The Jigsaw Technique: Experiences Teaching Analysis Class Diagrams

José Antonio Pow-Sang
Pontificia Universidad Católica del Perú
japowsang@pucp.edu.pe

Pedro G. Campos
Universidad del Bío-Bío
pgcampos@ubiobio.cl

Abstract

Cooperative or collaborative learning techniques are based on student cooperation aimed at the achievement of a common goal. This kind of techniques generates more significant and lasting knowledge. Additionally, the student has to face the challenge of not only learning individually, but also explaining to their classmates the ideas that they do not quite grasp, which implies a practice of their communication, argumentation and discussion skills. That is why this kind of techniques has been used in courses related to object-oriented software development at Pontificia Universidad Católica del Perú (PUCP) since 2002 and at Universidad del Bío-Bío (UBB) since 2006 as a reinforcement for the lectures previously given on each subject. Feedback from students who have participated in cooperative classes has been very positive.

This paper presents the design of a cooperative learning-based class to teach analysis class diagrams using the jigsaw technique and shows the results obtained in two semesters at PUCP and one semester at UBB.

The results of the tests taken allowed us to corroborate that students who bore some misconceptions at first, eventually improved their performance after the cooperative work was finalized. Based on the results of the anonymous questionnaire, the students consider that the work carried out with the jigsaw technique improved their comprehension and learning of the subject.

1. Introduction

Active and cooperative learning focuses on the premise that the students can learn better by doing and working with each other [15]. One commonly used cooperative learning technique is jigsaw. Proposed by Aronson et al. [1] [14], it consists in dividing the learning material into partial tasks. Each student in a jigsaw team will have to perform one of these partial tasks, which eventually will end up integrated by all of the team members.

The growing complexity of software development, which provoked the so-called "software crisis", has been approached through the posing of new methods, methodologies, techniques and paradigms aimed to diminish the aforesaid "crisis impact". The object-oriented paradigm is one of the most recurrent nowadays. It is accepted that object-oriented development requires a different way of thinking than structured development. One factor that makes the teaching and learning of the object-oriented paradigm more difficult is that high level and abstract elements need to be taught early [2]. It is also important that students understand, besides object-oriented programming, analysis and design in order to develop good object-oriented software.

Leung and Bolloju analyzed a set of projects performed by undergraduate students [10] and they were able to identify the mistakes that students made during the elaboration of this kind of diagrams. One of these mistakes – also very usual among PUCP and UBB students – is identifying relationships among analysis classes incorrectly (association, aggregation and composition relationships). That is why one of the session's objectives was to have students learn how to perform this task properly.

Keeping in mind those issues, this paper shows the application results of the jigsaw technique in a class focused on learning an object-oriented software analysis task.

This document is structured as it follows: Section 2 shows a brief summary of some related work; Section 3 shows the design of the cooperative learning session; Section 4 details the results obtained from the application of learning assessment tools; Section 5 presents the final discussion of the obtained results; and finally, conclusions and future work are included.

2. Related work

The use of cooperative learning techniques is gaining adepts and its utilization in computing courses has increased in the last years. Much research is being done in the subject. It has been used quite long in the form of team projects.

However, for theory courses, the classic instructor-centric lecture mode tends to be applied more often. In spite of this, many researchers have sought for new applications of cooperative techniques on all kind of courses, including for theory-intensive courses.

For example, McConnell [11] explains how the use of active and cooperative learning methods improves student's final exam scores in a theory of computation course. Natarajan [13] describes the application of the jigsaw technique in an operating systems course, with very satisfactory results. Thomas [17] shows some commonalities between the principles of cooperative learning and object-orientation, and describes several examples of how the jigsaw technique could be used to teach object-orientation. McConnell [12] gives tips in how to design exercises for a particular goal. Franklin [5] uses cooperative learning techniques to tackle the problem of large class sizes, reducing the feeling of anonymity that many students experience in large classes. Deibel [4] focus on group conformation in order to obtain even better results from cooperative work. Soh [16] apply the jigsaw technique in closed labs and presents empirical evidence that a jigsaw-lab gets better results than a traditional lab.

3. Session Design

Analysis class diagrams proposed by Jaaksi's method [6] are similar to the domain model that is included in Larman's approach [9], which is used in the course at UBB. Both methods propose identifying one kind of analysis classes. Jaaksi's method differs from Jacobson's [7] approach because it proposes to identify three kinds of analysis classes: boundary, control and entity.

The session was designed for the students who had to draw analysis class diagrams for a case study. During the session, students used Jaaksi's and Larman's approaches to prepare class diagrams. They also had to utilize Coad's patterns [3].

