A PROPOSAL OF STRUCTURING THE DISCIPLINE OF REQUIREMENTS ENGINEERING USING PBL

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Abstract

Requirements engineering is a complex and abstract process and therefore difficult to teach and learn. In general, students do not have a practical experience of real problems in the discipline; often it is hard for them to achieve a complete understanding of the role of requirements and of their impact, and also they misunderstand diverse concepts of the Requirements Engineering discipline. Over the years, several researchers have studied and proposed alternatives for a more effective teaching of this discipline; most of the works reinforces the need to expose students to more realistic and challenging environments, in order to provide a better practical insight into requirements engineering. In the other side, in several disciplines, many researches propose the use of problem-based learning (PBL) as a way to provide a practical learning of the content taught. In PBL, due to the emphasis on active's acquisition of information and on student skills, there is a reliance on the student's ability to identify their own needs and their best way of learning. This paper makes a proposal of structuring the Requirements Engineering discipline by concomitantly applying PBL, to provide a practical and real view of the discipline, and the students' evaluation of their own learning styles, in order to help them in self-knowledge and in the development of new ways of improving their learning.

Keywords: PBL, requirements engineering, learning, teaching.

1 INTRODUCTION

The teaching of requirements engineering (RE) encompasses the unambiguous understanding and specification of system functionalities. This knowledge is fundamental for the correct progress of the remaining steps of the software engineering process. Therefore, a limit understanding of the RE contents, in professional training, can lead to misguided projects and damages to the customers, breaking the reputation of who provided the service.

The RE teaching comprehends foundations about activities, concepts, methods and techniques needed for activities such as: the elicitation, modelling, analysis, documentation, validation and requirements management [23]. It is a big challenge teaching these concepts in a way that reflects the reality and attracts students' attention [10]. Generally, students have difficulty in gaining a practical understanding of the RE [6], not reaching a full comprehension of the role and impact of requirements [31] or getting a wrong understanding of various concepts of the discipline [3]. On the other side, the insertion of practice on educational process provides learning to learn and learning to think in the construction of knowledge. Through practice, students can sediment the concepts to which they are being exposed [20].

Also, according to Vygotsky, the student's mental development can be exercised through collaborative work. When students are subjected to group learning, they develop skills that go beyond their actual level of development. What the individual can do in collaboration is more indicative of intellectual development than what he can do alone [19]. Collaborative learning encourages student participation in the learning process, making it an active and effective process [25]. In these groups, the participants' communication has a fundamental role through artefacts that consist of an oral explanation for a colleague to a text or drawing made for the purpose of informing [1].

For an effective instruction, it is necessary to use a methodology of teaching and learning that provides students with spaces to learning by doing, working as a team, learning to learn, and reflecting on learning through oral and written communication. In the literature, several works discuss different ways of dealing with the main problems concerning the teaching and learning of requirements engineering; some of these works include the use of practical activities and real problems [29][4], the involvement of several universities in the same course [21], and the use of agile practices [11].

A possible solution to improve RE teaching and learning is the application of problem-based learning (PBL), an educational strategy, student-centred, that helps him/her to develop reasoning and

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communication [7]. For the professional training of software engineers, PBL approaches can assist student's development by promoting the ability to work in teams, solve problems, and also encourage the development of their skills and attitudes, such as teamwork, cooperation, ethics, and respect for other people's views and self-directed learning skills [28].

According to Barrows, the most valuable aspect of self-directed learning is that it allows the learner to learn in the way he feels is more natural to him or in what he learns best. If the student has never thought about it, it may be valuable for him to reflect on his past learning and how he thinks he learns most effectively [12]. In this regard, providing students with means for identifying their own learning styles can help them in self-directed learning. Learning styles are models that indicate the predilections of students in the study. Identifying the student's styles a way to obtain his/her preference in relation to the acquisition of knowledge, allowing the student to better understand their own abilities and difficulties [15] [16].

This paper proposes the structuring the RE discipline using PBL methodology and also enriching it with learning styles evaluation (instructing the learner about his/her own learning model). The rest of the paper is organized as follows: section 2 describes the applied methodology; section 3 details PBL methodology; section 4 describes learning styles, highlighting the Felder-Silverman's model; section 5 shows the proposes the structuring of the RE discipline; section 6 describes this proposal's execution; section 7 shows the results, and finally, section 8 makes some conclusions.

2 METHODOLOGY

This research followed four phases for proposing the structure of the RE discipline: preparation, construction, execution and analysis.

