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A Survey of Instructional Approaches in the Requirements Engineering Education Literature

Marian Daun
The Ruhr Institute of Software Engineering
University of Duisburg-Essen
Essen, Germany
marian.daun@paluno.uni-due.de

Alicia M. Grubb
Department of Computer Science
Smith College
Northampton, MA, United States
amgrubb@smith.edu

Bastian Tenbergen
Department of Computer Science
State University of New York at Oswego
Oswego, NY, United States
bastian.tenbergen@oswego.edu

***Abstract*—Requirements engineering (RE) has established itself as a core software engineering discipline. It is well acknowledged that good RE leads to higher quality software and considerably reduces the risk of failure or exceeding budgets of software development projects. Therefore, it is of vital importance to train future software engineers in RE and educate future requirements engineers to adequately manage requirements in various projects. However, to date there exists no central concept of what the most useful educational approaches are in RE education in order to best interweave theory with practice. To lay the foundation for this important mission, we conducted a systematic literature review. In this paper, we report on the results and provide a synthesis of instructional approaches in RE education. Findings show that experiential learning through projects, collaboration, and realistic stakeholder involvement are among the most promising trends to teach both RE theory and develop student soft skills.**

***Index Terms*—Requirements Engineering, Requirements Engineering Education, Systematic Literature Review, Learning Outcomes, Educational Approaches, Pedagogy.**

I. Introduction

Requirements engineering (RE) is commonly accepted as the foundation of high-quality software [1]. Teaching good RE practices in university education is not only important to ensure industry-ready students but is also mandated by accreditation standards [2] and standard curricula [3]–[5]. Given this mandate, educators can use the Software Engineering Body of Knowledge (SWEBOK, [6]) as guidance for the content for RE modules. Similarly, when it comes to industrial training, practitioners can benchmark their training against the certificates issued by the International Requirements Engineering Board (IREB, [5]). Thus, within the RE community, there is a common understanding of what is part of good RE and should therefore be taught.

RE is a socio-technical, iterative process to elicit, document, and manage the requirements of a system under development [7]. RE education must not only teach students how to specify formal and informal requirements but also how to uncover and negotiate conflicts between requirements from different sources—particularly human stakeholders. Thus, RE education must make students aware of the socio-technical challenges and human-related aspects. This human component results in the mixing of instructional approaches with RE techniques and leaves RE education in a special position compared to the majority of technology-centered learning subjects in academic degree programs. In consequence, it is not only important for RE instructors to know *what* to teach, but also *how* to teach it.

This work complements prior literature surveys in the field of software engineering (SE) education at large [8]–[11], only one of which pertains to RE education. This study by Ouhbi et al. [10] concluded data collection in 2012 and compared current RE education approaches against the knowledge areas specified in the accreditation standards, curricula, and bodies of knowledge introduced above. As Ouhbi et al.'s work demonstrates, RE education literature has yet to create a common foundation for suitable instruction of RE content. Yet, an investigation on instructional approaches was beyond the scope of their work.

In this paper, we investigate what *educational approaches* are currently used and most effective in RE education and who benefits from this instruction. We define educational approaches as "[t]echniques and methods used for teaching and learning, as well as classroom characteristics which may affect teaching and learning" [12]. We use the terms *instructional approach* and *educational approach* interchangeably.

> *The* **research goal of this paper** *is to synthesize best practices in educational approaches for RE Education by analyzing current trends in literature.*

To achieve this goal, we contribute a systematic literature review (SLR) of the field of RE education. Our findings enable researchers and educators to gain an overview of the current state of the art and distill an instructional approach that suits their needs to deliver learning outcomes more efficiently, laying a foundation for a RE education "toolbox" for instructors.

The paper is structured as follows. Section II discusses studies related to RE education. Section III explains in detail our search method, knowledge extraction and data analysis procedure. In Section IV, we first discuss quantitative results to get an impression of the field of RE education. Subsequently, Section V qualitatively synthesizes findings regarding trends in instructional approaches. Qualitative and quantitative results are discussed in Section VI. Section VII concludes this paper.

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II. Related Work

A series of reports were published over the past 20 years into the state of the art of software engineering (SE) education. While not focusing on RE education per se, they included relevant observations about the field. In one of the earliest, Mary Shaw [13] argued that SE education should begin at the undergraduate level and not—as was common until then—at the graduate level. Shaw identified "forces" impacting the SE industry and derived "aspirations" for higher education. Shaw aspired for SE education to include the need for novice software engineers to specialize into roles and sub-fields (e.g., RE). Shaw foresaw that systems would increasingly be entrusted with safety-critical functionality and stressed that SE educators take an experience-based stance to enable learners to put theory into practice.

As pointed out by Regev et al. [8], undergraduate RE education was slow to address Shaw's aspirations. This was mainly due to discrepancies between project-based learning common in higher education and industry-typical experiences. According to Regev et al., conventional academic classroom projects poorly translate to the industry because of the "sterile" nature of these projects, which inadequately reflect industrial practice. The authors attribute this to the fact that academic projects must be narrow enough in scope such that they can be solved within one semester by a small number of students, where the students do not have prior knowledge in the application domain.

Three systematic mapping studies by Malik and Zafar [9], by Ouhbi et al. [10], and by Cico et al. [11] were conducted from 2012 until quite recently in 2020. Cico et al. [11] do not place particular emphasis on RE education. Malik and Zafar report that while some of the mapped primary studies are concerned with project-based learning, the vast majority are concerned with educational technology and tools. Moreover, none of the 70 studies mapped by Malik and Zafar could be easily classified into the knowledge area "Requirements Engineering" according to the reference curricula available then (i.e., "Knowledge Area A" in [14] or "Knowledge Area C" in [4]). This indicates that RE education research was incongruent with reference curricula and that SE education research largely ignored RE as a topic. The work by Ouhbi et al. is more focused on RE education and reveals a similar trend: only 19 out of 79 mapped primary studies mention reference curricula. The vast majority of papers (77%, see [10]) present solution proposals agnostic of reference curricula and only a minority describe some evaluation of existing approaches.

In summary, past studies investigating the state of the art of RE education have been conducted and published in loose intervals. Since the newest RE education specific study conducted by Ouhbi et al. [10] stems from 2012, we expect the RE education field to have evolved in light of changes within the RE field driven by new technologies. Therefore, in this paper we provide an up-to-date investigation of the current state of RE education with particular focus on *how* to teach RE, rather than *what* to teach about, as previous studies did. Moreover, we seek to complement Ouhbi et al.'s mapping study [10]. In contrast to their work, which placed particular focus on standard curricula and how they have been addressed by RE education literature until 2012, our goal is to survey the field and compile a list of trends in promising instructional approaches.

III. Research Method

We followed the guidance of Kitchenham et al. [15] in the design of our systematic literature review (SLR).

A. Research Questions

To contribute to the goal of this study from Section I, we define the following research questions for the SLR:

- RQ1 What is the number of papers in the area of RE education published each year?
- RQ2 What are the research methods in research about RE education?
- RQ3 Who are the learners (e.g., pre-college, undergraduate, or graduate students, or industry professionals)?
- RQ4 What are trends in instructional approaches used in RE education?

We use the answers in RQ1–RQ3 to give context to RQ4, which allows us to synthesize the contributions and current trends in the field and to derive the common practices for RE education.

B. Search Procedure

We conducted a database search using broad search terms (i.e. *Requirements Engineering* AND *Education* in the area of *Computer Science*) to lower the risk of missing relevant papers. We specifically excluded "training" and "learning" from the search string as pilot testing the search string with these terms yielded a sizable number of machine learning and artificial intelligence approaches to be included in the results. Similarly, we excluded "teaching" from the search string as this term yielded a many results pertaining to teacher education not specific to computer science. Both of these areas were considered beyond the scope of this study.

We searched using Scopus, as it indexes many publishers, including the most common publishers of computer science research (e.g., ACM, IEEE, Elsevier, Springer, etc.). Unlike Google Scholar, Scopus allows filtering non-peer reviewed publications. The search string above was developed based on the goal and research questions outlined in Section III-A, as is commonly done in SLRs [15], [16].

C. Study Selection

The search was conducted by three different researchers who evaluated each paper based on the inclusion and exclusion criteria (see Table I) on their own. We considered papers published at any time until December 31, 2020. Papers were *included* in the set of relevant papers if all researchers found the paper relevant. Papers were *excluded* if all found the paper irrelevant. In cases of inconsistent perceptions of the paper's relevance, the paper was discussed among the researchers until agreement was reached.

