responses. A few of these responses cited problems that students encountered in fulfilling assignments. Three representative comments are as follows:

- It would be great if the instructor can customize assignments for students based on their interests.

- I'm not interested in assignments the teacher gives. But it's also difficult for me to come up with some new ideas myself. It's a contradiction.
- Students from Africa or Australia may have different life experiences and interest points. This is hard to know for an instructor staying in America.

To address these limitations of traditional assignment methods, a more effective method should meet the two following requirements: (1) *Way to stimulate student interest*. Students possess varied academic interests and ambitions, so a single topic can hardly meet all their needs. (2) *Way to improve student's ability*. An assignment should be carefully designed to relate to the world of students, giving them strong operability and better sense of achievement.

III. Peer-Formulated Assignment Method

Considering the requirements of comprehensive experimental projects, a peer-formulated assignment method is introduced. This method is based on the idea of a problem and solution exchange among students. To the best of our knowledge, this is the first work that applies the contributing student approach to CS experimental projects [8]. Regarding the its complexity, we emphasize on four aspects: (1) the generation process of problems for comprehensive projects; (2) the stage control of the whole project process; (3) the reconsideration of the role of instructor in this method; (4) evaluation of the experimental projects.

When a course proceeds to a certain stage, which has a basic understanding of the course, each student or group of students are tasked to put forward a problem according to their knowledge and experiences. A complete and detailed description of the problem should be provided. The focus should be on the problem, and solutions or conclusions should not be included. Rather, the objective of solving this problem is clearly stated, which quantifies the expected results and identifies the projected timing.

Students can be divided into several groups. Each group will choose a problem from other groups as a project assignment. A good and interesting problem may be chosen by more than one group. To emphasize the importance of problem proposal, the final scores include the students scores on their proposed problems and the solution to the problem raised by others. In addition, the most popular problems may be given appropriate bonus points to stimulate self-confidence.

Students are prohibited to choose their own problems for three reasons. First, some students tend to be lazy. If they can choose their own problems, then they are likely to reduce the difficulty. Second, problem proposers can easily fall into their inherent ways of thinking, mitigating the production of solutions. Finally, selecting other students problems make students better understand user needs, which is also the case for most real CS projects. In addition, doing so spurs students' enthusiasm in interactively exploring different knowledge structures and viewpoints.

In a peer-formulated assignment method, the role of instructor is not weakened but rather becomes more important. One natural question is how can instructors ensure that students practice what they need. Students may not realize that their problem is poorly specified, or they may get stuck on a less important portion of the problem that an instructor could have warned them about. Therefore, instructors are important for assessment and guidance. To encourage the innovation of students, instructors should show how to propose interesting problems from the start. Then, instructors should judge the value of the problems proposed as soon as possible. The judgment includes the complexity, suitability, and inspiration of the problem. Instructors can also provide several directives and related works to widen the scope. For bright new ideas, instructors should figure out whether solving them is possible for students at this stage. If not, then instructors can suggest what knowledge adjustment or supplement can be done. As the range of proposed problems can be wide, instructors may be unfamiliar with certain cases. In such a situation, instructors need to study relevant knowledge, which can broaden their visions.

If different students/groups choose the same problem, then certain techniques can be employed to avoid plagiarism. Students may be required to solve the problem using different approaches. If they are unwilling, then they can choose another problem as the number of problems is sufficient. During project implementation, instructors can also set one or more stages for discussion. In this stage, instructors gather students who propose and solve the problems together to ensure that all initial goals are achieved and listen to all useful opinions from problem proposers. The final score is based on the quality of assignment completion and value of the proposed problem at every stage. Figure 1 specifies the score criteria in the peer-formulated assignment method. The problem and solution scores entail evaluation from instructor (I) and students (S). The specific proportion of each factor is determined by instructors according to the course. The assessment by students has demonstrated to provide many potential benefits to learning [2]. For example, students can gain insights into their own learning, and evaluation results can provide a valuable source of feedback.

Project assignment could be semester-long projects or small projects. Peer-formulated assignment method is not suitable for all kinds of occasions because it would take more times for students. It is more suitable for comprehensive experimental courses with semester-long projects, especially for experiments that educate students' creativity and practical abilities. It would be better if this approach can be introduced to the students at the introductory courses before actual practice. This would make students have enough time to prepare some interesting problems and adapt it smoothly

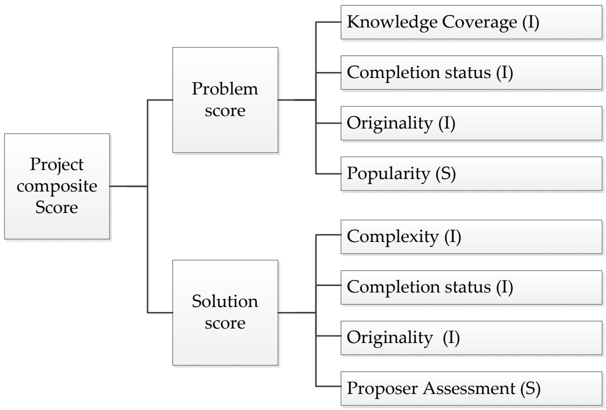

Figure 1: Project score constitution in peer-formulated assignment method

for maximizing the effect. In addition, this approach also require instructors to provide students sufficient guidance along the experimental process.

