A SYSTEMATIC REVIEW OF THE LITERATURE ON THE TEACHING AND LEARNING OF REQUIREMENTS ENGINEERING

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Abstract

Requirement Engineering (RE) have been widely introduced as an obligatory discipline in most of the software engineering curricula at the universities. Requirement Engineering comprises concepts, activities, methods and techniques that enable modeling, analyzing, documenting, validating and managing requirements for software systems. The process of teaching and learning this discipline, however, covers a number of challenges. In practice, this happened for both teachers and students. For the former because they need to be qualified to create an environment in which students can learn and practice requirements engineering skills; and for the latter, as they require several skills for the correct understanding of the discipline. This paper presents a systematic review which aims at characterizing the teaching and learning of RE, by identifying and classifying the available papers related to this context; the review considers four questions: (1) What are the teaching and learning problems mentioned? (2) What strategies are being used for teaching and learning requirements engineering? (3) Do the papers mention the motivation of the student in the studies? (4) Which countries and research institutions are involved in related researches? The systematic review covers papers published between 2010 and 2016, available in seven different scientific databases. In the initial phase of the review’ search, 956 papers were returned. After applying the criteria for exclusion and inclusion of the papers, and after adding 4 studies recommended by specialists, the set was reduced to 86 papers, which were fully read, reviewed and analyzed. The results indicate that the greatest challenges are the difficulty in understanding the theoretical RE concepts without the use of a real software development scenario; this makes difficult the creation of associations between theory and practice. To mitigate these problems, some papers mention the application of techniques like exposing students to more realistic and challenging environments, trying to generate a more attractive and practical learning.

Keywords: Learning, teaching, systematic review, requirements engineering.

1 INTRODUCTION

Software enable technological advancements that lead to new high performance products and systems to different industry areas, such as medical devices, automobiles, airplanes, power generation systems, cell phones and entertainment [24]. Hence, computing increasingly plays a central role in people's lives.

In the academy, to deal with computational development it is necessary to have a structure that adequately prepares the engineers to evolve the technology. It is important that computing disciplines attract good students and prepare them to be capable and responsible professionals [25].

Over the years, Requirement Engineering has been introduced as an obligatory course in most of the Software Engineering curricula, in several universities [23]. RE is a discipline that provides the necessary foundation to make successful software systems by eliciting the appropriate information from the relevant stakeholders and by offering the methodological means to analyze and document the findings such that they can be incorporated throughout design and implementation [5].

Teaching Requirements Engineering covers a number of challenges. Correct understanding of the discipline requires various students’ skills. In order to deal with several stakeholders, it is necessary for the student to be able to hear, understand and consolidate clearly all the needs of those involved. Also, the students must develop the ability to create and imagine the system with all the connections, and verifying the impacts with the existing systems and with the real daily life.
Understanding requirements in a practical way needs to be a realistic experience; in that way, students can realize the repercussions of poorly elicited or poorly documented requirements [13]. Often, the student does not understand the role and impact of requirements [35]. Teaching RE is a challenge for teachers and can become boring for students, when they fail to fully understand the subject [23].

The purpose of this study is to analyze and evaluate the scientific production of the literature on how has been the teaching and learning of requirements. In order to understand this teaching and learning context, a systematic review was performed, which analyzed 954 works published between 2010 and 2016. The results indicate that the greatest challenges in the education of RE are related to the difficulty in understanding the theoretical concepts and the practical learning of the discipline.

This systematic literature review followed the guidelines proposed by Kitchenham [3]. Thus, the review included three main steps: planning, conducting and reporting. These three steps are detailed in the next sections.

2 PLANNING

The planning of the systematic review included the definition of the review protocol: the research questions, the search sources and the inclusion and exclusion criteria.

2.1 Research Questions

Research questions are the most important structure of a systematic review [26] because from these questions the researchers define the studies that will be considered and how the data will be analyzed. The research questions addressed by this study are:

- RQ1: What are the teaching and learning problems mentioned?
- RQ2: What strategies are being used for teaching and learning requirements engineering?
- RQ3: Do the papers mention the motivation of the students in the studies?
- RQ4: Which countries and research institutions are involved in related researches?