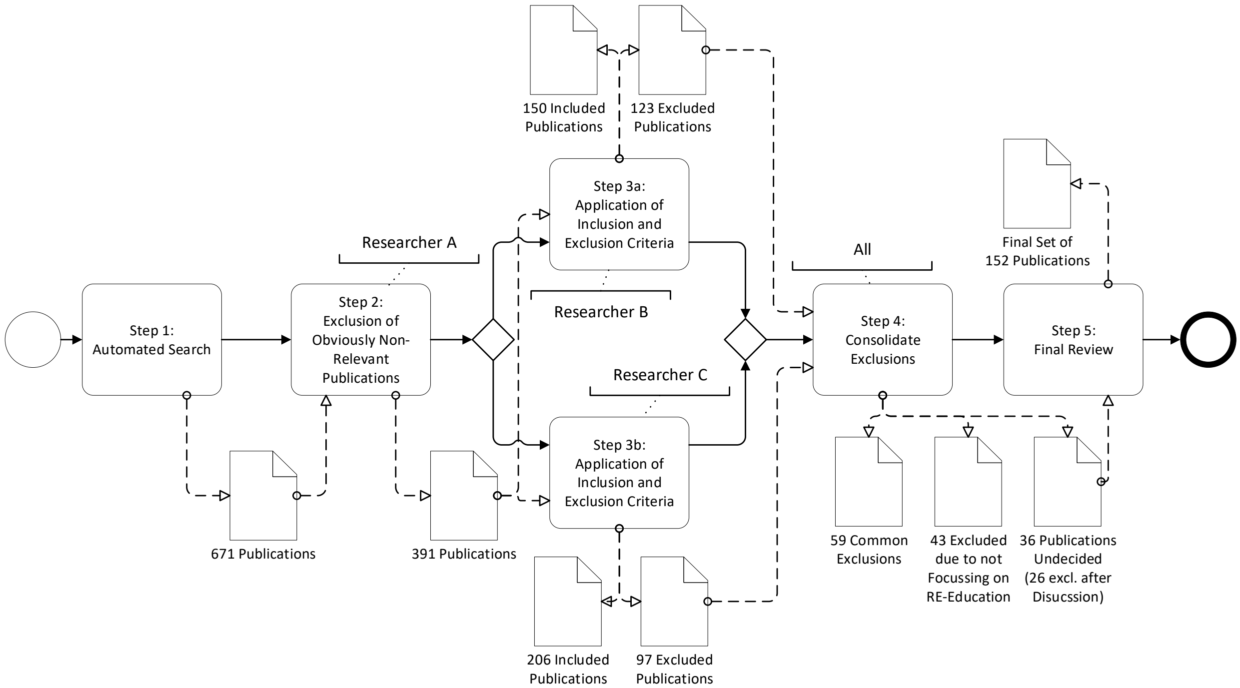

Fig. 1: Study Selection Process

TABLE I: Inclusion and Exclusion Criteria

Inclusion Criteria
• Published in a peer-reviewed journal or conference/workshop proceedings • Focus on requirements engineering education
Exclusion Criteria
• Papers not focused on education • Papers about requirements for engineering education • Focus on requirements engineering for education systems • Introductory papers for special issues, conferences, or workshops • Publications shorter than three pages • Publications not written in English • Full text neither available online nor via inter-lending

Figure 1 shows the process of step-wise exclusion of studies to derive the final set of included studies. In summary, we identified 671 candidate papers, from which we excluded 519 papers. Resulting in the final set of 152 included publications[1].

D. Data Extraction

For RQ1, we extracted each paper's meta-data from Scopus. For RQ2–RQ4, each included paper was read carefully by all researchers to extract data pertinent to the research questions. Researcher B and C began the analysis. Whenever there was disagreement between the two researchers, Researcher A evaluated the paper and the resulting classification was determined through discussion. In a final validation step, Researcher B and C reviewed all selections, classifications, and extracted data, discussing discrepancies and alternatives. Conflicts were resolved through mutual agreement of all researchers or by classifying a study in more than one category (if permitted by the associated RQ).

[1]The data set is available at: doi.org/10.35482/csc.003.2021

E. Quality Assessment

The application of qualitative quality assessment criteria is often seen as error prone and may, therefore, result in the erroneous exclusion of papers [17]. Thus, in contrast to [10], we follow a commonly suggested quantitative approach to quality assessment by only including publications that have been peer-reviewed. Our quality assessment criteria are established by the inclusion and exclusion criteria listed in Table I.

F. Analysis and Classification

For RQ1, we extracted publication year metadata from Scopus. For RQ2-RQ4, we read the papers and used word-tags (i.e., simple nouns or adjectives that describe the content of the paper) to identify common themes for synthesis. We discussed our findings and grouped selected studies into appropriate categories. For RQ2, we relied on a commonly accepted category list provided by [18] (see list in Table II). We used a predefined set of categories for RQ3 (see Figure 3) to classified the papers depending on the type of learner mentioned, if any.

TABLE II: Classification of research methods used for RQ2 (provided in [18]).

Type of Research Method	Description
Evaluation research	Examines a problem or an implementation of a technique in practice.
Proposal of a solution	Proposes a solution technique and demonstrates why it is relevant without offering a sound validation.
Validation research	Investigates of a proposed solution through a sound validation method such as experiment, for example.
Philosophical papers	Suggest a new outlook on something.
Opinion papers	Report the personal opinions of the authors.
Experience papers	Report the personal experience of the authors.

Each paper was potentially tagged with multiple word-tags, but only ever mapped to exactly one category. Finally, rather than starting from a pre-defined list for RQ4, we generated our own list of word-tags (e.g., "game", "collaborative", or "industry-centric") throughout the review process. We used an inclusive definition of educational/instructional approaches (see Section I) as many of these approaches arose from the study of active learning techniques [19].

Categorization was not always clear. For instance, in RQ2 evaluation research and validation research differ depending on completeness and rigor of the evaluation. Hence, making a clear distinction can be difficult. In these cases, if any two researchers classified a paper differently, the proper word-tags and category was selected using the conflict resolution process outlined in Section III-D, considering the contributions stated in the paper. We disregarded any activity which was hinted at, yet not reported on. Each paper was assigned the tags and category that fit best, taking into account follow-up papers by the same authors, in which case we occasionally classified the earlier paper into the less rigorous category, while using the same tag.

G. Validity Evaluation

Some threats to validity for SLRs from [20] pertain to this work and were mitigated as follows.

1) Descriptive validity: Misclassification of papers may lead to threats to descriptive validity. Therefore, we built our classification to a large extent on existing and accepted classification schemes. Furthermore, we classify papers as intended by the authors (e.g., type of research contribution), which have been substantiated in the peer review process, to avoid threats from misinterpretations, and applied a rigorous n-fold cross validation approach among three researchers as outlined in Section III-D. Nevertheless, it cannot be completely ruled out that we erroneously classified certain papers. However, given our rigorous approach and large amount of selected studies, we assume this occurred rarely enough, if at all, such that our findings do not misrepresent the field.

2) Theoretical validity: A major threat in this category typically stems from selection bias. To avoid this bias, we defined objective inclusion and exclusion criteria and applied them rigorously. Inclusion and exclusion criteria were applied independently by two different researchers, with a third researcher validating the choices. Also, the classification was done by two researchers independently, again with a third conducting quality assurance. In case conflicts in the inclusion/exclusion or classification of a paper arose between any two researchers, a another researcher was involved, and the conflict was solved by discussion among all researchers, switching roles between "classifier" and "validator" in order to help each individual maintain an objective point of view.

TABLE III: Data for RQ2: Research Methods and RQ3: Type of Learners.

(a) RQ2: Research Methods

Method	Count
Solution Proposal	68
Experience Report	40
Evaluation Research	18
Validation Research	15
Philosophical Paper	9
Opinion Paper	2

(b) RQ3: Type of Learners

Group	Count
Undergraduate	44
Graduate	21
Postgraduate	3
Industry Practitioners	17
Unspecified Student	52
Other / Unknown	15

3) Generalizability: Generalizability of the findings deals with the question whether the set of papers included into the SLR are representative and do not miss important aspects. Comparison with previous secondary studies on RE education outlined in Section II indicates that we did not miss a considerable number of relevant primary studies to be included, but instead took a wider approach. Nevertheless, not all educators document their instructional approaches, so the reported literature may not represent a complete picture.

4) Repeatability: To ensure repeatability, we report the search and selection process as well as the inclusion and exclusion criteria in sufficient detail to enable other researchers to verify our work. We make our data available for other researchers[1]. Additionally, abstaining from applying qualitative exclusion criteria improves repeatability. However, as is commonly the case for SLRs, it cannot be ruled out that different researchers might have classified some of the papers in some cases into different categories, especially during the synthesis portion of our data analysis. Since we have a large number of included publications, we are confident that this would not alter the implications of our findings.

IV. Quantitative Overview of Findings

In this section, we present the quantitative findings for RQ1–RQ3, and connect these findings to examine trends over time (RQ4). This quantitative data sets the context for our synthesis of approaches to fully answer RQ4 (see Section V) and our discussion of broader implications (see Section VI).