IV. Practices

To assess the effectiveness of the proposed method, it was applied to two experimental courses, namely, SE and DSD. These two courses emphasize practice, as both involve comprehensive projects. Fifty-six students were enrolled in SE course; fifty-two students, DSD course.

A. SE Experimental Project

Students were divided into 19 groups. Each group had three students except one group with two students. When the peer-formulated assignment method was discussed to the students, many of them became excited. A few students did express at the beginning that it would be better to create the problems by the instructor. But after they understood the whole process, they found it more interesting and did not think it is the responsibility of an instructor to create the problems. However, they did not understand why the problem and solution each accounts for 50% of the total score. With a small investigation, 29 students thought that completing the project was time consuming and should take a higher proportion, 4 students figured it does not matter, and 23 students supported this proportion. After a detailed fact-finding on the positive responses, 18 of the students simply thought that this large proportion of score for proposing a simple problem simplifies the assessment. Only five students perceived that proposing problems would be more difficult than completing the project.

To clear up the students doubts, an example about how to propose a problem is explained in detail. Each problem proposer should provide standard software requirement analysis and specification, which includes information about the entire functionality of the software system and the analysis model to analyze the requirements in the software. This

Topics	Group count	Proportion
Games	7	36.8%
Apps	4	21.1%
Websites	3	15.8%
Message tools	2	10.5%
Workflow management	1	5.3%
Chat robot	1	5.3%
Image processing	1	5.3%
Total	19	100%

Table II: Assignment topics for SE course

process is especially difficult in actual software product development. Shortly after the explanation, most students began to think allotting 50% of the score to the problem is reasonable. Students were given a month to propose problems. At the end of the first two weeks, 10 of the 19 groups already had ideas, but the rest experienced difficulty. Therefore, teaching assistants were arranged to offer a good starting point for these students. One week before the deadline, two groups still felt they could not open their minds. Step by step, the instructor taught them how to look up information and follow the ideas of others. With the instructors guidance, the two groups formulated their problems according to their experiences. All the groups submitted their problem report on time.

Students possessed varied interests on software designs, so the problems they came up with belong to a wide range of topics (see Table II). The games are always the hotspot of software designs, accounting for the largest share. Many problems are close to the lives of students, such as mobile applications. During problem selection, most students chose the problem related to the one they proposed, indicating that their academic interests are relatively fixed.

For the problem selection, most groups quickly decided. Only three groups hesitated, asking why they cannot choose their own problem. After the benefits of this selection procedure were explained, these groups selected problems by other students that are related to their interests without excessive dissatisfaction. This situation shows that students have the same interest and can ensure the efficiency of such a problem and solution exchange.

When the experiments were carried out, the process can be abstracted into five basic activities: high level design, low level design, coding, testing, and re-engineering. We added the content of software re-engineering, which allows students to reach practical realization about reconstructing software structure. During the experiments, students were guided by the instructor to overcome difficulties in real time. The instructor could help students understand the causes of the problem and related background knowledge. The instructor could also provide students with reference materials or ask the students to access information. Familiarity with relevant work can lay the foundation for the next step.

Group discussion was carried out for requirement analysis

Problems	Group count	Proportion
Electronic organ	6	23.1%
Ticket Dispenser	5	19.2%
Intelligent thermometer	4	15.4%
Smart watch	3	11.5%
Scientific calculator	2	7.7%
Intelligent calendar	2	7.7%
Smart keylock	2	7.7%
Wireless messager	2	7.7%
Total	26	100%

Table III: Assignment problems for DSD course

and related solution in which the problem proposers were also invited. Each group was required to submit their internal solution report and the optimal and sub optimal solutions. To encourage student innovation, non-mainstream designs should be supported to a certain degree. Students could experience accessing the pros and cons of each design during the final implementation. This process was actually a microcosm of the high level design. Many contents would appear in this stage, such as software structure and module division. The instructor could adjust the assessment of the experiments according to the difficulty of the problem. Some problems focus on algorithm design, whereas other problems emphasize software structure or design patterns.