2.2 Search Sources

The study considered the search engines: Elsevier, ACM, IEEE and Wiley, the conference REET (Requirements Engineering Education and Training), the journal RBIE (Brazilian Journal of Information Technology), and the research project EVELIM (Experimental Improvement of Learning Software Engineering). The Table 1 summarizes the search sources websites.

<table>
<thead>
<tr>
<th>SEARCH ENGINES</th>
<th>SITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elsevier - Science Direct</td>
<td><a href="http://www.sciencedirect.com/">http://www.sciencedirect.com/</a></td>
</tr>
<tr>
<td>ACM</td>
<td><a href="http://dl.acm.org/dl.cfm">http://dl.acm.org/dl.cfm</a></td>
</tr>
<tr>
<td>IEEE</td>
<td><a href="http://ieeexplore.ieee.org">http://ieeexplore.ieee.org</a></td>
</tr>
<tr>
<td>Wiley</td>
<td><a href="http://onlinelibrary.wiley.com/advanced/search">http://onlinelibrary.wiley.com/advanced/search</a></td>
</tr>
<tr>
<td>JOURNAL</td>
<td>SITE</td>
</tr>
<tr>
<td>RBIE</td>
<td><a href="http://www.br-ie.org/pub/index.php/rbie">http://www.br-ie.org/pub/index.php/rbie</a></td>
</tr>
<tr>
<td>RESEARCH PROJECT</td>
<td>SITE</td>
</tr>
<tr>
<td>EVELIM</td>
<td><a href="http://www.evelinprojekt.de/en/">http://www.evelinprojekt.de/en/</a></td>
</tr>
</tbody>
</table>

As a complement to the research, a consultation to a specialist was performed requesting the suggestion of typical papers and relevant journals of the study area. Dr. Yvonne Sedelmaier participated in the research suggesting some studies. Dr. Yvonne Sedelmaier holds a PhD and a degree in pedagogy from the University of Bamberg, Germany. Her research interests are teaching and learning of software engineering at universities and the didactics of software engineering. After ten years of acting in the education sector and in quality management, she now works as an academic...
researcher in the project of experimental improvement of learning of software engineering and in the research of students in the process of learning them.

2.3 Inclusion and Exclusion Criteria
The systematic review considered as inclusion criteria:

- Studies written in English or Portuguese.
- Studies that answer at least one of the research questions.
- Studies available on the web with open access through the license of the University of Pernambuco – Brazil, where the systematic review was conducted.

Were considered as exclusion criteria:

- Studies prior to the year of 2010.
- Studies that do not have full text.
- Studies that do not refer to teaching and learning.
- Replicated studies.

When there was doubt about the inclusion of the paper it was maintained.

3 CONDUCTING
During this step the papers search and selection were realized.

3.1 Search String
The search string was defined from the research questions, using the following terms and synonyms:

- Pedagogy: education, learning, teaching, didactic.
- Requirements engineering: requirements; software engineering.
- Experience: experiences, experience report, methodology, methodological skills, method, competencies.

Terms and synonyms used resulted in the following search string:

(pedagogy OR education OR learning OR teaching OR didactic) AND ("requirements engineering" OR RE OR requirements OR “software engineering”) AND (experience OR experiences OR "experience report" OR methodology OR "methodological skills" OR method OR competencies)

3.2 Search Strategy
The strategy used to select the research papers was conducted in three steps. In the first step, the papers were collected from the scientific databases using the proposed search string and from the specialist consultation. Professor Yvonne Sedelmaier has indicated the following four papers:

1. A Software Modeling Course at the Age of Three [33].
2. Using Business Process Models to Foster Competencies in Requirements Engineering [35].
3. Practicing Soft Skills in Software Engineering [34].
4. A Multi-Level Didactical Approach to Build up Competencies in Requirements Engineering [32].

Two of the papers indicated by Dr. Sedelmaier (papers [35] and [32]) had already been included from the search string. Paper [33] was published after the selection of papers in the scientific databases and the studies [34] because it was a book chapter was not in the scope of the research. Paper [33] and [34] were added to the research. At the end of first step, a total of 982 studies were returned of which 26 were replicated and therefore were removed, resulting in 956 studies.
In the second step the titles, abstracts and keywords of the papers were read. At the end of this step, 320 papers were selected. The last step involved reading the introduction and conclusion of the papers, giving a total of 86 papers that were fully read. Table 2 shows the results of the papers selection during the three steps.