A. RQ1: Published Papers Per Year

We begin by addressing part of the question in RQ1: "What is the number of papers in the area of RE education published each year?". Figure 2 shows the distribution of publications by

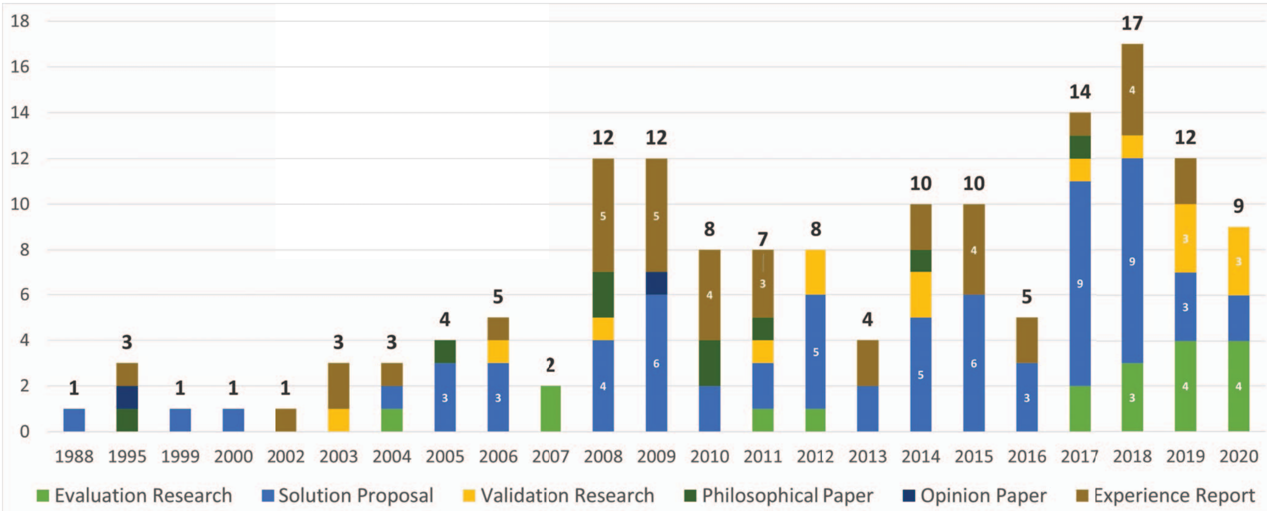

Fig. 2: Publications and research methods per year. Each bar represents one year, with cumulative counts of publications per year (RQ1) listed at the top of each bar. Bars are sub-divided by research method (RQ2) to illustrate changes in research methods over time. Counts added for subdivisions with three or more papers to increase readability.

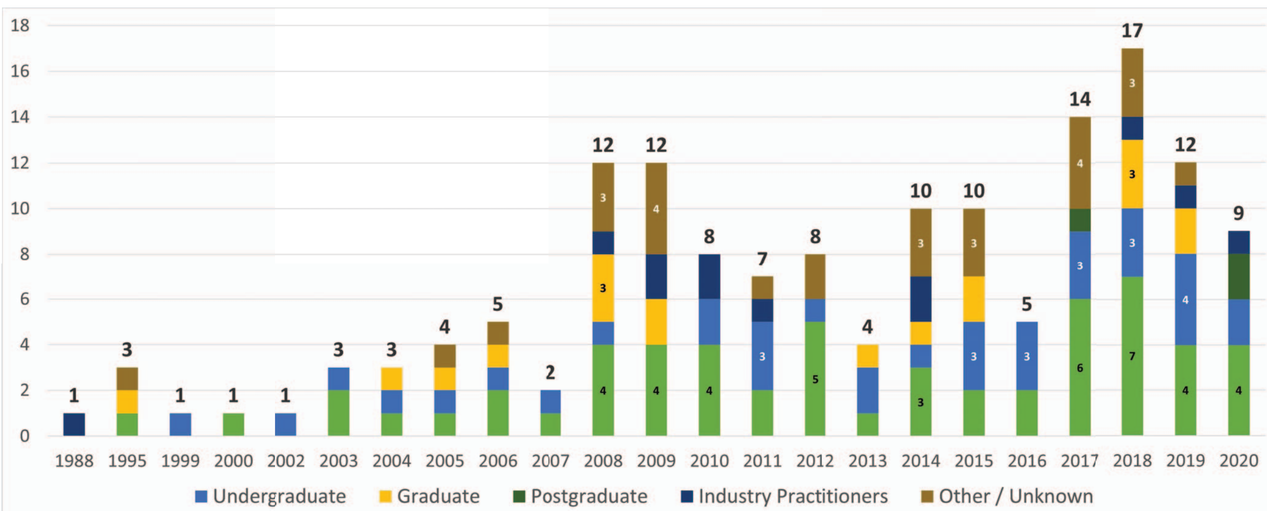

Fig. 3: Publications separated by type of learner per year. Each bar represents one year and is sub-divided by type of learner (RQ3) to illustrate which learners are studied in the literature over time. Counts added for subdivisions with three or more papers to increase readability.

year, where each full bar represents the number of publications in a given year (see counts on top of each bar). As can be seen in Figure 2 research on RE education started slowly in the beginning with only four papers between 1988 and 1998. From 1999 to 2007, few papers were regularly published. Publication counts increase considerably after 2007.

This is consistent with findings reported by Malik and Zafar [9] (see Section II). Since 2008 publications in RE education have considerably increased, reaching a maximum of seventeen publications in 2018. Thus, RE education has gained interest since the work conducted in [9], [10] and its importance is shown with still increasing numbers of publications each year.

B. RQ2: Research Methods

Next we consider RQ2: “What are the research methods in research about RE education?” We evaluated the included papers based on the type of research presented (i.e., the underlying research method), as categorized in Table II. Table III (a) lists the results. The vast majority of publications either gives solution proposals (68) or experience reports (40). In contrast, evaluation research and validation research is only conducted sparsely: while there exists a plethora of approaches aiming at improving RE education and a variety of personal experience reports, more thorough empirical investigations of the field are missing.

Thus, we consider the maturity of the field to be low, which can be mitigated by either exploratory evaluation studies or thoroughly validated solutions.

C. RQ3: Learners

RQ3 looks at which types of learners are observed in the literature. We group learners into four categories: undergraduate, graduate, and postgraduate students, as well as industry professionals. We also include two additional categories, one for papers that did not specify which level of student (e.g., undergraduate or graduate) and another for papers that do not study a group of learners (e.g., philosophical papers). Table III (b) lists the distribution of the emphasized audience of teaching approaches as stated by the included publications. The vast majority of papers (over 100) clearly address university students, of these are 44 that study undergraduate students (i.e., bachelor-seeking), 21 focus on graduate students, 3 on postgraduates, and 52 do not further specify the level of the learner (see *Unspecified Student* in Table III (b)). Seventeen papers address teaching industry professionals. Fifteen papers were counted as *Other* or *Unknown*. This category includes one paper that places emphasis on RE education at the high-school level and another one that investigates RE knowledge in alumni, as well as thirteen papers that omit any audience. We suppose that some of these omissions address university education and that authors did not explicitly mention the audience because it was considered obvious. The lack of information regarding the target audience also indicates immaturity of the field, as established standards (e.g., [21]–[23]) for reporting research are not strictly adhered to.

D. RQ4: Trends in Instructional Approaches Over Time

To distill trends in instructional approaches reported in RE education literature, we return to RQ1 and investigate the publication rate of papers classified for RQ2 and RQ3 over time. To this end, we have included quantities of papers classified for RQ2 and RQ3 proportionally for each year in Figure 2 and Figure 3, respectively. These considerations will assist in further synthesizing trends in approaches in Section V.

As can be seen in Figure 2, the relative amount of solution proposals has steadily increased since roughly 2004. However, validation and evaluation research has not seen a corresponding increase at the same rate, albeit marginally more papers have been published each year since around the same time. As Table III (a) suggests, experience reports are the predominant type of evidence produced by RE education literature, with publication numbers per year slightly increasing over time. Philosophical papers are only sporadically published. There is a recent increase in opinion papers since 2017, which is surprising. We expect that as a field matures over time, there are fewer opinion papers and more validation and evaluation research. Yet, this is not the case, further indicating a lack of maturity in the field. The comparatively high amount of evaluation papers in later years might be confounded by the recent body of work from a small cluster of authors in short succession [24]–[27].

Figure 3 shows that there has been a sudden and significant increase in approaches targeting undergraduate learners since 2008. Between 2000 and 2007, the years following Shaw's call for role-specific undergraduate SE education [13] (see Section II), the number of approaches targeting undergraduate, graduate, or "unknown" students was roughly equal. Since 2008, the number of studies specifically targeting undergraduates has steadily increased. However around the same time, the number of studies not mentioning students specifically and the number of "unknown" student types increased in parallel. As well, in the same time frame, there was an increase in publications targeting industry professionals.

