# Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση

Τόμ. 1 (2018)

11ο Πανελλήνιο και Διεθνές Συνέδριο «Οι ΤΠΕ στην Εκπαίδευση»


## A Two-year Evaluation of Distributed Pair Programming Assignments by Undergraduate Students

*Stelios Xinogalos, Maya Satratzemi, Despina Tsompanoudi, Leonidas Karamitopoulos*

# A Two-year Evaluation of Distributed Pair Programming Assignments by Undergraduate Students

**Stelios Xinogalos[1], Maya Satratzemi[1], Despina Tsompanoudi[1], Leonidas Karamitopoulos[2]**
stelios@uom.edu.gr, maya@uom.edu.gr, despinats@uom.edu.gr, lkaramit@otenet.gr
[1] Department of Applied Informatics, University of Macedonia
[2] Department of Information Technology, Alexander TEI of Thessaloniki

## Abstract

Pair Programming (PP) has a long history both in software industry and education. More recently, specially designed environments have made possible the application of Distributed Pair Programming (DPP) as well. In our institution we have applied DPP in the context of an undergraduate Object-Oriented Programming (OOP) course for five years. Specifically, we have used the educational DPP system of SCEPPSys in the context of Java programming assignments. In this paper, we analyze students' replies in a questionnaire filled in after the end of the course for two consecutive academic years. This study aims to investigate students' experience and perceptions on DPP assignments. The following issues are investigated: overall experience on DPP, preference in working individually or collaboratively in programming assignments, selection criteria and satisfaction with partners, benefits and shortcomings of DPP assignments. The results are rather positive and give instructors some guidelines for the effective application of DPP.

**Keywords:** Distributed Pair Programming, Object-Oriented Programming, Assignments, Java

## Introduction

Pair Programming (PP) has a long history in software industry, as part of Extreme Programming. The benefits of PP are many and they were considered important for the teaching of programming as well. Collaboration, sharing of knowledge and skills, as well as easier detection and correction of errors are some of the factors that assist pairs of students in implementing programs. More recently, specially designed educational programming environments have given rise to Distributed Pair Programming (DPP), where pairs of students apply PP remotely from anywhere and at anytime.

In our institution we use the educational DPP system SCEPPSys (Scripted Collaboration in an Educational Pair Programming System) that applies collaboration scripts for more effectively defining the pairs of students, dividing assignments in tasks/steps connected with specific educational goals and hints, defining task distribution policies and scheduling assignments. SCEPPSys has been utilized for the assignments in an undergraduate "Object-Oriented Programming" (OOP) course that is based on Java for several years. Our research has focused in studying the effects of DPP assignments both in students' performance and their perceptions on the benefits and shortcomings of DPP assignments. In this paper, we focus on analyzing students' replies in a questionnaire filled in after the end of the course for two consecutive academic years (2015-2017). The following issues are investigated: overall experience on DPP, preference in working individually or collaboratively in programming assignments, selection criteria and satisfaction with partners, benefits and shortcomings of DPP assignments.

Στ. Δημητριάδης, Β. Δαγδιλέλης, Θρ. Τσιάτσος, Ι. Μαγνήσαλης, Δ. Τζήμας (επιμ.), Πρακτικά Εργασιών 11ου Πανελλήνιου και Διεθνούς Συνεδρίου «Οι ΤΠΕ στην Εκπαίδευση», ΑΠΘ – ΠΑΜΑΚ, Θεσσαλονίκη, 19-21 Οκτωβρίου 2018, ISBN: 978-618-83186-2-5

The rest of the paper is organized as follows. In the second section we provide some information for the methodology of the study and the underlying research questions and in the next section we analyze its results. Finally, we draw some conclusions and practical implications that could be useful for instructors.

## Methodology of the study

### *Course Outline*

The study presented in this paper took place in the context of a 3rd semester undergraduate "Object-Oriented Programming" course during the academic years 2015-16 and 2016-17. The OOP concepts are approached through hands on exercises carried out in lab sessions. Information regarding the course is summarized in Table 1.

