How Experimentation in Software Engineering has been taught? Survey and Research Agenda

Anonymous Author(s)

ABSTRACT

[Background:] Experimentation in Software Engineering (ESE) has increased in the last several years as a way to provide evidence by using statistical techniques. These techniques contribute to an auditable and reliable body of knowledge towards evolving a given topic. Therefore, teaching ESE becomes an essential task while disseminating and establishing an experimental culture to both academia and industry. **[Aims:]** In this paper we seek to understand how ESE has been taught including contents, materials used, strategies employed, and evaluation method applied. We also provide a research agenda on the subject. **[Method:]** We conducted a web-based questionnaire survey with 31 instructors who teach ESE. **[Results:]** We see several aspects, such as: ESE is mainly taught in an exclusive course; most of the materials used to teach ESE concepts are from third parties and some of them themselves; most people do not use any type of license; the core materials used to define the content of the courses are papers and books; learning management systems are most often used to share materials with students; key learning practices used are active learning, project-based learning, and problem-based learning; and most instructors assess their students with experimental projects and seminars. Based on such results, we provide and discuss a research agenda to improve teaching of ESE. **[Conclusions:]** This survey provides results towards planning a research agenda to improve teaching of ESE, thus benefiting instructors, researchers, and practitioners.

CCS CONCEPTS

• **Software and its engineering**;

KEYWORDS

Software Engineering Experimentation, Experiment, Teaching, Survey, Research Agenda

ACM Reference Format:

Anonymous Author(s). 2022. How Experimentation in Software Engineering has been taught? Survey and Research Agenda. In *EASE '22: International Conference on Evaluation and Assessment in Software Engineering, June, 13-15, 2022, Proceedings Only*. ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/1122445.1122456

EASE '22, June, 13-15, 2022, Proceedings Only

ACM ISBN 978-1-4503-XXXX-X/18/06…$15.00
https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

Experimentation is the basis of the scientific method, a systematic way of exploring the world [5]. Although science experiments[1] are usually associated with laboratories, they can take place in any environment, in different disciplines, including in the software development life cycle [5].

Experimentation in Software Engineering (ESE) plays a central role in the software engineering (SE) researchers and practitioners communities. This is because ESE is intended to provide evidence about theories and technologies related to the software development life cycle [22].

The application of experimentation in SE has exponentially increased recently due to the effort of the SE community towards providing reliability of the results and reproducibility of methods [20]. SE literature (e.g., [4, 7, 18]) and specialized conferences like ESEM and EASE, have promoted ESE. Even with this evident growth, little is known about teaching and learning ESE as a way of strengthening this research topic and spreading of the word in our communities.

Although there has been some work about software engineering education using experimentation [10, 11] and using students in software engineering experiments [2], it does not cover the topic of how ESE is being taught. Wohlin [21] and Host [8], for instance, claim that most empirical studies on students context rely on controlled experiments. Wohlin also discusses different ways of teaching empirical software engineering into the curricula. Therefore, in this paper we seek to **understand how ESE has been taught, thus provide a research agenda on this topic**. To do so, we present incipient results of a survey with ESE[2] instructors from different teaching and learning aspects. With such results we propose a research agenda for evolving this topic in the next years.

This paper is organized as follows: Section 2 presents essential concepts and discusses related works; Section 3 presents the research questions; Section 4 presents this study methodology; Section 5 analyzes results with respect to the research questions; Section 6 discusses the obtained results; Section 7 discusses main threats to validity; Section 8 proposes a research agenda for teaching ESE; and Section 9 presents final remarks.

2 BACKGROUND AND RELATED WORK

This section presents essential background on teaching ESE and discusses related work.

2.1 Software Engineering Education and ESE

Software-based solutions are part of our daily lives, making us dependent on their uses in today's society [11]. With the due central role of software in today's world, a general concern has emerged with the quality of software processes and products. This

[1] In this paper we focused our rationale on both software engineering quasi-experiments and experiments.

[2] In this work, ESE refers exclusively to controlled (quasi-)experiments.

fact brought more attention on how students learn and perceive concepts and processes throughout the study of Software Engineering [15].

There are several discussions in the existing literature about issues faced in the teaching-learning process in Software Engineering, thus demanding greater integration and cooperation among instructors. In software engineering teaching, it is a major challenge to integrate applied methodology and theory into the practice of software development instead of learning concepts and methodologies as abstract ideas [3].