We conclude from this that RE education in recent years pays increasing attention to undergraduates. Yet, proposed approaches are largely unvalidated and unevaluated, relying mainly on qualitative and experiential evidence to demonstrate efficacy. In responding to RQ4 in the next section, we discuss in what way these trends relate to instructional approaches.

V. Synthesis of Instructional Approaches

In this section, we synthesize instructional approaches in further response to RQ4: "What are trends in instructional approaches used in RE education?". To do so, we completed a qualitative classification of the publications included in our SLR (see Section III-F). We considered multiple axes of analysis, including the focus of each paper and whether it centered around individuals, technology, or a process, as well as whether learners engaged in collaborative or individual learning. Additionally, we considered emergent topics (e.g., games), types of assessment (e.g., low-stakes [28], [29]), and whether the researched aimed to improve soft skills of the learners. These results are listed in Table IV, with counts given for each tag we identified while coding. Papers may have been assigned more than one tag, thus the total number of tags in Table IV is greater than the total number of papers. For example, a tool paper focused on industry may be labeled as both "industry-centric" and "technology-centric" (e.g., [30]).

Synthesis of our findings across all word-tags allows us the identification of three major trends in instructional approaches for RE education. These themes emerged from the analysis and classification discussed in Section III-F:

- Project/Problem-based Learning and Collaboration
- Soft Skills, Role Playing, and Stakeholder Involvement
- Games, Gamification, and Simulation

In the following subsections, we discuss each of these themes in detail. Throughout this section and Section VI, we cite papers from our list of included publications. In some cases we identify all papers that satisfy a specific criteria, whereas in other cases, we give only a few examples. However, not all included papers are listed in the References section. We refer the reader to our supplement[1] for the full list of included papers and their classification.

A. Project/Problem-based Learning and Collaboration

The first theme that emerged from our SLR is the prominence of project- and problem-based learning. As listed in Ta-

TABLE IV: Types of Educational Approaches. Subcategories of soft skills (*) are listed in Figure 4. “Focus” refers to the nature of the educational approach, while “Topic” refers to the authors’ stated learning outcome.

(a) Contribution Focus

Focus	Count
method-centric	47
industry-centric	32
technology-centric	27
inquiry-based	20
instructor-centric	13
project-based	13
problem-based	9
no approach mentioned	22

(b) Contribution Topic

Category	Count
collaborative	29
individual	12
low-stakes	24
high-stakes	9
soft skills*	49
games	13
simulators	7

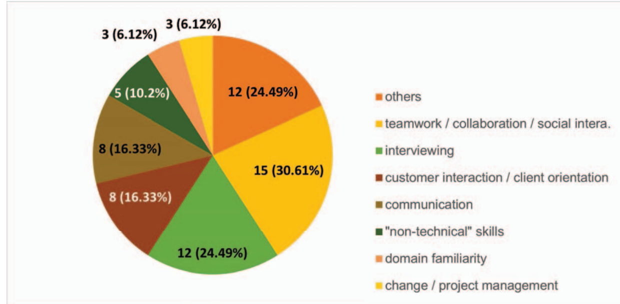

Fig. 4: Publications pertaining to Instruction of Soft Skills. Studies may target more than one soft skill. Percentages are relative to the amount of papers marked ‘*’ in Table IV (b).

ble IV (a), many publications are classified as either “industry-centric”, “project-based”, or “problem-based”. Industry-centric in this sense means that the proposed approach emphasizes industry-readiness or an industry-authentic experience for students. These experiences are frequently facilitated through the application of projects in conjunction with industry (e.g., [31]–[36]), but are also applied to non-governmental organizations [37], non-profit organizations [38], other external stakeholders (e.g., [39]), or simply use projects from other industrial contexts (e.g., [40]).

A second subset of publications classified as problem- or project-based use realistic constraints in an academic contexts to engage learners in an authentic experience of RE (e.g., [41], [42]), as well as using geographically distributed teams to collaborate on a single project (i.e., [33], [43]–[46]). These approaches are interesting as they address marketable RE soft skills in addition to addressing industry-readiness. Like most project-based approaches, these too aim at improving communication and collaboration, as well as time management and customer-orientation.

Together with eleven other project-based learning approaches (e.g., [47]–[50]) and six other problem-based approaches (i.e., [51]–[56]), we identified more than 40 individual studies (30% of all identified studies, not counting those tagged in more than one focus or category in Table IV) that employ a project-based, problem-based, collaborative, or some other type of low-stakes approach.

Looking at this data from a different perspective, many publications incorporate collaborative learning (see “collaborative” in Table IV (b)), but may not necessarily do so in an industry-realistic context (e.g., [43], [44], [57]–[64]). These approaches make use of case studies (e.g., [65], [66]) or games (e.g., [62], [67], [68]) to simulate RE phases. They are used to teach elicitation (e.g., [69]) or management skills (e.g., [31], [70], [71]), as well as modeling (e.g., [36], [72]–[74]) and formal methods (i.e., [75]–[77]). We also found evidence that these approaches tend towards using low-stakes assignments or small projects (see “low-stakes” in Table IV (b)), and focus on student soft skill development (see Section V-B) and the socially interactive aspects of RE.

We contrast these collaborative approaches with “inquiry-based” methods in Table IV (a), which refers to approaches aimed at students’ individual knowledge discovery (e.g., [30], [35], [78], [79]). Of these inquiry-based publications, only a minority (i.e., [32], [34], [80], [81]) make use of projects or low-stakes problem-based learning.

This suggests a trend away from instructor-centric instruction focusing on memorization of theory and individual high-stakes problem solving (e.g., through lectures followed by exams) toward an approach that promotes student-centric knowledge discovery and problem solving. Project- and problem-based learning may foster RE instruction while providing students with realistic industry-ready experience.

B. Soft Skills, Role Playing, and Stakeholder Involvement

The second theme that emerged from our analysis is that teaching RE must include strengthening students’ soft skills. Based on our analysis (see Table IV (b)), 49 publications include explicit instruction to improve the learners’ soft skills, which are sub-classified in Figure 4. As can be seen, the most frequently addressed soft skills are teamwork, collaboration, or social interaction (30.61% of the 49 approaches explicitly mentioning soft skills, e.g., [38], [40], [42], [43], [45], [58]–[60], [62], [82], [83]), interviewing skills (24.49%, e.g., [26], [29], [45], [79], [84], [85]), customer interaction or client-orientation (16.33%, e.g., [30], [74], [82], [83], [86]–[88]), and communication (16.33% of mapped approaches, e.g., [32]–[34], [46], [81], [89], [90]). Note that some of the studies reported in Table IV (b)) target multiple soft skills.

Most publications with soft skill development as a primary focus did so in the context of project-based learning. While, the majority of the studies identified in Section V-A propose unique approaches in each contribution, we found a secondary trend regarding the use of stakeholder involvement within these and other studies (e.g., non-collaborative, yet industry-centric approaches). Many of the projects involve consulting external stakeholders in realistic situations (e.g., [37]–[39], [63], [91]), while others involve the instructor or some other non-industry representative to engage in role-playing to create an industry-realistic project experience (e.g., [30], [34], [35],

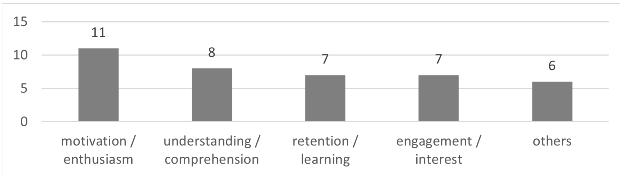

Fig. 5: Publications pertaining to improvement of student factors as stated by the authors.

[78], [79], [81], [92]). In most of these cases, stakeholders (either real or role-played) serve as a partner to help students with elicitation (e.g., [34], [93]) and management (e.g., [81], [94]) of requirements, as well as validation to some extent (e.g., [95]).

Hence, the main motivation in applying real or realistic stakeholders (including role playing) seems to be RE content delivery as well as soft skill development. Only one study (i.e., [35]) reports on positive benefits for students' attitudes to their own learning (specifically, using Wikis to improve student enthusiasm about the RE process). By contrast, we identified a total of 32 studies that motivate their approach specifically to improve student factors or report incidental improvement as evidence to its success. The most common factors reported were "motivation / enthusiasm" (34% of the 32 studies targeting student factors, see Figure 5, i.e., [35], [38], [40], [42], [50], [55], [64], [67]–[69] and [96]) and "understanding / comprehension" (25%, i.e., [50], [63], [76], [77], [90], [97]–[99]).

Recently, agile development has received a lot of attention throughout the SE literature [100]–[102]. Most studies focusing on collaboration and communication applied a project-centric and industry-centric (see Section V-A) learning environment that often employs agile methods. Yet, only two of the studies we surveyed specifically focused on agile as a soft skill (i.e., [103], [104]). While educators may consider agile to be a technique rather than a soft skill, this may be an opportunity for expanding soft skill development in RE education.