**Table 1. Course outline**

| | |
|---|---|
| Course | Object-Oriented Programming |
| Semester/ Duration | 3rd / 13 weeks, 3 hours per week |
| Programming language | Java |
| Syllabus | Objects and classes (necessity of using classes); Class definition (fields, constructors, methods); Constructing objects and calling methods (main); Class associations; Groups of objects (array, ArrayList); Inheritance, polymorphism and overriding; Abstract classes and interfaces; Graphical User Interface (constructing a simple GUI, event handling, interaction with domain classes); Collection framework of Java; Manipulation of text and binary files |

### *DPP Assignments*

In the context of the course students carried out DPP assignments in pairs using the educational DPP system SCEPPSys. Important information for the DPP assignments carried out is summarized in Table 2.

### *The DPP System SCEPPSys*

SCEPPSys (Tsompanoudi et al., 2015) is an educational DPP system that comprises of an Eclipse plugin installed by students and a web-based authoring tool used by instructors for scripting DPP. SCEPPSys includes typical features of DPP systems, such as providing a shared editor, supporting the roles of the driver and navigator, and a communication tool (text-based chat tool). In order to start a DPP session both students must log in to the system, while assignments are solved synchronously. Remote code highlighting (a basic gesturing feature) enables the navigator to point out code parts in order to indicate potential problems. The remaining features, the so-called "awareness indicators", aim to provide to pair programmers information about user's status and performed actions within the workspace (like editing, saving etc.). However, it also includes some unique features that serve specific didactical needs: assignments comprise of small and manageable tasks or steps associated with specific didactical goals or else OOP concepts; hints can be retrieved for each task that support students in completing each task.

### *Research Questions*

The study aimed to investigate the following research questions (RQ):

- **RQ1**: How do students evaluate the experience on DPP assignments?
- **RQ2**: Does free selection of partners by students themselves lead to effective group formation?
- **RQ3**: What are students' perceptions on the benefits of DPP assignments?
- **RQ4**: What factors hinder student collaboration and experience on DPP assignments?

**Table 2. DPP assignments**

| | **2015-2016** | **2016-2017** |
|---|---|---|
| Participants (DPP assignments) | 94 (47 pairs) | 88 (44 pairs) |
| Participants (survey) | 57 | 78 |
| Prior Programming knowledge | 1st semester "Procedural programming course based on C" | |
| Prior experience on DPP | None | |
| DPP system | SCEPPSys | |
| Group formation | Free selection of partner | |
| Assignments | 1. Class definition, main | 1. Class definition, main |
| | 2. Class associations | 2. Class associations |
| | 3.Object collections – ArrayList | 3.Object collections – ArrayList |
| | 4. Inheritance & polymorphism | 4. Inheritance & polymorphism, GUI, event handling |
| | 5. GUI, event handling (& inheritance) | |
| | 6. Binary files (& inheritance, ArrayList, Comparator) | 5. Binary files (& inheritance, ArrayList, Comparator) |

### *Data collection and statistical analysis*

The data analyzed in this paper were collected from a questionnaire distributed to students as a Google Form after the end of the DPP assignments. Two questions were used for each one of the first two RQs and one question for the last two RQs. Descriptive statistics (percentages or means and standard deviations) were used for presenting the results. Moreover, chi-square tests for homogeneity were utilized for the questions prepared for RQ1 and RQ2, and Mann-Whitney tests were utilized for the questions prepared for RQ3 and RQ4.

## Results

### *Overall Experience (RQ1)*

Students' overall experience on DPP assignments was investigated with the use of the two questions that are analyzed in the following paragraphs.

***Q1***. *How would you evaluate the distributed, collaborative solution of assignments as an overall experience? (1=Very bad, 2=Bad, 3=Neutral, 4=Good, 5=Very good)*

Students' replies in Q1 are presented in Table 3. The chi-square test of homogeneity showed no statistical significant difference between the two groups ($X^2 = 4.428$, df=4, $p = 0.351$). More

than three out of four students evaluated positively the overall experience on the distributed and collaborative solution of assignments.