After completing the experiment, students presented their implementation results. They explained the detailed process as well as code writing style, implementation efficiency, and functionality accuracy. Using the report, code, and presentation as bases, the instructor and the problem proposers gave reference scores and corresponding comments. We found that students showed great enthusiasm toward their assessment.

B. DSD Experimental Project

The students in DSD course were divided into 26 groups, each group with two students. The underlying experimental platform was a FPGA main board with extensible daughter board. Students were required to implement a digital system in this platform. Application of the peer-formulated assignment method in this course features similarities and differences with that in SE course. Students were interested in proposing new problems. However, unlike in the SE course, most of the problems proposed were difficult to implement under current knowledge reserve and objective condition. Students mainly focused on new ideas, such as fingerprint identification and electronic reader, and did not consider the actual limitations. After discussion, eight problems were selected as the candidate problems (see Table III). For other problems, students were encouraged to solve them in extracurricular time. Surprisingly, many of them performed well under guidance of the instructor.

The main idea of the experiment was to use Verilog hardware description language to achieve the core control and program processing in the FPGA chip and then combine the external circuit modules for creating flexible and diverse designs. As students had great interest to develop their favorite hardware products, the entire flow for FPGA design was well learned, including RTL design, compilation, simulation, timing analysis, and verification. Most of the assignments could be submitted ahead of time. Students handed in their completed work with a sense of pride. Some students stated that they had professional help from their seniors, such as timing analysis or sensor selection. Such a behavior was not perceived to break any honesty rules.

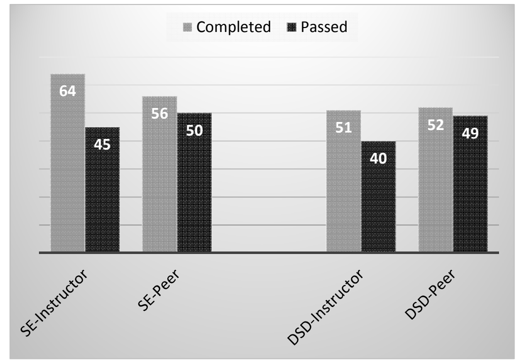

Figure 2: Comparison results of course completion and passing rates for SE and DSD courses

V. RESULTS

A. Performance Comparison

For comparison, the performance results for the instructor-assignment method were also evaluated. Figure 2 presents the pass rate comparison result of SE and DSD courses for students graduates in 2016 and 2017 academic years. The SE-peer and DSD-peer courses used the peer-formulated assignment method for the current academic year, whereas SE-instructor and DSD-instructor courses used the instructor-assignment method in the preceding academic year. Each course was taught by the same instructor, with various assignment methods in different semesters. The same score standard considering problem complexity and solution quality was used for different assignment methods. In such circumstances, for the SE course, approximately 89.2% of students passed the course with peer-formulated assignment; 70.3% with instructor-assignment. For the DSD course, approximately 94.2% of students passed the course with peer-formulated assignment; 78.4% with instructor-assignment. The completion rates improved significantly, indicating that stimulating interests of students by peer-formulated assignment also enhances their performance.

To further analyze the performance results, we also compare the detailed scores for the two courses, as listed in Table IV and V. The scores are divided into five grades: Excellent (90-100), Good (80-89), Average (70-79), Qualified (60-

Grade	SE-Instructor	SE-Peer (P)	SE-Peer (F)
Excellent	4.7%	16.1%	16.1%
Good	14.1%	37.5%	32.1%
Average	26.6%	26.8%	32.1%
Qualified	25.0%	8.9%	8.9%
Failed	29.7%	10.7%	10.7%

Table IV: Score analysis for SE course

Grade	DSD-Instructor	DSD-Peer (P)	DSD-Peer (F)
Excellent	7.8%	23.1%	19.2%
Good	19.6%	30.8%	34.6%
Average	27.5%	30.8%	26.9%
Qualified	23.5%	9.6%	13.5%
Failed	21.6%	5.8%	5.8%

Table V: Score analysis for DSD course

69) and Failed (0-59). For the instructor-assignment, the scores are valued by the instructor according to complexity, completion status and originality. For the peer-formulated assignment, two types of scores are presented: (P) and (F). The (P) type of scores are counted by part of the factors in the same way as instructor-assignment method. This ensures the same grading scheme for the sake of fairness. (F) type of scores are counted in the same way illustrated in Figure 1. In this score type, the problem score counts 20%, and solution score counts 80%.