In conclusion, outside of collaborative approaches reported in Section V-A, using real stakeholders or using role playing to simulate stakeholder involvement is a key strategy to drive RE instruction. In doing so, soft skill development is the main goal, alongside RE theory instruction. Most commonly, social soft skills (e.g., teamwork, communication, or client orientation) are targeted by our surveyed studies. Open opportunities remain for the development of other soft skills throughout RE education, including technical soft skills (e.g., agile development).

C. Games, Gamification, and Simulation

Finally, the third theme that emerged from our analysis is that there is a prevalence of games, gamification, and simulations.

Despite the rising popularity of using games and gamification in education since around 2008 [105], and successful introduction in software engineering education at large [106], few (13, see Table IV (b)) of the selected studies propose games or gamification. We consider the following contributions to constitute this trend: [62], [67]–[69], [85], [96], [97], [107]–[111]. These papers differ greatly in almost all aspects. For example, Alami and Dalpiaz [67] and Yasinet al. [107] propose different games to foster security requirements engineering at large. Together with the contributions in [51], [65] and [112], which do not incorporate games, Alami and Dalpiaz [67] and Yasinet al. [107] are the only RE education contributions focusing on security requirements. Different games or modes of gamified instruction are proposed by Alexander and Beatty [108], Garciaet al. [68], [69], Rusu et al. [85], Soo and Aris [97], Vilela and Lopes [110], and Ibrahim et al. [111]. These solution proposals specifically target requirements elicitation (e.g., [68], [69], [85], [110], [111]) or the entire RE process (e.g., [97], [108]). Notably different are approaches proposed by Mayr [109], Oliveria et al. [96], and the aforementioned worked by Vega et al. [62]. Rather than proposing a gamified way or game designed to teach RE, the authors propose using existing games, i.e., "Monopoly" in the case of Oliveria et al. [96] or the social media game "Second Life" in the case of Vega et al. [62] to teach the RE process. Mayr's work [109] differs in this respect too, as it uses LEGO® serious Play™ to facilitate critical thinking and requirements validation and management.

Another interesting set of approaches proposes using simulators or simulation-type learning environments to instruct RE. We identified seven such studies, i.e., [29], [46], [57], [83], [113]–[115]. Some of these approaches use game-like constraints to reduce the solution space and guide students' knowledge discovery process (e.g., [57], [114]). In these studies, students are guided through the requirements elicitation process using collaborative projects (see Section V-A). In Minocha et al. [83] as well as Cybulski et al. [29] simulations are also used to foster requirements documentation and management, respectively. The work by Laiq and Dieste [115] takes a slightly different, albeit related approach. Instead of using constrained project/assignment rules or tools to simulate the RE process, Laiq and Dieste make use of a chatbot using a knowledge base to simulate real stakeholders (see Section V-B). Romero et al. [46], [113] also make use of simulation. Rather than looking at elicitation or interview skills, their approach considers the entire RE process to simulate distributed requirements engineering (like also in [83]) in socially distant development teams.

In conclusion, the commonalities among many instructional approaches outlined in sections V-A through V-C seem to be that RE is best instructed with experiential learning using collaborative approaches, real stakeholder interactions, or controlled environments simulating realistic experiences, rather than theory-heavy instruction. Doing so has the advantage of improving students' soft skills while also teaching RE theory. Specifically, role playing, games, gamification, and simulation can be a key asset in educational situations where authentic projects or stakeholders are not available to the educator.

VI. Discussion

Mastering RE is not only a monumental task for the learner, but also for the educator [116]. On the one hand, the theory behind concepts, techniques, and ontologies is quite technical and demands a high amount of memorization [40]. On the other hand, most of the RE process is "learning by doing". The RE education community seems to know this, as evidenced by a steadily growing effort in the RE education literature to enable learners to discover RE knowledge and skills themselves. Our results in Section IV show that some of the aspirations Mary Shaw raised in her 2000 paper [13] have been answered, specifically to diversify SE knowledge into roles like "requirements engineer" at the undergraduate level. Moreover, the RE education community actively embraces problem-based and project-based learning, thereby enabling learners to experience the RE process, rather than study it from the "outside" [117]. Evidence to this effectiveness is limited and mostly rests on experience reports (see Figure 2), but the existing evidence shows that this enables students to gain deeper insights (and with repeated exposure, eventually master) the RE process and develop an intuition of when certain techniques are preferable over others, allowing "safe" exploration of the problem scope and experiencing the perils of improper RE without threatening project success.

Nevertheless, there seems to be some shortcomings in contemporary RE education instruction. On the one hand, instructing attention to detail and requirements consistency seems to be an ongoing issue, particularly in project-based settings. As students struggle with learning and applying RE theory as well as how to properly manage the RE process in a team, ensuring high requirements quality is particularly burdensome for students. At the same time, we identified only four approaches aiming to improve students' focus on consistency (i.e., [36], [52], [72], [74]) and one approach on traceability (i.e., [53]).

On the other hand, only a minority of approaches focus on safety or security requirements engineering. In fact, only five selected studies (i.e., [51], [65], [67], [107], [112]) deal with security requirements and how to effectively instruct an appreciation for the intricate notions they may impose on the system under development. We did not find any studies that deal with safety requirements. Considering that for the past 30 years, the role of safety and security in software systems has consistently increased [118], it is urgent that RE educational approaches focus on safety requirements to meet this demand.

Moreover, systematic application of pedagogy is largely ignored by contemporary RE education literature. While two approaches make use of Bloom's taxonomy to guide their instruction (i.e., [119], [120]), only seventeen of the surveyed studies (i.e., [25], [27], [79], [80], [86], [93], [95], [119], [121]–[129]) consider pedagogy in one form or another, more or less systematically, with more or less evidence. Some of these approaches merely mention pedagogy. No common pedagogical framework nor a common basis of systematic evidence regarding the effectiveness of teaching approaches is apparent in our review of the literature.

VII. Conclusion

In this paper, we presented the results of a systematic mapping study and literature review into instructional approaches portrayed in RE education literature. We selected 152 primary studies from 1988 to 2020 to synthesize the best practices and current trends from these studies in order to provide guidance such that RE instructors can define educational approaches suitable for their needs.

Results indicate a steady increase in RE education literature, especially since after Ouhbi et al. [10] concluded. Studies target undergraduate students increasingly often. Yet, a large number of studies do not adequately describe the type of learner. Moreover, most contributions are of type "solution proposal" and evidence is mostly presented in the form of experience reports, indicating overall low maturity of the field.

Our findings demonstrate trends toward project-based and problem-based learning, predominantly in collaborative settings, by involving real or realistic stakeholders, or by having an instructor engage in role playing. We found games, gamification, and simulation tools to be a suitable approach for instructing a vast amount of RE theory, as well as for instructing students' in developing their soft skills, including collaboration, teamwork, and industry-readiness.

We conclude that Shaw's "aspiration" to specialize SE in undergraduate curricula [13] was in part answered. A sizable proportion of the instructional approaches proposed after 2008 that we surveyed were targeted at undergraduate learners, and trained them for the role of "requirements engineer". However, our findings also show that Shaw's aspiration for flexible yet robust pedagogical approaches and curricula remains unsatisfied. Our findings suggest that very few studies deal with instructing requirements consistency, traceability, safety, and security. Moreover, RE education presently suffers from a lack of a common pedagogical basis and systematically gathered evidence. While a plethora of successful and effective techniques are proposed, more thorough empirical investigations and systematic attempt to propose educational approaches that are tailored to student outcomes are desirable.

With the work at hand, we lay a foundation for the RE education community to produce an evidence-based pedagogical foundation for RE educational approaches to address specific learning outcomes in students and optimally prepare them for industry responsibilities. The RE educator's "toolbox" is rich and full, but rather unstructured. We hope that this work serves as an initial structuring of this "toolbox". However, to do so, we seek to further investigate the identified literature with regard to learning outcomes addressed by the proposed approaches. This will allow us to compare our findings against the satisfaction of reference curricula reported by Ouhbi et al. [10].

References

[1] B. Nuseibeh and S. Easterbrook, "Requirements engineering: A roadmap," in *Proceedings of the Conf. on The Future of Software*

Engineering, ser. ICSE '00. New York, NY, USA: Association for Computing Machinery, 2000, pp. 35–46.

[2] A. E. A. Commission, "Criteria for accrediting engineering programs, 2018 – 2019," 2018.

[3] IEEE & ACM JTFCC, Software Engineering 2004, "Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering," IEEE & ACM; The Joint Task Force on Computing Curricula, Tech. Rep., 2004.

[4] D. Klapholtz, J. McDonald, and A. Pyster, "The graduate software engineering reference curriculum (gswerc)," in *2009 22nd Conf. on Software Engineering Education and Training*, 2009, pp. 290–291.