**Table 2. Summary of the papers selection.**

<table>
<thead>
<tr>
<th>Resource</th>
<th>First step</th>
<th>Second step</th>
<th>Third step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elsevier - Science Direct</td>
<td>173</td>
<td>144</td>
<td>2</td>
</tr>
<tr>
<td>ACM</td>
<td>270</td>
<td>91</td>
<td>27</td>
</tr>
<tr>
<td>IEEE</td>
<td>285</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>Wiley Inter Science</td>
<td>29</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>REET</td>
<td>17</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>RBIE</td>
<td>170</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>Project Evelin</td>
<td>10</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Specialist consultation</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>956</strong></td>
<td><strong>320</strong></td>
<td><strong>86</strong></td>
</tr>
</tbody>
</table>

4 REPORTING

The papers read in full were distributed among four researchers; frequently they have discussed in pairs the papers that were read. When the reading of an article was completed, a worksheet was filled with the correspondent data; this guaranteed a coherent summary of all articles, available for all the researchers.

The questions answered for each paper are shown below.

1. Is student motivation addressed in the study? How?
2. Is there any use of educational software/games? Which are?
3. What teaching and learning problems are mentioned in the paper?
4. What skills and competencies are expected of the student at the end of the course?
5. What benefits and limitations are being reported by using the proposed approaches?
6. What are the research institutions/countries involved in related research?
7. Which requirements engineering steps were covered by the proposal?
8. What is the paper learning approach (see Table 3 for the available alternatives)?
9. What is the assessment perspective (see Table 4)?
10. Which types of evaluation are used (see Table 5)?

At the end of the reading, one of the researchers reviewed all the articles, and contacted other researchers when he had doubts.
Table 3. Learning approaches. Adapted from [12].

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active learning (general)</td>
<td>General term that refers to several models of education that focus the responsibility of learning on learners. This classification was used when there was no specification of the type of active learning that was being used.</td>
</tr>
<tr>
<td>Case-based learning</td>
<td>Approach where students develop skills in analytical thinking and reflective judgment by reading and discussing complex, real-life scenarios organized by the teachers.</td>
</tr>
<tr>
<td>Game-based learning</td>
<td>Learning that involves students in some sort of competition or achievement in relationship to an educational goal. Attempts to increase student motivation by providing a playful environment.</td>
</tr>
<tr>
<td>Peer/Group/Team learning</td>
<td>Educational practices in which students interact with other students to attain educational goals.</td>
</tr>
<tr>
<td>Problem-/Project-/Inquiry-based learning</td>
<td>A collection of approaches that use projects or problems to drive the learning process. Students learn about a subject through the experience of problem solving, by working in groups with the help of facilitators.</td>
</tr>
<tr>
<td>Studio-based learning</td>
<td>Students undertake a project under the supervision of a master designer. It uses a learning cycle of construction, presentation, critique and response, that is repeated until project completion.</td>
</tr>
<tr>
<td>Not specified</td>
<td>None is mentioned in the paper.</td>
</tr>
</tbody>
</table>

Table 4. Assessment Perspective. Adapted from [12].

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student perspective</td>
<td>Students assess their learning by either self- or peer evaluation.</td>
</tr>
<tr>
<td>Faculty perspective</td>
<td>Students are assessed by faculty or teaching assistants.</td>
</tr>
<tr>
<td>Product perspective</td>
<td>Specific criteria are defined to assess students’ products.</td>
</tr>
<tr>
<td>Does not apply</td>
<td>Work is not related to an experience where assessment is necessary.</td>
</tr>
<tr>
<td>Not specified</td>
<td>No assessment is mentioned in the paper.</td>
</tr>
</tbody>
</table>

Table 5. Assessment Types [12].

