A Two-Level Problem Solving Practicing Approach using a Location Based App

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Abstract. *Mastering problem solving reasoning is an important skill for computing students. In order to acquire this ability, students might use a collaborative approach and work in groups, getting explanations about problems solved in the past, discussing advantages and disadvantages of specific choices, taking into account different points of view. This paper presents a two-level approach for practicing problem solving skills. In this approach, different computing students enrolled in two courses practice their collaborative problem solving skills in distinct ways. Those students enrolled on the most advanced course develop apps for the freshmen enrolled in the introductory course. These freshmen students learn to solve basic logic problems as part of their course. An exploratory case study was conducted in order to observe and evaluate how students interact in groups developing or using the app.*

1. Introduction

Problem solving reasoning is a fundamental activity for system developers and engineers. Practice is the only way towards evidencing the processes underneath it, what is the essential way for acquiring such skill. However, practicing problem solving is not a simple process and often it is not as stimulating as it could be. Like all other cognitive processes, problem solving activities can be boring if they are presented simply as tasks to be carried out. In this case, it is an activity concerning knowledge assimilation, which involves a set of skills necessary to obtain knowledge on a particular subject or area.

Engineering and Computer Science majors have many courses, which require high levels of problem solving skills, including most of introductory programming courses. Serna [Serna and Serna 2015] mentions that complex problem solving involves thinking, reasoning, abstraction, language, memory, attention, creativity, and deductive logic, among other functions. Also in [Serna and Serna 2015], the author mentions that this process happens in a spiral and continued way, which means that we have development, adaptation and learning.

Developing these skills is a challenge for students and teachers at universities and on the other hand, industry is expecting to hire technology professionals able to work in teams for solving technological problems and being able to propose new solutions. Several complicating factors, including the difficulty with abstraction and lack of coordination within the group may lead to incomplete understanding of problem solving process in groups [Salgado and Castro 2012].

There are some initiatives of teaching problem solving skills in the first year of engineering and computing students [Lin et al 2015], [Admiraal et al 2011], [Sung and Hwang 2013]. Independently of the method used, a collateral problem can be raised. If the problem solving activities are given in a very traditional way students might start not solving some of them and this would lead to a sense of

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frustration, causing them to disconnect from the course contents and in the worst cases, dropping out [Castro et al 2011].

Aiming at soften the aforementioned problem, some approaches have been successfully applied, such as the problem based learning, as described in [Tran et al 2013]. Their proposal involves teaching problem solving techniques in two consecutive courses for first year Information Technology students. They pose a concrete problem for students to solve like a house to build (in a model) with some constraints and materials and students themselves have to articulate the group to come up with a solution. In the second course they do a more abstract problem with software application.

Problem based learning approach has turned more and more popular among computing and engineering majors. There are many proposals involving blended learning [Kadam and Iyer 2014] and location based learning in different scenarios. One particular scenario that got great attention in the last years is museum visiting for children, as the work described in [Rubino eta al 2015]. This particular scenario can be easily adapted to any classroom context use.

Another approach that has many adepts, specially because of the age range matches those of first year students, is using games, as those described in [Hwang, Wu and Chen 2012] and [Sung and Hwang 2013]. The first paper is for a stand-alone player and the second one describes on a more sophisticated scenario, a collaborative version. Both papers describe a virtually location based learning game where students from a school learning Natural Science virtually go to specific places and earn points for getting answers correctly about that subject. There are other activities on the game for practicing knowledge about the subject, but what is most important for the context of problem solving and collaboration is the use of the game itself and that results says it is valuable.

In this paper we describe how we tackled problem solving reasoning in computing courses. We have designed a two level approach involving different groups of students, one in the third and other in the first year of computing majors. We present a collaborative mobile game for problem solving the third year students designed for the first year students. We show results of an acceptability test conducted at the end of the semester and discuss about the improvements for the app and possible follow ups of the approach.

2. Method

The approach described on Section 1 is based on the Polya's problem solving method [Polya 1987], adapted for groups working collaboratively towards the development and use of apps. Our application scenario requires the involvement of two courses taught in parallel for students in different years of their computing majors, which can be Computer Science, Computer Engineering, Information Systems or Applied Mathematics. For students in the third year, the most advanced ones, their role is to act as a service provider, using their computer programming abilities and some of their team collaboration techniques, while they are enrolled in the course of "Collaborative Systems", to develop a mobile collaborative system. The other level is for first year students enrolled in the "Introductory Programming" course. The latter students learn to program with Scratch and rudiments of Python, practicing problem-solving skills alone and in groups according to their Scratch tasks.