In this section we present the case studies and the instruments used to evaluate students learning and the tasks performed in class. We also describe the tasks which were performed during the jigsaw session and the characteristics of the students who participated in the class.

3.1 The case study used for the session

Although the case study used at PUCP was different from the one at UBB, both had the similar difficulty degree and scope. We have only included the case study used at PUCP as example.

The case study at PUCP sessions consisted of a musical CD playing/recording software, and it was divided in two parts: one of them was "record CD to tape" and the other "play CD".

The students were provided with the use case specifications and diagrams (see Figure 1).

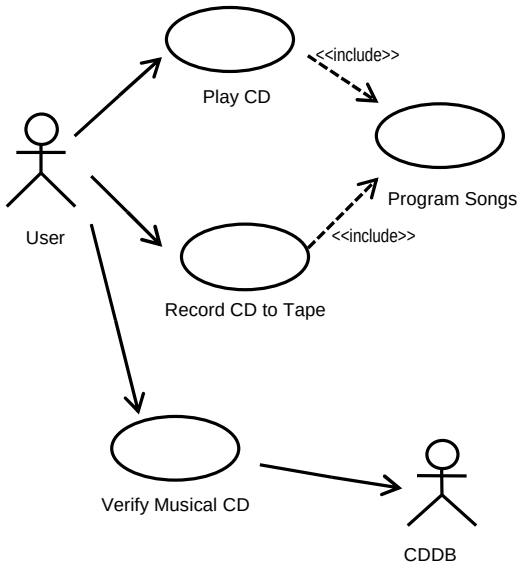

Figure 1. Use case diagram of the case study

The description of use cases are:

- Verify Musical CD: This use case corresponds to the verification of musical CD entered by the user. If it is a musical CD the software will get CD information from CDDB (Internet CD Database).
- Play CD: This use case corresponds to play songs selected by the user.
- Record CD to Tape[1]: This use case corresponds to generate a song list for each side of the tape by using a complete list selected by the user. For this case, it is assumed that a tape recorder has to be plugged to the computer and the software only reproduces song lists to be recorded in each side of the tape. The software has to reduce the waste of the tape.

[1] In next experiences, this use case will be replaced with another functionality. Nowadays, cassette tapes are becoming obsolete.

- Program Songs: This use case corresponds to the selection of songs that they will be recorded or played.

3.2 Instruments used in the session

Following are the instruments used to gauge if the session influenced the students' learning positively:

- Two tests evaluating theoretical knowledge. One was taken at the beginning and the other at the end of the session (The tests at PUCP and UBB were slightly different, due to the differences between Jaaksi's and Larman's approach).
- An anonymous questionnaire consulting the student's opinion about the session.

The tests included a question demanding the elaboration of a class diagram. The purpose was to determine if they could apply the analysis class concepts accurately in order to elaborate the diagram.

It is important to mention that the same anonymous questionnaire was used at both universities. Due to the differences from the case studies, the tests utilized at both universities were different; however their scope and objectives were the same.

Further details of the case studies and instruments used can be found at the following links:

- http://inform.pucp.edu.pe/~jpowsang/jigsaw/analysis.html
- http://www.face.ubiobio.cl/~pcampos/documents.html

3.3 Tasks performed in the session

The following table shows the tasks carried out in the session, together with the approximate duration times.

Table 1. Tasks of the session

No.	Task	Duration
1	Initial test	10'
2	Delivery of material, explanation and formation of groups (2 students)	10'
3	Performance of an assigned task by the students	15'
4	Formation of expert groups (maximum of 6 students) and performance of an activity	15'
5	Formation of groups of students who will integrate diagrams (maximum of 6 students)	15'
6	Closure of cooperative work	15'
7	Final test and questionnaire	10'
	Total	**90'**

After the initial test was taken, working groups were formed, materials were delivered and the session's dynamics was explained. For example, at PUCP, one group had to prepare analysis class diagram of Record CD to Tape and the other group of Play CD and Verify musical CD.

During task 3, the groups formed for the previous task elaborated a class diagram corresponding to the appointed functionality.

In task 4, groups of 6 maximum were formed; in which all members had elaborated the same diagram (these groups are called the "experts"). They had to compare their diagrams in order to refine them and elaborate only one definitive diagram per group. Besides, they had to answer questions that were designed to generate discussion among them. These questions were related to which Coad's pattern had to be used to elaborate the diagram. This kind of task was not included in the original jigsaw but it is described since jigsaw 2 [9].

Then, after task 5, "mixed" working groups were formed, so that each one contained students that had carried out diagrams of different functionalities. This task's goal was to combine both types of diagrams in a single one. The students had also to answer questions related to the subject that were designed to generate discussion among them.

Finally, there came the session's closure, after which the final test and the anonymous questionnaire were taken.