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exams</td>
<td>Students are assessed by means of written exams.</td>
</tr>
<tr>
<td>Reports</td>
<td>Students should write a report for assessment.</td>
</tr>
<tr>
<td>Software artifacts</td>
<td>Students are assessed through developed software artifacts.</td>
</tr>
<tr>
<td>Interviews</td>
<td>Interviews are conducted to assess learning.</td>
</tr>
<tr>
<td>Seminars</td>
<td>Students are assessed by their performance in seminars.</td>
</tr>
<tr>
<td>Portfolio</td>
<td>Students should produce a portfolio as result of their work.</td>
</tr>
<tr>
<td>Exercises</td>
<td>Students are assessed by means of exercises.</td>
</tr>
<tr>
<td>Surveys</td>
<td>A survey is conducted to assess learning.</td>
</tr>
<tr>
<td>None</td>
<td>No assessment instrument is mentioned in the paper.</td>
</tr>
<tr>
<td>Does not apply</td>
<td>Work is not related to an experience where assessment is needed.</td>
</tr>
</tbody>
</table>

4.1 Threats to Validity

Although the protocol has been followed as faithfully as possible, there are some threats to the validity of the research:
5 DATA ANALYSIS

Among the selected papers, this research found relevant data to answer the proposed research questions. In this section, we discuss the answers to our 4 research questions.

5.1 RQ1: What are the teaching and learning problems mentioned?

Requirement Engineering discipline have been widely introduced in most of the software engineering curricula as an obligatory course at the universities [23]. The importance of requirements engineering for software systems development has been known for decades. This relevance led educators to employ different ways for creating an environment in which the students were able to learn and practice requirements skills. However, on our days, the discipline continues to be a challenge in the software development process, being one of the most common causes of project failures. In practice, teaching and learning requirements engineering is not so simple.

The main challenges were: practical understanding of theoretical concepts (38 studies), gap between academia and industry (15 studies), skills development (12 studies) and work with globally distributed teams (6 studies). See details next.

1 Practical understanding of theoretical concepts: teaching RE requires the transference of fundamental knowledge about the activities, concepts, methods and techniques required to obtain, model, analyze, document, validate and manage requirements for software systems. However, teaching RE in a classroom is challenging because nontraditional didactic approaches are needed. To clearly demonstrate the need for RE involves exposing students to realistic sceneries in which they are able to experience the sensations of a real project such as fear and joy.

2 Gap between academia and industry: preparing computer science students to be software engineers that will work in the industry is a challenging task. The gap between the knowledge taught in academy and the needs of the industry is currently one of the major challenges of teaching and learning requirements in software engineering.

3 Development of important skills for RE: one of the characteristics of software development is the critical need for teamwork of people with different skills and levels of knowledge [9]. Universities, which are educating computer science professionals, have an important responsibility in developing professional skills for their students. Among the challenges found, the following can be highlight: communication, team management, time management and problem solving.

4 Difficulty in working on distributed teams: distributed software development, with teams located in different locations, represents a new challenge for requirements engineering. This scenario is highlighted by the constant increase of software developed in this way [21].

5.2 RQ2: What strategies are being used for teaching and learning RE?

Throughout the reading of the studies the following points were analyzed: the learning approaches (according Table 5 in section 4), the assessments (according Tables 3 and 4 in section 4), and software, platforms and games used to support teaching.

- Learning approaches: most of the studies (58.1%) used the Problem-/Project-/Inquiry-based learning approach for teaching the discipline of requirements. Of this works, 50% reported the main discipline learning problem is the practical understanding of concepts.

- Assessments: among the papers that cited learning assessments, 95% reported that assessments were conducted by teachers. However, most papers carry out evaluations based on various materials such as: documents produced by students and/or working groups, presentations, reports, etc. None of the studies reported the evaluation being performed based solely on exams.
• Software, platforms and games: 53.5% of the papers cited the use of some software to support the teaching of requirements such as:
  o Modeling tools;
  o Learning platforms (15.1%); 3 papers use Moodle as a learning platform [6], [17] and [19];
  o Simulators or games (only eight studies): Hoffmann et al. propose the use of the RE-O-Poly board game [1]; Liang et al. the Role playing game [23]; Lima et al. suggest the UbiRE game [29]. In [10], the authors propose SimVBSE, qGame and TREG simulators for use in learning requirements.