The preparation phase comprised the conducted study in the literature, required to carry out the proposal. It included: a systematic review of the literature on RE teaching [34], a study of the PBL methodology, and a study about learning styles.

The construction phase consisted of adapting the PBL methodology, including the use of learning styles by the students, to the RE course. After, a plan for executing the structuring proposal, in a RE course, was established and also its execution mode (see section 5.1 and 5.2). In this stage, the learning objectives were defined, and based on them the lessons plan was constructed. All necessary artifacts, for the execution phase, were prepared: problem situations, lesson plan, and support materials that cover the specified learning objectives. In the execution mode, after the application of each problem situation, the methodology is always reevaluated; and, if it is necessary to adjust the methodology, the learning proposal is adjusted and the execution of the next problem situation follows this new model.

To validate the structuring proposal, it was applied in a real RE discipline at State University of Pernambuco, Brazil; this occurred in graduate course of the first semester of 2017 (see section 6 for more details) .Finally, the analyses phase occurred, considering the evaluation of the applied structure and process.

3 PROBLEM-BASED LEARNING

Problem-based learning emerged in the late 1960s from the work of Howard S. Barrows, who first applied the methodology in the medical course at McMaster University in Canada [12]. The PBL is a methodology of teaching and learning in which there is a problem as the beginning of the educational process from which the acquisition of knowledge is directed [17].

The problem is the central element of PBL being used to initiate, direct and motivate learning [12]. The teacher, who in the PBL is called tutor, is responsible for proposing one or more problems that will be presented to the students, always at the beginning of the learning process before introducing any kind of theoretical concepts. Students then identify the knowledge they have and what they need to learn by assuming responsibility for their own instruction, identifying what they need to know in order to better understand and manage the problem they are working on, and determining where they will get the information they need to learn [13]. To solve the problem, the student performs his own study and research, as well as real practitioners. Then, students develop their self-learning skills by working together in small groups, discussing, comparing, revising and debating what they have learned [13]. In this way, it is necessary that the problem motivates the student in the search of knowledge by arousing the curiosity and interest of the learners in solving them [18]. When the problem is related in

a practical way to a future professional activity of the student, the student begins to understand the importance of that learning, making the problem a motivating element [14] [13].

The problem permeates the entire PBL process, which can be described by five activities [17]:

1. A problem situation is presented to the students who, organized in groups, try to solve it by applying knowledge they already have. So, students experience the development of self-directed learning skills when they assess their knowledge and define the nature of the problem.
2. In a brainstorming session, students identify the learning questions required to understand the problem. Students are highly encouraged to improve their learning ability by defining what they know and do not know about the problem.
3. Students prioritize the learning questions, identified by the group, defining which will be studied. The questions can be studied individually, by all or part of the group. The students and the teacher can talk about the sources needed for the study and about where they can get the material.
4. After the individual study, the students meet again and each one presents to the rest of the group the studied material, sharing the knowledge with the group. Students will continue to define new learning questions as they move toward solving the problem.
5. After solving the problem, the students carry out a self-evaluation and an evaluation of the other members of the group, putting into practice the capacity for directed learning

It is important to highlight some points during the application of this methodology [12]:

- The problem should be presented at the beginning of the learning process, before any preparation or study.
- The problem situation should be presented to the student in the same way in which it occurs in reality, thus promoting a practice that is closer to what the students will find in the future.
- The student must work with the problem in order to allow his / her capacity to direct and apply the knowledge to be challenged and evaluated according to his level of learning.
- The required learning areas should be identified in the process of working with the problem and used as a guide to self-directed study.
- The skills and knowledge acquired by the self-directed study should be applied back to the problem, to evaluate the effectiveness and to reinforce learning.

4 LEARNING STYLE

The styles of teaching and learning have been extensively studied over the years. Since the early 19th century, scholars such as Vygotsky, Piaget, and Dewey work on the basis of what would be the progressive education. Unlike the existing view of traditional teaching, according to the progressive education, a person not just attends a class but it is able to create their own connections according to their life experiences, feelings, and prior knowledge. It is understood that each student has its own ideas and in the same class each student can make different connections on the subject taught, and may even disagree with the teacher or contribute with new ideas. Each student realizes the various types of information differently, reacting to a unique way and demanding a proper time to set your choices. Such perceptions, of the ways and forms that the student prefers to learn, are called learning styles [32].