**Table 3. Overall experience on DPP Assignments**

| | 2015-16 | 2016-17 |
|---|---|---|
| Very bad | 5% | 4% |
| Bad | 5% | 3% |
| Neutral | 7% | 18% |
| Good | 50% | 50% |
| Very good | 33% | 26% |
| Total | 100% | 100% |

***Q2**. Based on your experience in DPP would you prefer to work individually or collaboratively in programming assignments?*

Students' replies in Q2 are presented in Table 4. The chi-square test of homogeneity showed a statistically significant difference between the two groups ($X^2 = 6.221$, df=1, p = 0.013). Before analyzing the results we must mention that students in both groups had experience in carrying out programming assignments individually from the prior "Procedural Programming" course. Regarding the results we can see that the percentage of students that prefer to carry out assignments collaboratively using SCEPPSys increased in the 2016-17 group (92.3%) and this difference is statistically significant, as already mentioned. This can be attributed to a number of reasons. In a qualitative analysis of the results for Q1 and Q2 for the 2015-16 group it came out that students' bad experience was mainly attributed to coordination problems between partners, as well as technical problems (Xinogalos et al., 2017). Based on this result an effort was made to improve the infrastructure for hosting SCEPPSys, as well as informing students of good and bad practices during collaboration sessions and this seems to have had a positive impact on students' experience. Moreover, as will be analyzed in the 'Group Formation' section, the aforementioned gathered experience gave us the chance to give students some guidelines, or else factors that they should take into account, for a more effective formation of groups.

**Table 4. Preferred mode of carrying out programming assignments**

| | 2015-16 | 2016-17 |
|---|---|---|
| Individually | 22.8% | 7.7% |
| Collaboratively | 77.2% | 92.3% |
| Total | 100% | 100% |

## *Pair Formation (RQ2)*

Pair formation is an important factor that affects the effectiveness of PP and consequently DPP. Pairs can be formed by instructors based on various criteria or by students themselves. Criteria that are usually used for pair formation are actual or perceived skill level (or more specifically prior programming knowledge), personality type and self-esteem. Jacobson & Schaefer (2008) stated that a very high rating of compatible pairs can be accomplished by

having students choose their partner on their own. In our study, students chose their partners freely. During the academic year 2015-16 no specific hint or guideline was given to students. However, during the academic year 2016-2017 students were given some advice for effective pair formation based on the results of the qualitative analysis of students' replies on the questionnaire from the previous application of DPP (Xinogalos et al., 2017). Specifically, students were consulted to take into account each one's schedules and whether they both have common available slots for collaboration. Students' selection criteria (Q3) and satisfaction with their partner (Q4) were investigated with two questions.

***Q3**. What was the main selection criterion of your partner?*
*Being a friend*
*Having the same level of programming knowledge with me*
*(I think) we fit as personalities (included only in the 2016-17 questionnaire)*
*Other (please specify):*

Students' replies in Q3 are presented in Table 5. The chi-square test of homogeneity showed a statistically significant difference between the two groups ($X^2 = 24.614$, df=2, $p < 0.001$). Before analyzing the results we must mention that in the questionnaire filled in by the 2016-17 group the predefined answer "(I think) we fit as personalities" was added in order to investigate whether just friendship or similarity in personality is one of the selection criteria of partner. The results showed that personality is an important criterion for one fifth of students (21.8%) of the 2016-17 group and it is not necessarily considered to be the same with friendship relationships. Friendship relationships remains in both groups the main selection criterion of partner (2015-16: 87.7%, 2016-17: 47.4%). An important difference between the two groups lies in the criterion of "having the same level of programming knowledge" that was the selection criterion for 28.2% of the students in the 2016-17 group instead of 10.5% in the 2015-16 group. It seems that the hint given to students of the 2016-17 group regarding the importance of pair formation resulted in more informed and thoughtful choices.

**Table 5. Selection criteria for partners**

| | **2015-16** | **2016-17** |
|---|---|---|
| Being a friend | 87.7% | 47.4% |
| Having the same level of programming knowledge with me | 10.5% | 28.2% |
| (I think) we fit as personalities* | - | 21.8% |
| Other | 1.8% | 2.6% |
| Total | 100% | 100% |

** This choice was included only in the questionnaire for the 2016-17 group*

We must notice that although students could specify other selection criteria, just one student from the 2015-16 group and two students of the 2016-17 group specified their criteria (this is our own translation of students' words): *"wanted to have a new experience and found a student that was eager to participate as well"* (student from 2015-16 group), *"She was a friend and we have collaborated in the past"* (student from 2016-17 group), *"We have worked together in past projects and there was no problem"* (student from 2016-17 group).