[5] IREB, "Certified professional for requirements engineering foundation level syllabus v3.0.1," Int. Requirements Engineering Board e.V., Tech. Rep., October 2020.

[6] P. Bourque, R. E. Fairley, and I. C. Society, *Guide to the Software Engineering Body of Knowledge (SWEBOK(R)): Version 3.0*, 3rd ed. Washington, DC, USA: IEEE Computer Society Press, 2014.

[7] M. Glinz, "Standard glossary for the certified professional for requirements engineering (CPRE) studies and exam v2.0.0," Int. Requirements Engineering Board e.V., Tech. Rep., October 2020.

[8] G. Regev, D. C. Gause, and A. Wegmann, "Requirements engineering education in the 21st century, an experiential learning approach," in *2008 16th IEEE Int. Requirements Engineering Conf.*, 2008, pp. 85–94.

[9] B. Malik and S. Zafar, "A systematic mapping study on software engineering education," *Int. Journal of Educational and Pedagogical Sciences*, vol. 6, no. 11, pp. 3343 – 3353, 2012.

[10] S. Ouhbi *et al.*, "Requirements engineering education: A systematic mapping study," *Requir. Eng.*, vol. 20, no. 2, pp. 119–138, Jun. 2015.

[11] O. Cico *et al.*, "Exploring the intersection between software industry and software engineering education - a systematic mapping of software engineering trends," *Journal of Systems and Software*, p. 110736, 2020.

[12] A. W. Mitchell and J. R. McConnell, "A historical review of contemporary educational psychology from 1995 to 2010," *Contemporary Educational Psychology*, vol. 37, no. 2, pp. 136–147, 2012.

[13] M. Shaw, "Software engineering education: A roadmap," in *Proceedings of the Conf. on The Future of Software Engineering*, ser. ICSE '00. New York, NY, USA: Association for Computing Machinery, 2000, pp. 371–380.

[14] A. Abran, P. Bourque, and L. L. Tripp, *Guide to the Software Engineering Body of Knowledge (SWEBOK(R)): Version 3.0*, 1st ed. Washington, DC, USA: IEEE Computer Society Press, 2004.

[15] B. Kitchenham and P. Brereton, "A systematic review of systematic review process research in software engineering," *Information and software technology*, vol. 55, no. 12, pp. 2049–2075, 2013.

[16] K. Petersen, S. Vakkalanka, and L. Kuzniarz, "Guidelines for conducting systematic mapping studies in software engineering: An update," *Information and Software Technology*, vol. 64, pp. 1–18, 2015.

[17] M. Lavallee, P.-N. Robillard, and R. Mirsalari, "Performing systematic literature reviews with novices: An iterative approach," *IEEE Transactions on Education*, vol. 57, no. 3, pp. 175–181, 2013.

[18] R. Wieringa *et al.*, "Requirements engineering paper classification and evaluation criteria: a proposal and a discussion," *Requirements engineering*, vol. 11, no. 1, pp. 102–107, 2006.

[19] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences*, vol. 111, no. 23, pp. 8410–8415, 2014. [Online]. Available: https://www.pnas.org/content/111/23/8410

[20] K. Petersen and C. Gencel, "Worldviews, research methods, and their relationship to validity in empirical software engineering research," in *2013 Joint Conf. of the 23rd Int. WS on Software Measurement and the 8th Int. Conf. on Software Process and Product Measurement*. IEEE, 2013, pp. 81–89.

[21] C. Wohlin *et al.*, *Experimentation in software engineering: An introduction*, ser. Kluwer Int. series in software engineering. Boston, Mass.: Kluwer Academic, 2000, vol. 6.

[22] A. Jedlitschka, M. Ciolkowski, and D. Pfahl, "Reporting experiments in software engineering," in *Guide to Advanced Empirical Software Engineering*, F. Shull, J. Singer, and D. I. K. Sjøberg, Eds. Springer London, 2008, pp. 201–228.

[23] R. Wieringa *et al.*, "Lessons learned from evaluating a checklist for reporting experimental and observational research," in *ACM-IEEE Int. Symp. on Empirical Software Engineering and Measurement*, ser. ESEM '12, 2012, pp. 157–160.

[24] M. Bano *et al.*, "Teaching requirements elicitation interviews: an empirical study of learning from mistakes," *Requirements Engineering*, vol. 24, no. 3, pp. 259–289, Sep. 2019.

[25] A. Ferrari *et al.*, "SaPeer and ReverseSaPeer: teaching requirements elicitation interviews with role-playing and role reversal," *Requirements Engineering*, vol. 25, no. 4, pp. 417–438, Dec. 2020.

[26] M. Bano *et al.*, "Learning from mistakes: An empirical study of elicitation interviews performed by novices," in *IEEE 26th Int. Requirements Engineering Conf. (RE)*, 2018, pp. 182–193.

[27] M. Bano *et al.*, "Inspectors academy : Pedagogical design for requirements inspection training," in *2020 IEEE 28th Int. Requirements Engineering Conf. (RE)*, 2020, pp. 215–226.

[28] D. Berry and C. Kaplan, "Planned programming problem gotchas as lessons in requirements engineering," in *5th Int. WS on Requirements Engineering Education and Training*, 2010, pp. 20–25.

[29] J. Cybulski, C. Parker, and S. Segrave, "Touch it, feel it and experience it: Developing professional is skills using interview-style experiential simulations," in *17th Australasian Conf. on Information Systems*, 2006.

[30] T. Nakamura, U. Kai, and Y. Tachikawa, "Requirements engineering education using expert system and role-play training," in *IEEE Int. Conf. on Teaching, Assessment and Learning for Engineering (TALE)*, 2015, pp. 375–382.

[31] J. M. Fernandes, R. J. Machado, and S. B. Seidman, "A Requirements Engineering and Management Training Course for Software Development Professionals," in *2009 22nd Conf. on Software Engineering Education and Training*, Feb. 2009, pp. 20–25.

[32] A. Connor, J. Buchan, and K. Petrova, "Bridging the research-practice gap in requirements engineering through effective teaching and peer learning," in *Sixth Int. Conf. on Information Technology: New Generations*, 2009, pp. 678–683.

[33] M. Romero, A. Vizcaíno, and M. Piattini, "Developing the skills needed for requirement elicitation in global software development," in *Tenth Int. Conf. on Enterprise Information Systems*, vol. DISI, 2008, pp. 393–396.

[34] Y. Tachikawa and T. Nakamura, "Education for requirements elicitation using group-work and role-play," in *2017 IEEE Global Engineering Education Conf. (EDUCON)*, 2017, pp. 780–783.

[35] P. Liang and O. De Graaf, "Experiences of using role playing and wiki in requirements engineering course projects," in *18th Int. IEEE Requirements Engineering Conf.*, 2010, pp. 1–6.

[36] K. Sikkel and M. Daneva, "Getting the client into the loop in information system modelling courses," in *6th Int. WS on Requirements Engineering Education and Training (REET)*, 2011, pp. 1–4.

[37] G. Gabrysiak *et al.*, "Cooperating with a non-governmental organization to teach gathering and implementation of requirements," in *2013 26th Int. Conf. on Software Engineering Education and Training (CSEE T)*, May 2013, pp. 11–20.

[38] B. Penzenstadler *et al.*, "Using non-profit partners to engage students in RE," in *8th Int. WS on Requirements Engineering Education & Training (REET 2014)*, vol. 1217, 2014, pp. 1–10.

[39] B. Penzenstadler, M. Mahaux, and P. Heymans, "University meets industry: Calling in real stakeholders," in *2013 26th Int. Conf. on Software Engineering Education and Training (CSEE T)*, May 2013, pp. 1–10.

[40] M. Daun *et al.*, "Industrial case studies in graduate requirements engineering courses: The impact on student motivation," in *IEEE 27th Conf. on Software Engineering Education and Training (CSEE&T)*, 2014, pp. 3–12.

[41] M. Daun and B. Tenbergen, "Teaching Requirements Engineering with Industry Case Examples," in *Software Engineering Unterricht and Hochschulen (SEUH)*, 2020.

[42] M. Daun *et al.*, "Project-based learning with examples from industry in university courses: An experience report from an undergraduate requirements engineering course," in *IEEE 29th Int. Conf. on Software Engineering Education and Training (CSEE&T)*, 2016, pp. 184–193.

[43] K. Berkling *et al.*, "Offshore software development: Transferring research findings into the classroom," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 4716 LNCS, pp. 1–18, 2007.

[44] G. Auriol, C. Baron, and J.-Y. Fourniols, "Teaching requirements skills within the context of a physical engineering project," in *Seventh IEEE Int. WS on Requirements Engineering Education and Training (REET)*, 2008.

[45] D. Zowghi, "Teaching requirements engineering to the Bahá'í students in Iran who are denied of higher education," in *Fourth Int. WS on Requirements Engineering Education and Training (REET '09)*, 2009, pp. 38–48.