For this particular app context, teachers involved in these two courses proposed a challenge of developing a location based app for first year students to learn problem solving reasoning collaboratively. The approach presented is the same the group who volunteered to work with this project used (Figure 1).

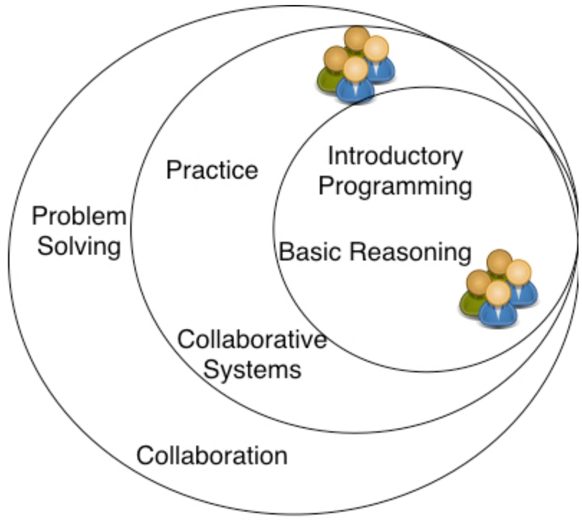

Figure 1 - Method for Developing the Collaborative App

The approach involves both groups of students and their teachers, forming a collaboration community for problem solving, as shown in Figure 1. The middle circle represents students enrolled in the Collaborative Systems course who developed a location-based app to support collaborative problem solving tasks. These students are themselves practicing collaborative problem solving when designing and developing the app. All students enrolled in the Introductory Programming course that are mainly practicing basic problem solving reasoning with practical lessons on scratch form the inner group. They use the app to solve general logic problems.

It is worth to mention that the approach presented in this paper stands always for two courses and it has been tested with the courses: Collaborative Systems and Introductory Programming. Both courses are offered on the second academic semester, each year. The idea is to replicate this method for practicing any other necessary skill through the development and use of mobile apps, as long as mobile apps are a challenging and interesting experience for students. This means that changing the developed object does not change the approach.

3. Example – Treasure Quest App

The Treasure Quest game aims to explore collaboration in teams through challenges on general logic problems. For receiving a question, each participant has to be located on the target position and to find that position he follows clues on the game, visualizing blue for cold if the participant is far from the mapped position and red for hot if he gets closer. These functionalities regarding clues are based on the patent claimed by Goodwin in [Goodwin 2005].

From the beginning of the development of Treasure Quest, because of its characteristics centred in collaboration, some functionality have been added to give all team members an idea about how their teammates were getting on with their tasks. For adding such functionalities, it was necessary to develop the app following a client-server architecture inspired on the papers [Kohen-Vacs, Ronen and Cohen 2012] and [Economou et al 2015].

The client application consists of an Android app developed using APPInventor [2016], a prototyping platform for apps developed and maintained by the MIT. This app is the game's interface with the participants, where geo-located questions are posed for them and they see the status of other team members. For each question found and answered successfully, the app records it and informs the respondent's status to the other team members. In this way everyone in the team is aware about each team member during a quest. Figure 2, illustrates four phases of the Treasure Quest. The first one is when the teacher creates the teams of four students, the second one is showing the thermometer indicating how far the student is from the clue to solve the problem, the third one shows the coloured squares indicating the completion of the tasks for each student and the last one shows the last question before the team task, which was answered by the student represented by the red colour.

The server application consists of a webservice responsible for keeping data game's persistence: geo-located questions and their answers, recorded teams, players on each team, quests going on and each player's status during a quest. The webservice was implemented using PHP 5 in a web server APACHE2, with database server MySQL 5.5 for data persistence. The service implements the architectural style REST [2016] (Representational State Transfer) which consists of a coordinated set of architectural restrictions applied to components, connectors and data elements inside a distributed hypermedia system. The data exchange between the client application and the webservice takes place through JSON [2016] (JavaScript Object Notation), a well-known lightweight format for computational data exchange.