*Q4. Were you satisfied with the selection of your partner?*

Students' replies in Q4 are presented in Table 6. The chi-square test of homogeneity showed no statistical difference between the two groups ($X^2 = 0.674$, df=1, $p = 0.412$). The vast

majority of students in both groups (2015-16: 93%, 2016-17: 95%) were satisfied with their partners. These results are in compliance with those by Jacobson and Schaefer (2008) who reported that less than 5% of the students have compatibility problems when they select their partner on their own.

**Table 6. Satisfaction with partner**

| | 2015-16 | 2016-17 |
|---|---|---|
| Yes | 93% | 95% |
| No | 7% | 5% |
| Total | 100% | 100% |

## *Perceived Benefits of DPP Assignments (RQ3)*

The benefits of PP (Cockburn & Williams, 2000) and DPP (da Silva Estácio & Prikladnicki, 2015) are various. In the context of this study an effort was made to investigate students' perceptions on the various benefits of DPP.

***Q5****.At what degree do you agree that you earned the following benefits from DPP? (1=totally disagree, 2=disagree, 3=neutral, 4=agree, 5=totally agree)*

Students' replies in Q5 are presented in Table 7. The Mann-Whitney test for comparing the two distributions was applied and no statistical difference was recorded. We consider it important that students in both groups have a uniform and rather positive opinion regarding the benefits of DPP.

**Table 7. The benefits of DPP**

| | 2015-16 | | 2016-17 | | | |
|---|---|---|---|---|---|---|
| **Perceived benefit** | **Mean** | **St.Dev** | **Mean** | **St.Dev** | **z** | **P** |
| Sharing knowledge and skills with my partner | 3.95 | 0.88 | 4.00 | 0.70 | -.150 | .881 |
| *Quicker correction of logic and syntax errors* | *4.09* | *0.91* | *4.13* | *0.67* | *-.233* | *.816* |
| Less time for completing an assignment | 3.68 | 0.93 | 3.46 | 1.00 | -1.187 | .235 |
| DPP assisted me in learning programming | 3.91 | 0.91 | 3.72 | 0.95 | -1.228 | .220 |
| *Learning programming was more pleasant* | *4.32* | *0.83* | *4.08* | *0.82* | *-1.936* | *.053* |
| Most questions were answered through conversation with my partner | 3.95 | 0.95 | 3.96 | 0.80 | -.302 | .762 |
| I was more confident for the correctness of my solutions | 3.82 | 0.93 | 4.01 | 0.75 | -.967 | .333 |
| *Feeling of responsibility for my participation in the assignments* | *4.16* | *0.84* | *4.21* | *0.67* | *-.034* | *.973* |
| It forced me to solve more assignments than I would if assignments were solved individually | 3.25 | 1.48 | 3.13 | 1.35 | -.555 | .579 |
| DPP helped me improve the quality of my code | 3.82 | 1.02 | 3.68 | 0.78 | -1.583 | .113 |

The three most prominent benefits of DPP assignments, recorded in both groups with a slightly different mean but without statistically significant difference, are the following:

- "Learning programming was more pleasant" for both groups of students (2015-16: mean 4.32, 2016-17: mean 4.08).
- Students had a "feeling of responsibility for their participation in the assignments (2015-16: mean 4.16, 2016-17: mean 4.21), without however "feeling forced to solve more assignments than he/she would if assignments were solved individually".
- "Quicker correction of logic and syntax errors" (2015-16: mean 4.09, 2016-17: mean 4.13).

### *Perceived Shortcomings of DPP Assignments (RQ4)*

***Q6**. What factors hindered the collaboration and the experience on DPP?*
*(1=very much, 2=much, 3=averagely, 4=a little, 5=not at all)*

Students' replies in Q6 are presented in Table 8. The Mann-Whitney test for comparing the two distributions was applied and no statistical difference was recorded. Once again the results obtained from the first group of students were confirmed by the second group of students. The factors that hinder averagely DPP are the technical problems that in several cases have to do with the students' infrastructure and Internet connection and at a lesser degree with coordination problems. Also, students from the period 2015-2016 stated that they experienced less difficulty in using the plugin than the students from the period 2016-2017.