[46] M. Romero, A. Vizcaíno, and M. Piattini, "Towards the definition of a multi-agent simulation environment for education and training in global requirements elicitation," in *2008 Conf. on Human System Interactions*, 2008, pp. 48–53.

[47] N. Jamaludin, S. Sahibuddin, and N. Hidayat, "Challenges of a Project-Based Learning approach towards Requirement Engineering," *Int. Journal of Computer Applications*, vol. 50, no. 3, pp. 66–71, July 2012.

[48] L. Beus-Dukic, "Final year project: A test case for requirements engineering skills," in *6th Int. WS on Requirements Engineering Education and Training*, 2011, pp. 5–8.

[49] M. Feldgen and O. Clua, "Teaching effective requirements engineering for large-scale software development with scaffolding," in *IEEE Frontiers in Education Conf. (FIE)*, vol. 2015-February, 2015.

[50] L. Mich, "Teaching requirements analysis: A student project framework to bridge the gap between business analysis and software engineering," in *8th Int. WS on Requirements Engineering Education and Training (REET)*, vol. 1217, 2014, pp. 20–25.

[51] N. Mead, D. Shoemaker, and J. Ingalsbe, "Teaching security requirements engineering using SQUARE," in *Fourth Int. WS on Requirements Engineering Education and Training*, 2009, pp. 20–27.

[52] P. Hasson and S. Cooper, "A case study involving the use of Z to aid requirements specification in the software engineering course," in *17th Conf. on Software Engineering Education and Training*, vol. 17, 2004, pp. 84–89.

[53] O. Gotel and S. Morris, "Case-based stories for traceability education and training," in *Seventh IEEE Int. WS on Requirements Engineering Education and Training (REET)*, 2012, pp. 1–8.

[54] P. Marques *et al.*, "Requirements engineering out of the classroom: Anticipating challenges experienced in practice," in *2020 IEEE 32nd Conf. on Software Engineering Education and Training (CSEE T)*, 2020, pp. 1–9.

[55] S. Kurkovsky, S. Ludi, and L. Clark, "Active learning with lego for software requirements," in *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, ser. SIGCSE '19, New York, NY, USA, 2019, pp. 218–224.

[56] V. G. Ferreira and E. D. Canedo, "Using design sprint as a facilitator in active learning for students in the requirements engineering course: An experience report," in *Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing (SAC19)*, 2019, pp. 1852–1859.

[57] D. Rosca, "Active/collaborative approach in teaching requirements engineering," in *30th Annual Frontiers in Education Conf.*, vol. 1, 2000, pp. T2C–9–T2C–12.

[58] J. Horkoff, "Observational studies of new i* Users: Challenges and Recommendations," in *1st Int. iStar Teaching WS (iStarT 2015)*, vol. 1370, 2015, pp. 13–18.

[59] T. Nakatani, "Requirements engineering education for professional engineers," *Frontiers in Artificial Intelligence and Applications*, vol. 180, no. 1, pp. 495–504, 2008.

[60] T. Nakatani, T. Tsumaki, and T. Tamai, "Requirements engineering education for senior engineers: Course design and its evaluation," in *5th Int. WS on Requirements Engineering Education and Training*, 2010, pp. 26–35.

[61] A. Berre *et al.*, "Teaching modelling for requirements engineering and model-driven software development courses," *Computer Science Education*, vol. 28, no. 1, pp. 42–64, 2018.

[62] K. Vega, H. Fuks, and G. Carvalho, "Training in requirements by collaboration: Branching stories in second life," in *Simpósio Brasilerio de Sistemas Colaborativos (SBSC 2009)*, 2009, pp. 116–122.

[63] S. Ludi, "Introducing accessibility requirements through external stakeholder utilization in an undergraduate requirements engineering course," in *29th Int. Conf. on Software Engineering (ICSE'07)*, 2007, pp. 736–743.

[64] B. Tenbergen and M. Daun, "Industry projects in requirements engineering education: Application in a university course in the us and comparison with germany," in *Hawaii Int. Conf. on System Sciences 2019*, ser. HICSS-53, 2019.

[65] N. Mead and E. Hough, "Security requirements engineering for software systems: Case studies in support of software engineering education," in *19th Conf. on Software Engineering Education and Training*, vol. 2006, 2006, pp. 149–156.

[66] S. Tiwari, "Impact of cbl on student's learning and performance: An experience report," in *13th Innovations in Software Engineering Conf. (ISEC 2020)*, ser. ISEC 2020. New York, NY, USA: Association for Computing Machinery, 2020.

[67] D. Alami and F. Dalpiaz, "A Gamified Tutorial for Learning about Security Requirements Engineering," in *IEEE 25th Int. Requirements Engineering Conf. (RE)*, 2017, pp. 418–423.

[68] I. García *et al.*, "A serious game for teaching the fundamentals of iso/iec/ieee 29148 systems and software engineering – lifecycle processes – requirements engineering at undergraduate level," *Computer Standards & Interfaces*, vol. 67, p. 103377, 2020.

[69] I. Garcia *et al.*, "Experiences of using a game for improving learning in software requirements elicitation," *Computer Applications in Engineering Education*, vol. 27, no. 1, pp. 249–265, 2019.

[70] S. Mohan and S. Chenoweth, "Teaching requirements engineering to undergraduate students," in *42nd ACM Technical Symposium on Computer Science (SIGCSE '11)*, 2011, pp. 141–146.

[71] R. Barnes, D. Gause, and E. Way, "Teaching the unknown and the unknowable in requirements engineering education," in *Seventh IEEE Int. WS on Requirements Engineering Education and Training (REET)*, 2008.

[72] B. Wei *et al.*, "A conceptual graphs framework for teaching UML model-based requirements acquisition," in *IEEE 29th Int. Conf. on Software Engineering Education and Training (CSEET)*, 2016, pp. 71–75.

[73] A. Bennaceur, J. Lockerbie, and J. Horkoff, "On the Learnability of i*: Experiences from a New Teacher," in *1st Int. iStar Teaching WS (iStarT 2015)*, vol. 1370, 2015, pp. 43–48.

[74] C. Iacob and S. Faily, "Using Extreme Characters to Teach Requirements Engineering," in *IEEE 30th Conf. on Software Engineering Education and Training (CSEE&T)*, vol. 2017-January, 2017, pp. 107–111.

[75] B. Westphal, "An undergraduate requirements engineering curriculum with formal methods," in *IEEE 8th Int. WS on Requirements Engineering Education and Training (REET)*, 2018, pp. 1–10.

[76] B. Von Konsky, M. Robey, and S. Nair, "Integrating design formalisms in software engineering education," in *17th Conf. on Software Engineering Education and Training*, vol. 17, 2004, pp. 78–83.

[77] R. France and M. Larrondo-Petrie, "Understanding the role of formal specification techniques in requirements engineering," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 895, pp. 207–221, 1995.

[78] T. Nkamaura and Y. Tachikawa, "Requirements engineering education using role-play training," in *2016 IEEE Int. Conf. on Teaching, Assessment, and Learning for Engineering (TALE)*, 2017, pp. 231–238.

[79] R. Svensson and B. Regnell, "Is role playing in Requirements Engineering Education increasing learning outcome?" *Requirements Engineering*, vol. 22, no. 4, pp. 475–489, 2017.

[80] K. Gary, "Contextual requirements experiences within the software enterprise," in *Fourth Int. WS on Requirements Engineering Education and Training*, 2009, pp. 12–19.

[81] G. Sindre, "Teaching oral communication techniques in RE by student-student role play: Initial experiences," in *18th Conf. on Software Engineering Education & Training (CSEET'05)*, 2005, pp. 85–94.

[82] D. Suri and J. Gassert, "Gathering project requirements: A collaborative and interdisciplinary experience," in *American Society for Engineering Education Annual Conf. & Exposition*, 2005, pp. 6759–6764.

[83] S. Minocha, M. Petre, and D. Roberts, "Using wikis to simulate distributed requirements development in a software engineering course," *Int. Journal of Engineering Education*, vol. 24, no. 4, pp. 689–704, 2008.

[84] B. Donati *et al.*, "Common mistakes of student analysts in requirements elicitation interviews," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 10153 LNCS, pp. 148–164, 2017.

[85] A. Rusu, R. Russell, and R. Cocco, "Simulating the software engineering interview process using a decision-based serious computer game," in *16th Int. Conf. on Computer Games (CGAMES)*, 2011, pp. 235–239.

[86] T. Nakatani, T. Tsumaki, and T. Tamai, "Instructional design of a requirements engineering education course for professional engineers," *Smart Innovation, Systems and Technologies*, vol. 3, pp. 119–151, 2010.

[87] L. Beus-Dukic and I. Alexander, "Learning how to discover requirements," in *Seventh IEEE Int. WS on Requirements Engineering Education and Training (REET)*, 2008.

