

# A Survey of Instructional Approaches in the Requirements Engineering Education Literature

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**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.

## 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.

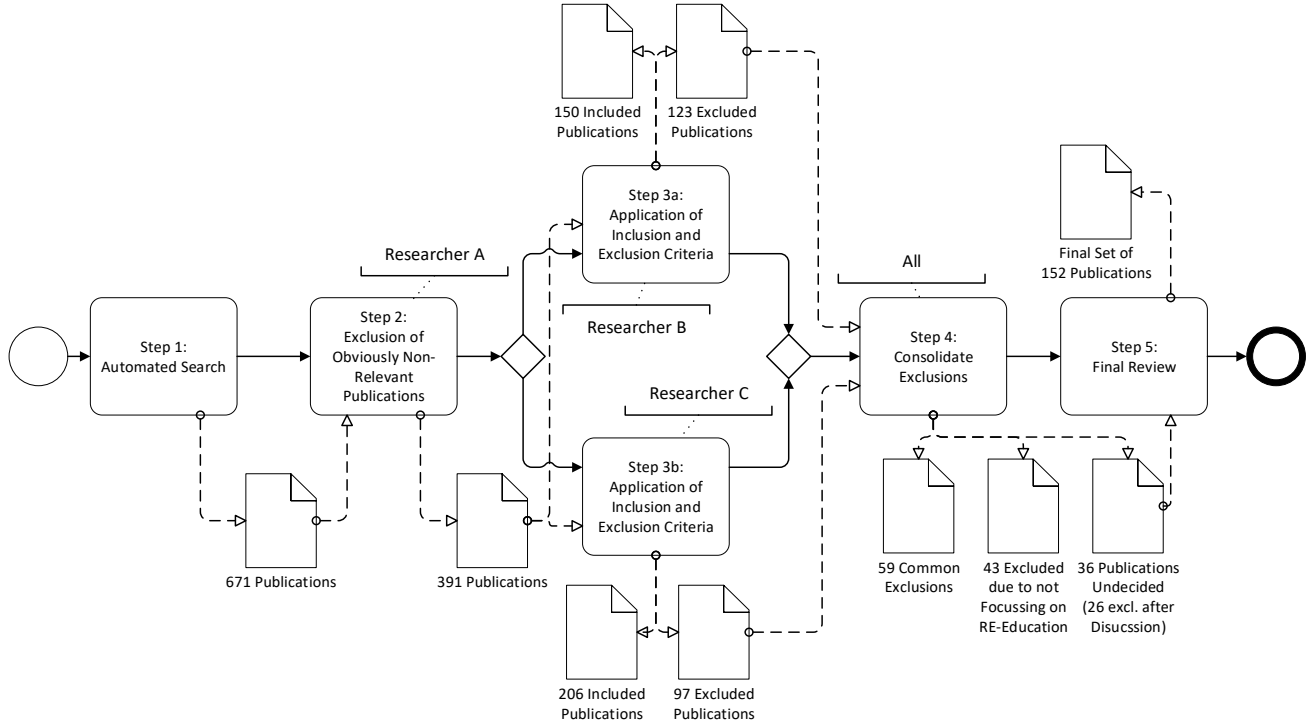


Fig. 1: Study Selection Process

TABLE I: Inclusion and Exclusion Criteria

Inclusion Criteria
<ul style="list-style-type: none"> <li>Published in a peer-reviewed journal or conference/workshop proceedings</li> <li>Focus on requirements engineering education</li> </ul>
Exclusion Criteria
<ul style="list-style-type: none"> <li>Papers not focused on education</li> <li>Papers about requirements for engineering education</li> <li>Focus on requirements engineering for education systems</li> <li>Introductory papers for special issues, conferences, or workshops</li> <li>Publications shorter than three pages</li> <li>Publications not written in English</li> <li>Full text neither available online nor via interlending</li> </ul>

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<sup>1</sup>.

#### 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).

#### 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.

<sup>1</sup>The data set is available at: doi.org/10.35482/csc.003.2021

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

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

(a) RQ2: Research Methods		(b) RQ3: Type of Learners	
Method	Count	Group	Count
Solution Proposal	68	Undergraduate	39
Experience Report	40	Graduate	19
Evaluation Research	18	Postgraduate	3
Validation Research	15	Industry Practitioners	17
Philosophical Paper	9	Unspecified Student	57
Opinion Paper	2	Other / Unknown	17

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.