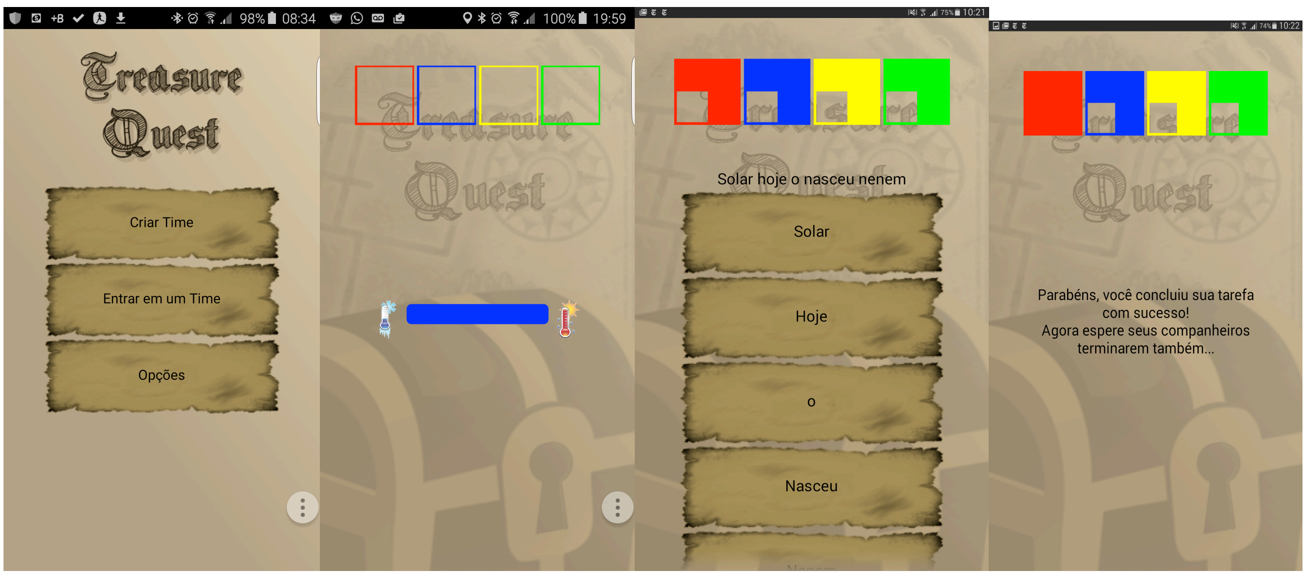

Figure 2 - Screenshots for Treasure Quest

The App interface is in Portuguese because of its original context, which is during two undergraduate courses at UFAM, a Brazilian University. The first screenshot from Figure 2 is translated as "Create Team", "Join a Team" and "Options", the third one is the question posed, meaning "Sunny today the was born baby" for choosing the word not connected to the others. Finally, in the last screenshot, the sentences mean "Congratulations, you finished your task successfully!" and "Now wait for your mates to finish theirs as well…".

4.1. Exploratory Case Study

In order to evaluate the effectiveness of our game, we defined an exploratory case study. According to [Yin 2013], an exploratory case study is a useful approach to pose problems, identify variables related to a particular phenomenon, investigate possible causes and consequences, and to develop a number of propositions. These aspects seemed adherent to our needs for evaluating the Treasure Quest as a means for practicing problem solving reasoning.

For this exploratory case study, the research was based on the questions:

a. Do students enjoy practicing problem solving in groups?

b. Do students have any difficulties to solve problems in groups?

c. Does the app really help them?

In order to answer the above questions a practical activity was carried out in the context of an assessment test, a typical kind of usability test according to Rubin and Chisnell [2008].

The setting for the practical activity was the campus community centre, because it is a big open space where we could mark the points in distinct locations but at the same time not very far that we could not see the whole quest going on. It is important to stress that GPS signal varies from one smartphone to another and the precision of the signal depends on the amount of users using the campus Wi-Fi network on a given moment. Given that restriction, we calculated an error about 10 meters radius where students could find their target. The elements of the case study were as follows:

- **Participants** – fourteen first year students of Applied Mathematics took part of the case study. Two groups of four, and, as mentioned before, six persons formed one group, but their representation on the app was of four. We had a special attention with the pairs on group C to check whether they were getting any benefit of working together. They were faster answering the questions but not in finding the marked locations. Group A was formed with participants Le, Ga, Gi and En; group B with Jo, Vi, Na and An and group C with FeFe, FaDa, Ab and Ad.
- **Material** – although students had their own smartphone we provided three smartphones and a tablet with good GPS signal and wifi access to campus network. A post-game personal perspective survey was conducted immediately after each group's activity to evaluate the game's usability using the assessment test. In order to evaluate their learning experience, they had to provide a post-game report about their personal experience with the game on the institutional LMS.
- **Procedure** – the work began with a meeting for guidance and clarification about the activity. Then, the students were divided into three teams of 4 members, to suit the structure of the game, following the restrictions we anticipated. The students themselves formed the teams. Two students remained without a group. As everyone had to take part, the teacher organized for the group C that two pairs of students represented two players in the game. From this point we refer to the groups as A, B and C. Each group took its turn to play the game. While a group was playing, the other two were outside the area, without any vision of the marked locations. We were careful to instruct the participants to do not talk with other groups after they finish their quest. It follows that all the groups started with no knowledge about the locations.