[88] S. Scepanovic and L. Beus-Dukic, "Teaching requirements engineering: EUROWEB experience," in *European Conf. on Software Architecture (ECSAW '15)*, vol. 07-11-September-2015, 2015.

[89] D. Rosca, "Developing teamwork and communication skills in a multidisciplinary experiment," in *33rd Annual Frontiers in Education Conf.*, vol. 3, 2003, pp. S4C14–S4C17.

[90] Y. Sedelmaier and D. Landes, "Using business process models to foster competencies in requirements engineering," in *IEEE 27th Conf. on Software Engineering Education and Training (CSEE&T)*, 2014, pp. 13–22.

[91] G. Hagel *et al.*, "Involving customers in requirements engineering education: Mind the tgoals!" in *3rd European Conf. of Software Engineering Education (ECSEE)*, 2018, pp. 113–121.

[92] G. Gabrysiak *et al.*, "Teaching requirements engineering with virtual stakeholders without software engineering knowledge," in *5th Int. WS on Requirements Engineering Education and Training*, 2010, pp. 36–45.

[93] A. Ferrari *et al.*, "Learning requirements elicitation interviews with role-playing, self-assessment and peer-review," in *2019 IEEE 27th Int. Requirements Engineering Conf. (RE)*, 2019, pp. 28–39.

[94] D. Zowghi and S. Paryani, "Teaching requirements engineering through role playing: lessons learnt," in *Proceedings. 11th IEEE Int. Requirements Engineering Conf., 2003.*, Sep. 2003, pp. 233–241.

[95] B. Al-Ani and N. Yusop, "Role-playing, group work and other ambitious teaching methods in a large requirements engineering course," in *11th IEEE Int. Conf. and WS on the Engineering of Computer-Based Systems*, 2004, pp. 299–306.

[96] A. de Pádua Albuquerque Oliveira *et al.*, "The Monopoly Game to Teach ERi*c - Intentional Requirements Engineering," in *1st Int. iStar Teaching WS (iStarT 2015)*, vol. 1370, 2015, pp. 49–54.

[97] M. Soo and H. Aris, "Game-Based Learning in Requirements Engineering: An Overview," in *2018 IEEE Conf. on e-Learning, e-Management and e-Services (IC3e)*, 2019, pp. 46–51.

[98] S. Tiwari *et al.*, "Teaching requirements engineering concepts using case-based learning," in *2nd International WS on Software Engineering Education for Millennials (SEEM'18)*, 2018, pp. 8–15.

[99] A. Heimbürger and V. Isomöttönen, "Infographics as a reflective assignment method in requirements engineering e-course?" in *2019 IEEE Frontiers in Education Conf. (FIE)*, 2019, pp. 1–5.

[100] M. F. Abrar *et al.*, "Motivators for large-scale agile adoption from management perspective: A systematic literature review," *IEEE Access*, vol. 7, pp. 22 660–22 674, 2019.

[101] I. Inayat *et al.*, "A systematic literature review on agile requirements engineering practices and challenges," *Computers in Human Behavior*, vol. 51, pp. 915–929, 2015, computing for Human Learning, Behaviour and Collaboration in the Social and Mobile Networks Era.

[102] A. S. Campanelli and F. S. Parreiras, "Agile methods tailoring – a systematic literature review," *Journal of Systems and Software*, vol. 110, pp. 85–100, 2015.

[103] A. Lopez-Lorca, R. Burrows, and L. Sterling, "Teaching motivational models in agile requirements engineering," in *8th Int. WS on Requirements Engineering Education and Training (REET)*, 2018, pp. 30–39.

[104] J. Horkoff, "The influence of agile methods on requirements engineering courses," in *IEEE 8th Int. WS on Requirements Engineering Education and Training (REET)*, 2018, pp. 11–19.

[105] D. Dicheva *et al.*, "Gamification in Education: A Systematic Mapping Study," *Journal of Educational Technology & Society*, vol. 18, no. 3, pp. 75–88, 2015.

[106] M. M. Alhammad and A. M. Moreno, "Gamification in software engineering education: A systematic mapping," *Journal of Systems and Software*, vol. 141, pp. 131–150, 2018.

[107] A. Yasin *et al.*, "Design and preliminary evaluation of a cyber Security Requirements Education Game (SREG)," *Information and Software Technology*, vol. 95, pp. 179–200, 2018.

[108] M. Alexander and J. Beatty, "Effective design and use of requirements engineering training games," in *Seventh IEEE Int. WS on Requirements Engineering Education and Training (REET)*, 2008.

[109] H. Mayr, "Teaching better requirements engineering using LEGO® serious Play™," in *ACM Conf. on Innovation and Technology in Computer Science Education (ITiCSE '15)*, 2015, pp. 126–131.

[110] J. Vilela and J. Lopes, "Evaluating the students' experience with a requirements elicitation and communication game," in *23rd Ibero-American Conf. on Software Engineering (CIbSE 2020)*, ser. CIbSE 2020, 2020.

[111] Z. Ibrahim *et al.*, "Design and development of a serious game for the teaching of requirements elicitation and analysis," in *2019 IEEE Int. Conf. on Engineering, Technology and Education (TALE)*, 2019, pp. 1–8.

[112] S. Pfleeger and C. Pfleeger, "Harmonizing privacy with security principles and practices," *IBM Journal of Research and Development*, vol. 53, no. 2, 2009.

[113] M. Romero, A. Vizcaíno, and M. Piattini, "A simulator for education and training in global requirements engineering: A work in progress," in *Eighth IEEE Int. Conf. on Advanced Learning Technologies*, 2008, pp. 123–125.

[114] R. Babiceanu, "A software and systems integration framework for teaching requirements engineering," in *121st ASEE Annual Conf. & Exposition*, 2014.

[115] M. Laiq and O. Dieste, "Chatbot-based interview simulator: A feasible approach to train novice requirements engineers," in *2020 10th Int. WS on Requirements Engineering Education and Training (REET)*, 2020, pp. 1–8.

[116] D. M. Fernández *et al.*, "Do we preach what we practice? investigating the practical relevance of requirements engineering syllabi - the ireb case," 2019.

[117] C. E. Hmelo-Silver, "Problem-based learning: What and how do students learn?" *Educational Psychology Review*, vol. 16, pp. 235–266, 2004.

[118] L. E. G. Martins and T. Gorschek, "Requirements engineering for safety-critical systems: A systematic literature review," *Information and Software Technology*, vol. 75, pp. 71–89, 2016.

[119] T. Bhowmik, N. Niu, and D. Reese, "Students vs. Professionals in assisted requirements tracing: How could we train our students?" in *121st ASEE Annual Conf. & Exposition*, 2014.

[120] F. Moreira and M. Ferreira, "Teaching and learning requirements engineering based on mobile devices and cloud: A case study," in *Blended Learning: Concepts, Methodologies, Tools, and Applications*, 2016, vol. 4, pp. 1190–1217.

[121] G. Anil and S. Moiz, "A holistic rubric for assessment of software requirements specification," in *5th National Conf. on E-Learning & E-Learning Technologies (ELELTECH)*, 2017.

[122] Y. Sedelmaier and D. Landes, "A multi-level didactical approach to build up competencies in requirements engineering," in *8th Int. WS on Requirements Engineering Education & Training (REET 2014)*, vol. 1217, 2014, pp. 26–34.

[123] ——, "Experiences in teaching and learning requirements engineering on a sound didactical basis," in *ACM Conf. on Innovation and Technology in Computer Science Education (ITiCSE '17)*, vol. Part F128680, 2017, pp. 116–121.

[124] R. Quintanilla Portugal *et al.*, "Facing the challenges of teaching requirements engineering," in *38th Int. Conf. on Software Engineering Companion (ICSE '16)*, 2016, pp. 461–470.

[125] M. Koch and D. Landes, "Making Means-End-Maps workable for recommending teaching methods," in *Eighth Int. i* WS*, vol. 1402, 2015, pp. 85–90.

[126] C. Rupakheti *et al.*, "On a Pursuit for Perfecting an Undergraduate Requirements Engineering Course," in *IEEE 30th Conf. on Software Engineering Education and Training (CSEE&T)*, vol. 2017-January, 2017, pp. 97–106.

[127] R. Memon, R. Ahmad, and S. Salim, "Problems in requirements engineering education," in *8th Int. Conf. on Frontiers of Information (FIT '10)*, 2010.

[128] L. Macaulay and J. Mylopoulos, "Requirements engineering: An educational dilemma," *Automated Software Engineering*, vol. 2, no. 4, pp. 343–351, Dec. 1995.

[129] Y. Sedelmaier and D. Landes, "Systematic evolution of a learning setting for requirements engineering education based on competence-oriented didactics," in *IEEE Global Engineering Education Conf. (EDUCON)*, vol. 2018-April, 2018, pp. 1062–1070.