There are several models of learning styles available in the literature. In [8], the authors conducted a systematic review, in works published between 1973 and 2003, and identified 71 different models of learning styles. In each of these models there was a way from which students learn more easily. A very well known learning style model, called Felder-Silverman's, which was applied in this paper's proposal, defines the learning style of the students answering four questions [27]:

1 What kind of information the student prefers to see?

2 What kind of information is more easily retained by the student?

3 How the student prefers to process information?

4 How the student organizes information during learning?

Each of these questions makes up a model's perspective: Perception, Presentation, Process and Organization. In [26] the authors detail each model perspectives:

1 Perception: It refers to how the student perceives the information presented. This perspective in Felder-Silverman model is identical to the indicator of Myers-Briggs types [22] comprising the sensory and intuitive dimensions.
   - Sensory: these students tend to favour externally generated information as a ready example of a problem similar to what they are studying. They prefer to deal with well defined problems that can be solved by conventional methods. They pay attention to details and are comfortable with practical concepts. Usually they are methodical and attentive.
   - Intuitive: these students tend to favour the information generated internally as a result of a personal interpretation. They prefer to deal with abstract problems that require innovation for a resolution. Usually they are good theoretical and inventors.
2 Presentation: it refers to how the student reacts to content presentation.
   - Visual: these students memorize better information in the form of pictures, diagrams and flowcharts.
   - Verbal: these students memorize better information in text or voice.
3 Processing: It refers to how the student reflects about the Information received. This perspective in Felder-Silverman model is identical to the active-reflective scale Kolb model [5] and similar to the extroverted and introverted dimensions indicator of Myers-Briggs types [22].
   - Active: these students better reflect the information in discussion groups. In this way, the student becomes involved directly with the environment to test abstractions and works with the real information in search results [30].
   - Reflective: these students process the information in an introspective way. The student is an objective observer who trusts in his own thoughts and feelings to form opinions and tend to carefully observe the event in many different possible ways [30].
4 Organization: refers to how the student progresses towards understanding the content.
   - Sequential: these students tend to think linearly and are able to understand the subject even when they have only a partial understanding of the material taught.
   - Global: for understanding a new subject, these students must first understand their relationship with the subjects they already know; and after, they can find innovative solutions to problems that sequential learners routinely take much or even do not reach.

5 LEARNING PROPOSAL

The structuring of the RE discipline, proposed in this paper, considers an educational solution that includes PBL and also the importance of making students get knowledge about their own learning styles. Next subsections detail the 2 steps followed towards structuring the learning proposal, that is, its planning and execution. Figure 1 shows a flow diagram to help understanding these steps.

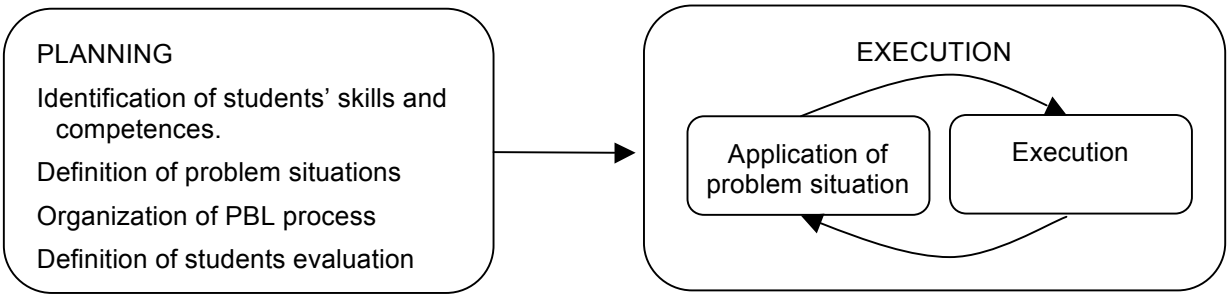

Figure 1. Flow Diagram of learning proposal.

5.1 Planning

The planning step involved the identification of students' expected skills and competences at the end of the course, the organization of PBL process, the definition of the ways to evaluate students during the discipline, and also the definition of the proposal evaluation.

5.1.1 Identification of skills and competences

The identified expected skills and competences, to be achieved by the students at the end of the course, include:

1 Students shall understand the main requirement engineering concepts (problem, context, objective, and requirements) and also know how they happen in practice.