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. Moreover, we make our data available (see Section III-D). 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

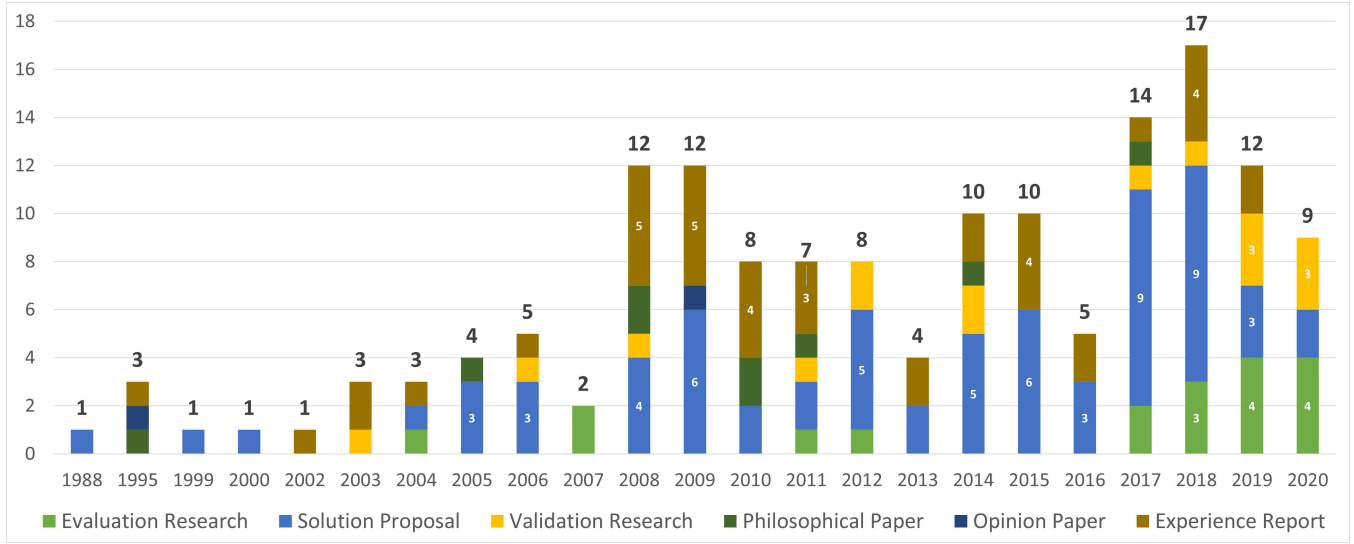


Fig. 2: Publications and research methods per year. Each bar represents one year, with cumulative counts of publications per year (RQ1) listed at the top of each bar. Bars are sub-divided by research method (RQ2) to illustrate changes in research methods over time. Counts added for subdivisions with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

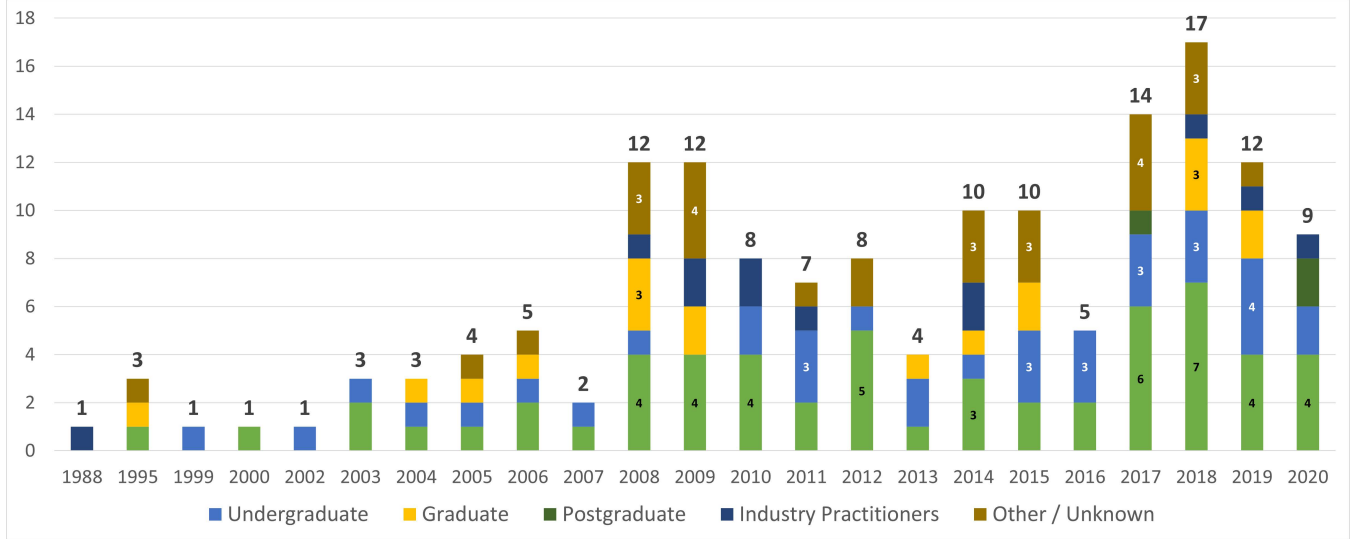


Fig. 3: Publications separated by type of learner per year. Each bar represents one year and is sub-divided by type of learner (RQ3) to illustrate which learners are studied in the literature over time. Counts added for subdivisions with three or more papers to increase readability.