**Table 8. Factors that hinder DPP**

| | 2015-16 | | 2016-17 | | | |
|---|---|---|---|---|---|---|
| **Perceived benefit** | **Mean** | **St.Dev** | **Mean** | **St.Dev** | **z** | **P** |
| *Coordination problems (collaboration time)* | *3.68* | *1.17* | *3.67* | *1.25* | *-.048* | *.961* |
| Unreliable partner | 4.61 | 0.82 | 4.42 | 1.21 | -.243 | .808 |
| Lack of partner knowledge | 4.04 | 1.22 | 4.05 | 1.18 | -.036 | .971 |
| Dominating role of partner | 4.63 | 0.84 | 4.35 | 1.20 | -1.348 | .178 |
| *Technical problems* | *3.04* | *1.07* | *3.13* | *1.25* | *-.779* | *.436* |
| Difficulty in using the plugin | 4.05 | 0.93 | 3.67 | 1.19 | -1.779 | .075 |

## Conclusions

OOP teaching and learning is accompanied with several difficulties. An important challenge is raising students' interest and motivating them to practice in implementing and debugging programs, which is undoubtedly a difficult and time-consuming task. This process can become more pleasant if students work in pairs. The advent of DPP and specially designed environments has given the chance to apply DPP having pairs of students working remotely from anywhere and at anytime. Although several benefits have been recorded in the literature, we consider it important to investigate students' perceptions on the effectiveness of DPP. With this aim we prepared an on-line questionnaire that was filled-in by undergraduate students after a one semester OOP course that utilized DPP assignments. Students used SCEPPSys for carrying out DPP assignments in Java throughout the semester.

Data from the questionnaire was collected for two consecutive academic years, namely 2015-2017.

The results recorded the second year confirmed the results of the first year:

- The majority of students had a positive *overall experience* from the distributed and collaborative solution of assignments and stated that would prefer to *work collaboratively* instead of individually in programming assignments.
- Having students themselves to *form freely pairs* leads to a high degree of satisfaction, as Jacobson & Schaefer (2008) have noted. The main selection criterion of a partner is *friendship* relationships, followed by the perception that the partner has the *same level of programming knowledge* and finally his/her *personality*. We must note that in the 2015-2016 group no guidelines were given to students regarding pair formation, while (based on the prior experience) in the subsequent group students were advised to pay attention and take into account each one's schedules and available slots for collaboration. This might be the reason for the more informed selection of partners in the 2016-17 group. Specifically, 28.2% of students in the 2016-17 group selected their partner with the criterion of having the same programming knowledge, while the percentage for this criterion in the 2015-16 group was 10.5%.
- When it comes to the benefits of DPP the results of our study confirmed more of the benefits recorded in the literature for PP and at a lesser degree for DPP that has not been so thoroughly studied. The most prominent benefits of DPP assignments lie in the fact that "learning programming becomes more *pleasant*", students have a "feeling of *responsibility* for their participation in the assignments" and "*quicker correction* of logic and syntax errors". The first and third benefit were also recorded by Cockburn & Williams (2000), while the feeling of responsibility was recorded by Williams & Kessler (2001).
- Finally, the two most prominent factors that hinder averagely the collaboration and overall experience in DPP are the *technical problems* and *coordination problems* (i.e. collaboration time). Technical problems in several cases refer to students' infrastructure, but special attention should be given in guaranteeing a reliable institutional infrastructure. Regarding coordination problems it is clear that the problem would be more severe if physical presence in a common place was required and consequently we consider it as another benefit of DPP assignments!

## References

Cockburn, A., & Williams, L. (2000). The costs and benefits of pair programming. *Extreme programming examined*, 223-247.

da Silva Estácio, B. J., & Prikladnicki, R. (2015). Distributed pair programming: A systematic literature review. *Information and Software Technology*, 63, 1-10.

Jacobson, N., & Schaefer, S. K. (2008). Pair programming in CS1: overcoming objections to its adoption. *ACM SIGCSE Bulletin*, 40(2), 93-96.

Tsompanoudi, D., Satratzemi, M., & Xinogalos, S., (2015). Distributed Pair Programming using Collaboration Scripts: An Educational System and initial Results. *Informatics in Education*, Vol. 14, No. 2, 291–314, 2015

Williams, L. A., & Kessler, R. R. (2001). Experiments with industry's "pair-programming" model in the computer science classroom. *Computer Science Education*, *11*(1), 7-20.

Xinogalos, S., Satratzemi, M., Chatzigeorgiou, A., & Tsompanoudi, d. (2017). Student perceptions on the benefits and shortcomings of distributed pair programming assignments. *Global Engineering Education Conference (EDUCON), 2017 IEEE*, 1513-1521.