2 Students shall be able to practice the elicitation, documentation and validation of requirements in practice:

   1.1. Understand requirements such as the proposed solution to a problem.

   1.2. Understand and shall be able to use various sources of requirements.

   1.3. Know how to help stakeholders identifying the problem they are dealing with.

   1.4. Understand approaches to conduct elicitation meetings.

   1.5. Understand appropriate approaches to write functional and non-functional requirements.

   1.6. Understand and shall be able to review a system specification document that other people have written.

3 Students shall be able to work on solving problems in a collaborative way.

4 Students shall be able to identify their learning needs and how to conduct their learning.

5.1.2 Definition of problem situations

Considering the skills and competences defined above, the problem situations on which the students will work were defined. Permeating the content of the discipline, ten (10) problem situations were specified for: requirements engineering processes; definition of a problem; teaching requirements elicitation techniques; application of requirements elicitation techniques; requirements negotiation techniques; vision documentation; requirements documentation; teaching requirements validation techniques and application of requirements validation techniques. In order to work with problems, as close as possible to reality, the problem situations must be real and include real stakeholders.

5.1.3 Organization of PBL process

The PBL process was organized in three stages, composed of two tutorial sessions and one individual study for each presented problem situation in the discipline.

The proposed order is:

1 The realization of the first tutorial session. A meeting in which students are exposed to the problem situation they will be dealing with. Students analyze the problem situation by checking what they understood and further trying to solve it with the knowledge they already have. Through discussion students identify what learning is needed to solve the problem situation, and also classify the importance of each identified point to learn. At this moment the student can observe what knowledge he has and what he still needs to learn. This student learning exercise helps in the development of directed learning ability. At the end of the problem situation the students plan, during the class, who will study what part of the required content to be studied and prioritized this content.

2 The individual study: time for students studying individually the planned content. The students at this time develop the ability to self-learn and at the same time commit to the group as the study will need to be passed to the rest of the group in the collective construction of knowledge.

3 The realization of second tutorial session: in this meeting each student presents to his/her group the studied content. After that, the group returns to the problem situation in order to a solution to the problem. At the end, each group presents its solution to the other students and to the tutors.

5.1.4 Students evaluation

It proposes the use of a formative evaluation of the students aiming the improvement of their learning, not only being a diagnostic tool for checking learning [33]. For the teacher, the student's evaluation has the objective of indicating if the results of the learning were satisfactory, providing the application of opportune corrections in the process of teaching and learning throughout the discipline. At the same time, the assessment provides the student a time for gaining insight into its own learning, understanding its difficulties, and making it capable of recognizing and correcting its mistakes.

In order to be effective, the evaluations must be carried out as a continuous and cyclical process, being repeated in all problem situations. In this way, the evaluation of the students is given to each problem situation through the following instruments:

- Problem report (40% of final grade): each group describes the rationale of the problem situation showing the hypotheses, the planning of the individual activities, the solution of the problem and the references.
- Self evaluation (15% of final grade): each student evaluated himself about the own learning; the presence in the classroom meetings; the ability to listen to the opinion of other team members; the contribution in the overall organization of the team; the contribution in the construction of consensus during the resolution of the problem; the participation in discussions; the conducting the self-directed study according to team planning and the contribution to the team from what was done in the self-directed study.
- Peer evaluation (15% of final grade): the students evaluate the members of the group regarding the presence in the meetings in the classroom; the ability to listen to the opinion of other team members; the contribution in the overall organization of the team; the contribution in the construction of consensus during the resolution of the problem; the participation in discussions; the conducting the self-directed study according to team planning and the contribution to the team from what was done in the self-directed study.

During the discipline the students must be invited to innovate during the resolutions of the problem situations, so that at the end of the discipline each group could develop an article related to the requirements engineering. The writing of the article represented 30% of final grade.

5.1.5 Artefact for Proposal evaluation

For the evaluation of the proposal, 2 questionnaires were developed and applied:

- Methodology evaluation questionnaire (after each problem situation): the students evaluate the motivation to solve the problem; the importance of the problem; the easiness of obtaining material; the time to solve the tasks and propose improvements to the problem situation and identify the difficulties in solving the problem.
- Discipline evaluation questionnaire: at the end of the semester the students evaluate the course regarding the own developing about the skills to evaluate their own learning needs; the methodological approach and the impact of the knowledge about their own style in the self-directed learning skills.

5.2 Execution

During execution, after each problem situation was carried out by the students, they evaluate themselves and their peers and in addition evaluate the learning methodology. The teacher also evaluates the groups from the two tutorial sessions, the results of the individual studies, the materials generated and the presentations of the groups held in the classroom.

From the data generated, to each application of the problem situation, the learning process is evaluated, so that changes could be made in the proposal for the application in the following problem situation.