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. Thirteen papers omit the audience, however, we assume some of these address university education and find this sufficiently obvious that authors do not deem it important to specify this further. One paper places emphasis on RE education at the high-school level and another one investigates RE knowledge in alumni (all counted under *Other* in Table III(b)).

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. While between 2000 and 2007, the years following Shaw’s “aspiration” to include role-specific SE education into undergraduate curricula [13] (see Section II), the number of approaches targeting undergraduate, graduate, or “unknown” students was roughly equal, since 2008, the number of students targeting undergraduates specifically is steadily increasing. However around the same time, the number of studies not mentioning students specifically and the number of “unknown” student types increase in parallel. As well, in the same time frame, approaches targeting industry professionals are published increasingly often.

We can 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. Please refer to the supplement<sup>1</sup> for a link to all included studies and their classification).

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		(b) Contribution Topic	
Focus	Count	Category	Count
method-centric	41	collaborative	29
industry-centric	36	individual	12
technology-centric	26	low-stakes	24
inquiry-based	22	high-stakes	9
instructor-centric	12	soft skills*	46
project-based	11	games	13
problem-based	6	simulators	7
no approach mentioned	21		

#### 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 Table 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 [51]–[56], we identified a total of 48 individual studies (31.5% 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

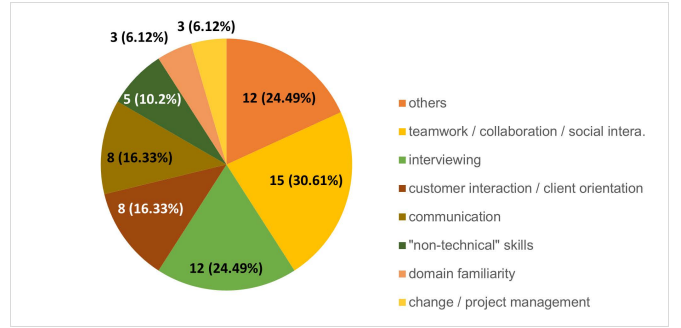


Fig. 4: Publications pertaining to Instruction of Soft Skills. Studies may target more than one soft skill. Percentages are relative to the amount of papers marked “\*” in Table IV (b).

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)), 46 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 (32.61% of approaches explicitly mentioning soft skills, e.g., [38], [40], [42], [43], [45], [58]–[60], [62], [82], [83]), interviewing skills (19.57%, e.g., [26], [29], [45], [79], [84], [85]), customer interaction or client-orientation (17.39%, e.g., [30], [74], [82], [83], [86]–[88]), and communication (17.39% 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

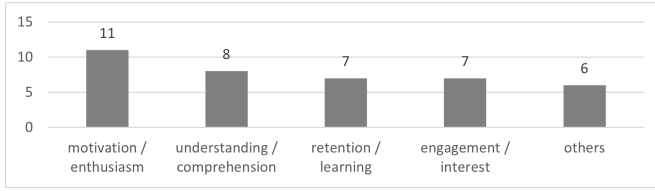


Fig. 5: Publications pertaining to Improvement of Student Factors as stated by the Authors

non-industry representative to engage in role-playing to create an industry-realistic project experience (e.g., [30], [34], [35], [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]) report 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 30 studies across those reported in Table IV that motivate their approach specifically to improve student factors or report incidental improvement as evidence to its success. Most commonly, motivation and enthusiasm (35.48% of surveyed studies, see Figure 5, i.e., [38], [40], [42], [50], [55], [64], [67]–[69], [96] and the aforementioned including [35]) and “comprehension and understanding” (25.8%, i.e., [50], [63], [76], [77], [90], [97]–[99]) are named as positively benefiting from such an approach.

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 other, perhaps more technical soft skills (e.g., agile development) throughout RE education literature.

### 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 Yasin et al. [107] propose different games to foster security requirements engineering at large. Together with contributions in [51], [65] and [112], which do not incorporate games, Alami and Dalpiaz [67] as well as Yasin et 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], Garcia et al. [68], [69], Rusu et al. [85], Vilela and Lopes [110], and Ibrahim, Soo et al. [97], [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 case of Oliveria et al. [96] or the social media game “Second Life” in 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 used to also 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. also make use of simulation in [46], [113], yet rather than elicitation or interview skills, their approach considers the entire RE process particularly to simulate distributed requirements engineering (like also in [83]) in socially distant development teams.

In conclusion, the common approach among all kinds of instructional approaches outlined in Section V-A, Section V-B, and Section V-C seems to be that rather than, theory-heavy instruction, RE is best instructed with experiential learning using collaborative approaches, real stakeholder interactions, or controlled environments simulating realistic experiences. Doing so has the advantage of improving students' soft skills while also teaching RE theory. Especially 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 some 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].

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