5.3 RQ3: Do papers mention the motivation of the students in the studies?

Among the selected studies, not all specifically mention treating students' motivation; although, there some report the use of strategies to keep students interested in the discipline. Creating a more realistic and challenging environment was the most cited way to maintain student's motivation. Motivation alternatives for the students include: help to develop teamwork, create responsibility, and encourage collaboration.

In general, studies report that students are unmotivated in learning requirements engineering. Students complain that the content of this discipline is boring with no opportunities to practice the methods learned in the classroom, as in other disciplines such as programming language, database, etc [23] based only in document writing.

The following are some mentioned ways of motivating students:

• Assign grades to students was considered very important as an incentive for student engagement during the course [32] [33] [14] [8].
• Create a more realistic and challenging environment, where the student can contribute in big projects, instead of different instances of small projects or previous courses [5] [34].
• Promotion of teamwork, in which each group has at least three students. In that way, if during the course a student quits the discipline, the remaining team members can continue [21].
• Use games of interest to students in the classroom [10] [28] [20].
• Create competitions between groups. In general, competitions and awards are attractive and encouraging not only to students and teachers, but also to the people in the industry who appreciate the work of the students [6] [16] [22].
• Use of different teaching techniques, such as classroom discussion, seminars, practical exercises and role-playing games (RPG - Role-playing game) [23] [27].
• Favor autonomy and team collaboration by allowing students to create their work groups and designate their leader and work rules, being responsible for their decisions [7].
• Use topics of interest to the students for projects such as game creation, web technology projects etc [30] [31].
• Check student motivation regularly, for example, through a questionnaire or meetings. In this way, students can talk about the challenges and frustrations they have experienced and whether they are comfortable with the course or not. So, it is possible to make small adjustments during the discipline [11] [15].

5.4 RQ4: Which countries and research institutions are involved in related researches?

There were 30 countries and 99 research institutions involved in writing the selected papers. Germany and the United States were the countries with the highest percentage participation in the studies; together these countries represent 40.9% of the total articles.

Considering the research institutions involved, the University of Applied Sciences and Arts Coburg (Germany) was the institution with the highest number of papers among the selected studies [5] followed by the University of Potsdam (Germany) with 6 papers.
6 CONCLUSIONS

Applying requirements engineering requires multiple skills and covers a number of challenges. In order to deal with several stakeholders, it is necessary for the student to be able to hear, understand and consolidate clearly the needs of all those involved. Also, having the ability to create and imagine the system with all the connections, verifying the impacts with the existing systems and on people’s lives.

In this paper, a systematic literature review was conducted to understand the context about RE teaching and learning. This research generates evidence that the problem of teaching and learning of RE is mainly related to the understanding of the fundamental concepts and how to put it into practice; the involved complexity in these activities arises a low interest of the students in the discipline. To mitigate these problems some techniques were mentioned, such as exposing students to a more realistic and challenging environment, trying to generate a more attractive and practical learning.

Regarding the learning approach, most of the papers cited the use of Problem-/Project-/Inquiry-based. Studies show that the use of active methodologies, such as this, in classrooms is more effective than traditional teaching. Strobel et al. found the use of problem-based learning outperformed traditional one [18]. Therefore, the result of our study shows that the teaching of Requirements Engineering is following pedagogical trends of progressive education. Another important point, also related to the use of more up-to-date theories, is that all papers propose the evaluation of the students through the use of more alternative ways, not only tests.

Considering the working groups, we only found in Germany the Evelim project (Experimental improvement of learning software engineering). This project was created and supported by the Federal Ministry of Education and Research of Germany and aims at improving the teaching of software engineering at universities. In Germany we also see cooperation between universities and between other countries. Although we have a greater number of articles from this country, many universities have contributed on this publishing. There are articles written with countries such as the Netherlands [2], [1] and Canada [4]. In particular, University of Applied Sciences and Arts Coburg, University of Potsdam and University of Applied Sciences Aschaffenburg, had the largest number of publications in the area.

This study mainly contributed to the identification of teaching and learning strategies that are being used in RE and the main ways to motivate students in the discipline.

ACKNOWLEDGEMENTS

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REFERENCES