We can find that peer-formulated assignment not just has more students passed, but also gets higher grades. For SE course, 53.6% of students in (P) type (More than half) can achieve grade above Good with peer-formulated assignment, while only 18.8% of students (less than one fifth) can achieve such result with instructor-assignment. Similar positive results can also be found for DSD course. The analysis data demonstrates that peer-formulated assignment can motivating more students to achieve better results. For the (F) type, the scores are slightly lower than (P) type. The reason could be that students are at an unfavourable position in proposing problem and more critical on others' work. But that may be the advantage of this way of scoring.

To show that the performance difference between peer-formulated assignment method and instructor-assignment method are statistically significant, the t-Test based on their corresponding students' scores was carried out. For peer-formulated assignment, the (P) type scores were used. First, we performed an f-Test to determine if the variances of the two methods are equal. This was the case. Then we performed t-Test under two sample assuming equal variances. For SE-Instructor and SE-Peer(P), the P value was 0.0000021 and lower than 0.001, meaning statistically significant performance difference between the two methods. Similar statistically significant difference could be obtained between DSD-Instructor and DSD-Peer(P).

For SE course, we find an interesting phenomenon about software design efforts. We have counted the amount of code lines developed by each project. About 5600 lines are coded for SE-Instructor projects on average, while about 8400 lines are coded for SE-Peer course projects on average. This shows from a side view that students are willing to spend more time and efforts on projects they are interested in. In addition, most software projects in SE-Peer courses are more complicated and comprehensive than the ones in SE-instructor courses.

The peer-formulated assignment method also resulted in many projects on extra-curricular innovative activities. According to the statistics, at least a third of students continue to refine their work after the course study. Students went deep into their problems for real applications under the guidance of the instructor. Some of them used their work to participate in competitions, and some of them even wrote patents for application. These works activated the entire academic atmosphere across all grades.

B. *Student Assessment*

To access the level of acceptance of the peer-formulated assignment method, we also conducted a simple survey. A questionnaire consisting five questions was devised (see Table VI). Complete responses were obtained from 108 students with 100% response rate. The students were from the SE and DSD courses using the peer-formulated assignment method. Most of the students were interested in their assignment, 81.5% positive; 14.8% no opinion. Four students had negative opinion on the proposed method, mainly because they encountered difficulties on completing their assignments. Question 2 is interesting, where only 31.5% gave a positive response; 63.9% of Students had no opinion. Students might think that creativity training is difficult to evaluate. Positive results were obtained for the three other questions.

We also asked which assignment method is the student's favorite. The peer-formulated assignment accounted for a large portion, which was 71.2%. The instructor assignment method had the second biggest number, which was 26.1%. The textbook assignment had the smallest number, which was 2.7%. This outcome showed that students prefer assignments to be flexible.

For the comments on the peer-formulated assignment method, 34 students wrote their suggestions, which represented 31.5% of the total responses. Many comments feature similar points, which can be roughly categorized. We summarized them into the five following aspects:

- It would be better if this method can be performed at the beginning of undergraduate courses. That way, proposing new problems will be much easier now.
- The thought of other students surprised me very much. There are indeed very new ideas.

Survey question	Positive	No opinion	Negative
1. Were you interested in the assignment?	88 (81.5%)	16 (14.8%)	4 (3.7%)
2. Did your creativity improve?	34 (31.5%)	69 (63.9%)	5 (4.6%)
3. Did you feel a sense of accomplishment after the implementation?	81 (75.0%)	22 (20.4%)	5 (4.6%)
4. Did your ability improve?	83 (76.9%)	19 (17.6%)	6 (5.6%)
5. Did the assignment present a real-life problem?	75 (69.4%)	30 (27.8%)	3 (2.8%)

Table VI: Results of the questionnaire regarding peer-formulated assignment method

- I can do more in-depth work by gradual accumulation. I can participate in a competition, complete the graduation thesis, or even submit the work to an academic conference.
- Some classmates are lazy and they are willing to take what is easy to get, even if it is not the things they are interested in. So, it's really necessary to force us to improve our own creativity.
- Currently, the spare time is rather limited. Although this method is very interesting, I feel that the exploration of the experiments is a bit difficult. So, it's really important for me to have more free time.

VI. Conclusions

The practical examples show that the peer-formulated assignment method has been well recognized by the vast majority of the students. This method not only consolidates the students understanding of knowledge but also has potential to meet their academic interests. This approach is flexible, compatible, and complements the assignment design in the comprehensive CS experimental course.

To perform well in the peer-formulated assignment, students are required to be knowledgeable and creative. They must propose problems with high quality and clear requirements, which are essential in the following experimental steps. The functionality of instructors is also not weakened; they serve an important role in the assessment and help their students propose problems and their corresponding solutions. For the future, it would be interesting to develop a software tool to facilitate the proposed assignment method.

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