3.4 Students who participate in the session

The session was applied in two academic-semesters at PUCP: 2005-2 (equivalent to Fall 05 term) and 2006-1 (equivalent to Spring 06 term), and in one academic semester at UBB: 2006-2 (equivalent to Fall 06 term). Table 2 shows the number of students who participated in the designed session.

Table 2. Number of students by academic semester

Academic Semester	Number of Students
2005-2 (PUCP)	36
2006-1 (PUCP)	52
2006-2 (UBB)	32

Expert authors in cooperative learning recommend sessions with maximum 30 people per teacher or teaching assistant. Unfortunately, in all semesters, sessions participants were more than 30 students and sessions were conducted by one lecturer. The number of students per class was assigned by the Faculty of our universities and it was not decided by the lecturer.

Previous knowledge that the students had prior to begin the academic semester in both universities consists on basic level of C++ and a high level of structured analysis and design techniques.

4. Obtained results and observations

This section presents the results obtained after applying the jigsaw technique in the session. First, it is showed information of the tests' results and then it is included the questionnaire's results.

4.1 Test results

Figure 3 presents the results obtained in three semesters at two universities of different countries regarding the question about the elaboration of a class diagram. It can be observed that percentage of students who improved their skills in the elaboration of class diagrams increases after cooperative work in the three semesters.

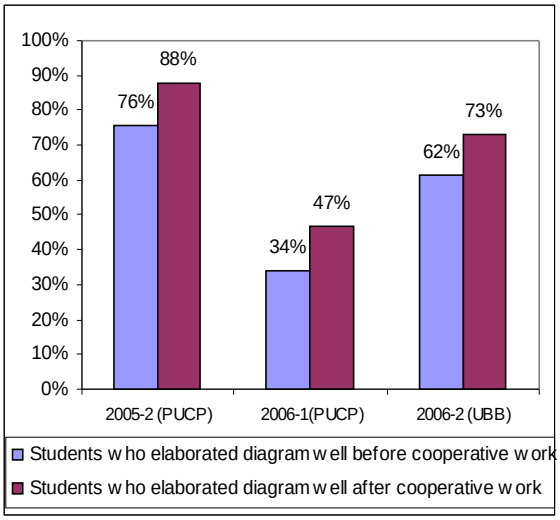

Figure 2. Results of the question corresponding to the elaboration of a class diagram

It can be seen in Figure 2 that at the 2006-1 session the results were very low compared with the other sessions. It is important to note that within this session it was very difficult to answer all students' inquiries and some students stayed with many doubts. This issue occurred in fewer situations in 2005-2 and in 2006-2. An important cause-factor in provoking this problem was the high number of students in 2006-1 semester. We think this is the rea-son why 2005-2 and 2006-2 results were better.

Although the results obtained in 2006-1 were the lowest among results obtained in others semesters, there were improvements of student's skills and knowledge. Figure 4 shows the percentage of students who improved their knowledge.

It can be observed in Figure 3 that 38% of students improved in some way their skills (not necessarily did the diagram perfectly) and 26% keep their knowledge and did the diagrams well. Unfortunately, they were students who decreased their knowledge (6%, 3 students) and kept their knowledge with mistakes (30%, 14 students). Similar tendencies were found at UBB.

In spite of the different results obtained in the three semesters, in Figures 3 and 4 it can be observed that, in general, there was an improvement in the students' learning.

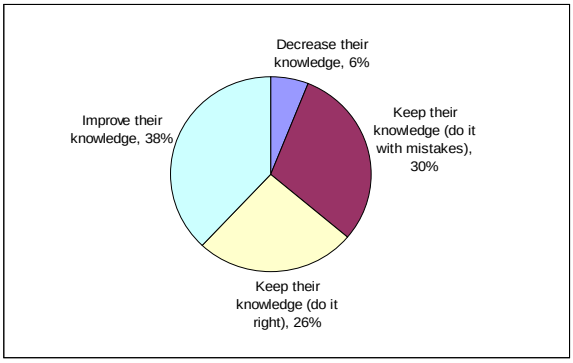

Figure 3. Results of students' improvement in 2006-1 at PUCP

4.2 Questionnaire results

In the anonymous questionnaire, students had to grade, by a 0-3 scale, some statements concerning the following points: course organization, dictation of lectures and the cooperative session as it was carried out.

We commented to the students that the purpose of the questionnaire is to know their honest opinion about the session in order to decide to use the jigsaw technique in other classes.

Tables 3 to 6 presents the assertions referring to the cooperative work carried out and the students' answers in 2005-2 and 2006-1 semesters at PUCP and in 2006-2 semester at UBB.