6 PROPOSAL EXECUTION

This proposal was applied in the first semester of 2017 in the discipline of RE (with 60 hours) at the Course of Computer Engineering - University of Pernambuco. The discipline has six students which

were divided into two groups; two tutors, a teacher and a teacher's assistant, gave support to the groups of students.

On the first class, the tutor explained how the discipline will function, the PBL methodology and the use of learning styles. After this lesson a social questionnaire and the index of learning styles (ILS) questionnaire by Felder-Silverman was sent to the students. As far as they have answered the questionnaire, students individually received the result of their own learning style along with learning strategies for each ILS profile. The goal was to instruct the student about their own learning style, so that he/she can develop his/her capacity for targeted learning, including expanding their learning profile.

The following classes occurred after the application of problem situations, following the process explained in 5.2. During the proposal execution some adjustments were made from the evaluations applied at the end of each problem situation. See some examples next:

- During the execution of problem situation 2, which was about problem definition, the students should define a problem that they had affinity to work with during the discipline. The proposal was that the groups would define a problem for which a software solution would be given during the discipline. One group had difficulty to complete this activity, so some possibilities were proposed to the team, among which they have selected one. With this, it was necessary to hold one more tutorial session for this group. Meanwhile, at this time, the other group refined the problem that had already been defined.
- Initially, for the problem situations the related learning content and objectives were not presented explicitly to the students; but this aroused a level of difficulty for the students to understand what they should do or study to solve the problems; in order to bypass this situation, the problem situation was rewritten and the discipline content was presented. At that time, the tutor tried not to leave situations so specific to problems, as this could remove the interdisciplinary purpose of them.
- As most of the students work in the industry, their time is limited and they had difficulty in performing the individual study outside the class' schedule. So, the tutor revised the discipline's calendar so that between the first and second tutorial sessions there would always be a weekend. Another change was that one of the problem situations (teaching requirements validation techniques) was removed to add two more individual study classes during class time. In these classes, students could go to university or study elsewhere.

7 ANALYSIS OF THE PROPOSAL'S APPLICATION

From the questionnaires, related to students' profile, it was observed that 66% of students were between 30 and 40 years of age, 33% were under 30 and over 40. All students work and study at the same time, and 83% work more than 40h per week.

The students learning profile shows that 100% of the students have sensory perception, 83% of them retain better information presented visually, 83% process better information actively participating in activities in groups, and 66% sequentially organize information into a logical progression of difficulty and complexity while 33% tend to prefer to get a global understanding of the subject before starting the study.

The discipline evaluation showed that:

- 66% of the students considered that there was a gain in their ability to identify high or very high their own learning needs.
- The majority of students (66%) believe that their knowledge about his own learning style does not change his self-directed learning skills, however one student mentioned that he/she have used the knowledge of his learning style to develop his/her weaknesses; another student mentioned that he/she has used mental maps and diagrams to better visualize the contents studied.
- 66% of students prefer to study in a discipline that uses active methodologies such as PBL.
- As difficulties, most students (66%) emphasize the short time to develop each problem situation, one student reported preferences for expository classes, thus presenting difficulties with the format of the class and another student cited teamwork as the main challenge.

8 CONCLUSION

This paper presents a proposal that aims at contributing with a new structuring of requirements engineering discipline; it focus in self-knowledge and in the development of new ways of learning. This paper includes the suggested process and all the artefacts needed to apply the proposal, besides the process evaluation methods.

As there are major challenges related to teaching and learning requirements engineering discipline, during the proposal execution, adjustments were carried out continuously in order to improve the initial proposal. The intention was to reach an application prototype of the PBL method, combined with the students' self-knowledge about their own way of learning to improve the assimilation of the discipline concepts.

Considering the use of learning style, some students reported that they had used their own learning style knowledge, while others did not make use of this information. We believe that the use or not of the student's learning style is a question quite related to the student's desire; as a result, we do not recommend the creation of a entire framework for learning styles within this discipline, but only the instruction about the use as it was done.

In general, after the proposal application in the discipline, the students achieved good results; they have applied the concepts of requirements engineering in a practical way, with real problems and real stakeholders.

In this perspective, the proposed goal of this paper seems to be achieved: to define an educational method to promote integration between education and labour market, combined with the new perspectives of projects promoted by the academy, culminating in the prospection of young talents attracted to the area of requirements engineering. It is expected that the application of this proposal can potentially help educate better professionals.

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