The assessment test aforementioned was carried on as part of the exploratory case study. While the purpose of the case study was to observe the way the both freshmen and sophomore students solve problems collaboratively, the assessment test, as part of the case study, aimed at seeing how students deal with the Treasure Quest tasks for identifying how the app helped them to accomplish those tasks.

4. Results

The post-game personal perspective survey took place right after each group's quest. Our benchmarks are the questions about problem solving, group work, finding clues activity and marked locations. For evaluating these benchmarks, we made a survey, where each participant had to express their evaluation. We considered a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" on a scale ranging from 1 to 5. Figure 3 illustrates survey results.

From the survey results on Figure 3 we can see most participants in groups A and B liked very much the challenge of finding clues, only En, a group A participant graded it below maximum (4). This process was more confused for participants of group C, who experienced some problems in findings clues because Wi-Fi network was more crowed when they started their quest. Their floating score for this particular benchmark reflects that frustration.

The benchmark about the questions presented for the treasure quest, participants' answers were surprisingly different from those we were expecting. Group A completed their quest in 40 minutes, group B in 38 and group C in 50. Group B's performance was the best one. As group A completed the quest, although on the second best performance, we expected they would put high scores for the questions and group C low scores. However, it was the opposite. Group A put their scores about the average, meaning they were not very satisfied (they did not like very much) with the questions and group C liked very much the questions. In their reports, participants of group A said they thought the questions were too easy for their level.

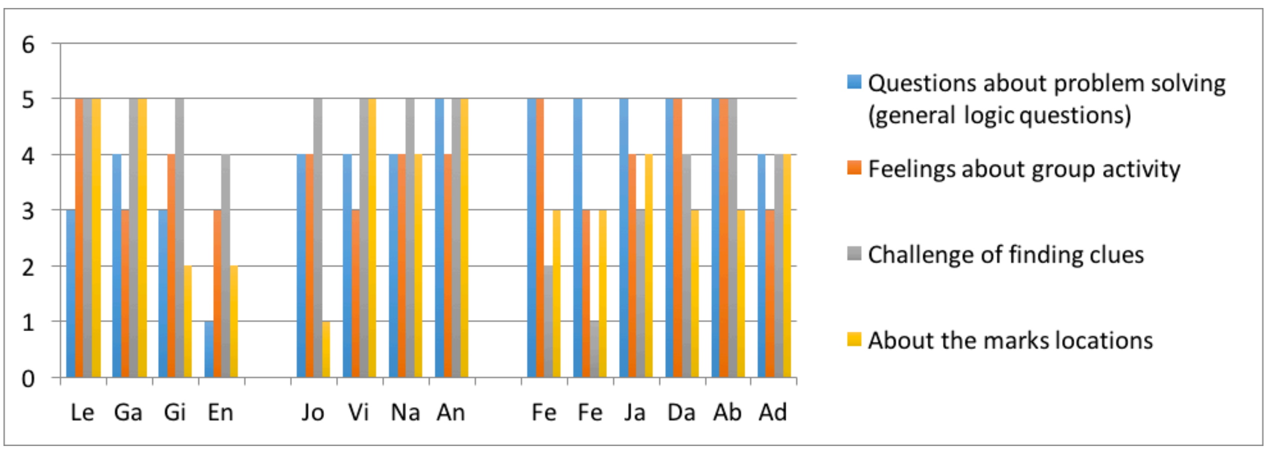

Figure 3 - Survey results showing each group's opinion

Besides technical (functional) aspects of the app, we were particularly interested in having some insight about how collaborative activities were engaging as seen by students. The benchmark for their feelings about group activity gave us that insight. Group A proved to be the most critical one and their minimum score was 3. One participant from group B graded it 3, the others graded it 4. On group C, out of 6, 2 graded it 3, 1 graded it 4 and 2 graded it 5. In general, they liked the group activity but it was not very exciting. In their report, students said they had many problems with connectivity during the quest. If those problems haven't happened they would've appreciated the game much more.