Table 3. Results of the question: "Before the group work kicked off, I felt I wasn't perfectly familiar with the subject"

Semester and University	Percentage of Students per Grade				Average Grade
	0	1	2	3	
2005-2 (PUCP)	3%	45%	24%	27%	1.76
2006-1 (PUCP)	2%	47%	44%	7%	1.56
2006-2 (UBB)	3%	44%	28%	25%	1.75

Table 3 shows the results of the question related to the experience with the subject. It can be observed that the average grade is approximately 1.6 and the answers lower than 2 and upper than 1 are proportional. The results show that many students who were not perfectly acquainted with the subject of cooperative work, though an important number of them were indeed familiar with it.

Table 4. Results of the question: "With my group work experience I have clarified some concepts taught in class, about which I had some doubts"

Semester and University	Percentage of Students per Grade				Average Grade
	0	1	2	3	
2005-2 (PUCP)	0%	0%	42%	58%	2.58
2006-1 (PUCP)	0%	7%	47%	47%	2.40
2006-2 (UBB)	0%	0%	53%	47%	2.47

Table 4 shows the results of the question related to the clarification of the concepts taught in class. It can be seen that the average grade is approximately 2.48 and almost all students select 2 or 3. The results present that students thought, in some way, group work has helped them to clarify some concepts taught in previous classes.

Table 5. Results of the question: "I feel more confident at elaborating class diagrams correctly after the group work was carried out"

Semester and University	Percentage of Students per Grade				Average Grade
	0	1	2	3	
2005-2 (PUCP)	0%	3%	42%	55%	2.52
2006-1 (PUCP)	2%	5%	40%	53%	2.44
2006-2 (UBB)	0%	9%	53%	38%	2.28

Table 6. Results of the question: "Our group activities provide us important learning opportunities, which wouldn't be the same in the context of individual work"

Semester and University	Percentage of Students per Grade				Average Grade
	0	1	2	3	
2005-2 (PUCP)	3%	0%	36%	61%	2.55
2006-1 (PUCP)	0%	2%	37%	60%	2.58
2006-2 (UBB)	0%	0%	25%	75%	2.75

Table 5 shows the results of the question related to the confidence at elaborating class diagrams. It can be seen that the average grade is approximately 2.40 and almost all students select 2 or 3 and few 0 or 1. The results present that almost every student considers that, in some way, group work has helped them to improve their knowledge in order to elaborate analysis class diagrams accurately.

Table 6 presents the results of the question related to the opinion about cooperative work. It can be observed that the average grade is approximately 2.59 and almost all students select 2 or 3. The results show that almost every student considers that cooperative work helps them to create learning situations that they can not figure out in the context of traditional lectures.

5. Final Discussion

Although we did not use control groups in all of the semesters in order to get more formal results, the results obtained from the application of the jigsaw technique in different groups from different countries could suggest us some valuable conclusions:

- It could be observed that the students who participated in a jigsaw session improved their skills to elaborate analysis class diagram.
- It could be observed that the students who took part in the jig-saw-sessions show a very positive attitude toward the applied learning method. What's more, from the answers given, we could tell that the students feel that the session helped them to learn the subject.

The results obtained in different countries (Chile and Peru) suggested us that the kind of session explained in this paper could be easily replicated in other universities. Jigsaw could also be applied to reinforce theoretical concepts about other tasks of object-oriented development, different from analysis.

The lessons learned from the application of this technique are:

- The number of students in a session should not be larger than 30 per teacher. Although this work was performed with 36, 52 and 32 students, it was a bit complicated at times to solve every group's inquiries. The results show a better performance of students in smaller sessions
- The closure of cooperative work is very important, since that is when the conclusions of the work done are presented, and the student becomes really aware of the achieved learning. This is why a proper time-controlling is necessary.
- It is advisable to have additional questions and tasks in store together with the already planned ones for the session, since there might be groups that perform their tasks more quickly than expected.

6. Conclusions and Future Work

The employment of the jigsaw technique in a class made students improve their knowledge about the correct elaboration of analysis class diagrams for object-oriented software.

The results of the tests taken at the beginning and the end of the session allowed us to corroborate that students who bore some misconceptions at first, eventually improved their performance after the cooperative work was finalized. According to the answers provided in the anonymous questionnaire, we can tell that students consider that the work carried out improved their comprehension and learning of the topic.

Although the technique was applied in different universities at different countries, also by different lecturers, the results obtained are very similar. These experiences show that the jigsaw technique could be very appropriate to use in software engineering teaching. It also could be investigated if a detailed selection of the group members for the experience may lead to better results than the obtained in this work.

Acknowledgments

The authors would like to thank Mónica Sánchez from MAGIS-PUCP for her valuable suggestions, which made it possible for us to prepare this article.

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