The last benchmark is about the accessibility of the location of the marks. Group A's answers were inconclusive because two participants graded it below the average and two graded it the maximum. Only one participant on group B did not like the location marks. It is possible that he graded this way because his smartphone stopped working and he was not finding any location after that. The others liked the locations.

On group C, they all graded it about average. For them to find location marks it was more difficult because the campus Wi-Fi network was very crowed and GPS on the smartphones and the connection with the webserver were not working properly.

This case study resulted in a set of recommendations for improvements on the app in order to tackle some of the problems specially those concerning connectivity and synchronization, such as: developing the app in C# for Android; including a point earning scheme; recording and showing the time the group is spending to accomplish the quest; providing questions for pairs from the same team; improving the questions by relating them with courses contents.

5. Discussion

The approach we proposed for collaboration (represented in Figure 1) where a problem solving community is created from the unified work of two different groups of students and teachers has proved to be functional although with some temporary technological restrictions.

From the surveys and observation during the test, it was identified that the proposed approach is effective if the teachers from both courses synchronize the content because in this way the apps can be used as a conclusive task for the Introductory Programming course. The two-layer approach for problem solving practice proved, through the analysis of the surveys answered by both courses' students, to be feasible and efficient to increase students' ability for collaboration.

On their surveys, students from both courses pointed out the approach as an interesting and challenging perspective because they can practice problem solving in a more relaxed environment and through a mobile game and at the same time it fosters the interaction among group members. Specifically, the group who developed the app said "It's really nice to see real students using what we developed as a group…". The fourteen students from the Introductory Programming course reported problems in the app but all of them see the approach as positive and "interesting".

The development team for the app was a group of three students enrolled in a course based on problem-based learning and collaborative systems, using a real application scenario, with real people who are using their tool in practice. These students practiced problem solving and collaboration. They developed the tool, they marked locations, they were present at the moment the test was carried on, fixing bugs on the tool and helping teachers. It was a real-world collaboration scenario.

Regarding the other group of students, it was the last activity of the semester. During the Introductory Programming course, they learn the basic principles of problem solving in the beginning and practice applying these principles on given problems. In this manner, the use of Treasure Quest is useful to test their ability to solve problems collaboratively. They went to another place outside the lab or the classroom and tried to experience a collaborative activity, where they had to be aware of where their colleagues were, they answered questions and had to reason about problem solving, which is an important skill for their curriculum.

Regarding the questions posed for the exploratory case study definition each one of them was answered analyzing the instruments survey, observation report (note taken by the teachers) and the assessment test. For the question (a) "Do students enjoy practicing problem solving in groups?" they clearly answered positively. For the second one (b) "Do students have any difficulties to solve problems in groups?" as the questions students from "Collaborative Systems" chose only easy questions they did not have difficulties answering them but with the problems that appeared on the location of the questions and clues (App problem). Finally, regarding the question (c) “Does the app really help them?” the answer was negative because the questions were too easy.

With the exploratory case study described here this approach proved to be effective, although the tool “Treasure Quest” needs some improvement. From hence we make a distinction between the approach itself from the developed tool. The approach involves a mix between two different undergraduate courses that, orchestrated by their teachers, can work together towards collaboration and problem solving. The artefact we described and also a contribution of this work is the Treasure Quest game, which was devised in the context of this approach, and through development, use and evaluation by students, has shown to be a helpful tool for practicing collaborative problem solving.

6. Conclusion

The research reported here involved the proposal of an approach for orchestrating collaboration and problem solving tasks between two different courses of computing students. The main product for this orchestration was the devising of a mobile collaborative game to practice problem solving reasoning, called Treasure Quest.

In order to check the usability of Treasure Quest and the efficacy of our approach we (teachers and Collaborative Systems students) conducted an assessment test with first year students from Applied Mathematics course. We used smartphones and tablets for the case study and, as post-test, we defined a survey and a report.

From the information gathered, we identified strengths as the use of motivation to reason on problem solving and the benefit of interaction that makes a direct reference to the context of collaboration. The game encourages this behaviour especially at the final challenge, where the team can only beat the game if all participants are in the same phase. Other relevant finding for the approach is the orchestration between different courses. It showed to be beneficial for students from both courses because one can see how difficult it is for the other students to do the task and so it creates a clear helping atmosphere.

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