In certain contexts, the teaching of higher education is based only on theoretical concepts, not applying a significant practice, a fact that could be harmful for students after graduation. Gnatz et al. [6] claim that, the only way that really prepares anyone for doing successful project work is learning by doing. From a university's perspective it is a challenging task to find a teaching concept for providing students with practical know-how regarding project work. In addition, Santos et al. [19] point out innovation challenges in recognizing and accommodating the skills and abilities of students in higher education, due to its breadth of research and application.

Cagiltay [1] reports industry and university environments change, industry demands for skills that should be owned by information technologists also change. What engineers find in practice differs from what they found earlier at university. For this reason, students must be able to apply the concepts learned during their education to real-world problem solving.

ESE is seen as a learning practice from an innovative pedagogical perspective, taking this necessary experience in the labor market to academics. In such market, there are problems with ever changing techniques or methods in software development organizations, thus it is necessary to present to students how ESE is carried out and how this can be applied in their daily lives [19]. ESE offers a systematic, disciplined, computable, and controlled way of evaluating human activities. New methods, techniques, languages and tools should not be suggested, published or presented for sale without experimentation and validation [20, 22].

ESE has been growing in recent years. Sjøberg et al. [20] describe the rise of experimentation-based investigation in software engineering. The growing importance of research activity in this field, aimed at producing knowledge that can be based on solid scientific methodology, has become one of the main challenges to strengthen the foundations of higher education as a discipline focusing its full maturity [16].

We straightforward believe that teaching ESE concepts appropriately will prepare the resources with a solid foundation and practice on experiments required by the software industry. However, as we have seen, a few teaching materials or formalization teaching on ESE is readily available, thus making this a valuable opportunity to explore and evolve this subject.

2.2 Related Work

As far as we could identify, no recent works have investigated ESE education. Anyway, we discuss three other work related to ours.

Host [8] firstly discusses the introduction of empirical software engineering methods in education. Although Host focused on undergrads and not exclusively on experiments, he presents a controlled experiment for evaluating pair reviews. In addition, Host evaluates different elements of the course, which are: lectures, literature study, project, exam, book, and other materials. Host's paper provided great insights for the design of the survey applied in the present work.

Wohlin [21] claims that most empirical studies on students context rely on controlled experiments. He also discusses different ways of include empirical software engineering into the course curricula, including: (i) `integrated into software engineering courses`, in which ESE is part of other courses and it is evaluated by means of essays or assignments, for instance, in a course of software requirements students can compare different techniques to specify requirements of a certain software system - use cases vs. user stories; (ii) as a `separate course`, in which the major advantage relies on the specific focus on experiments with assignments for, for instance, designing experiments, reviewing existing studies and write papers on a given experiment; and (iii) as `part of a research methodology course`, which is independent if students are enrolled in a bachelor course, Master or PhD thesis. This work contributed to ours at defining questions related to materials used and education levels.

Kuhrmann [10] presents an experience report on how to teach empirical software engineering using different empirical instruments to carry out mini-projects. He used a seminar-like learning model in which the students form expert teams. In addition, such students aid other teams, thus fostering cross-team collaboration. Such a work allowed us to reflect on questions about teaching and learning practices adopted by ESE instructors.

As we could see, although ESE is part of the education, the perspective of the instructors was not considered to further understand how ESE has been taught. Therefore, there is an opportunity to explore this gap and document initial findings towards understanding best practices and creating guidelines.

3 RESEARCH QUESTIONS

The core research question that guided this study is: "***RQ: How have ESE courses been carried out?***". Therefore, we want to understand what are the reference texts, teaching methods, materials used and other content that can aid in ESE teaching-learning process.

A better understanding of the structure of the courses and the materials used to support ESE teaching is important as an input to develop appropriate courses about the topic. Therefore, it will be useful for instructors when designing syllabi that include ESE topics.

According to Saglam [17], teaching materials provide a great convenience in the instructor's ability to convey a message to students accurately and appropriately in a clear and understandable manner, in making abstract knowledge concrete, and in enabling students to understand complex ideas through simplification.

Therefore, based on our main research question, we derived the following secondary questions that guided this study:

- **RQ1.1: How are the the main materials used by ESE instructors created and licensed?**. This question aims at identifying what are the main materials used in ESE courses, how they are licensed, and whether they are developed by the instructors or are reused from other colleagues.
- **RQ1.2: How do ESE instructors organize their teaching materials to guide their students?**. In this question we

are interested on how instructors organize their materials to teach ESE. In addition, we want to identify whether instructors provide any guidance to students on how to use such materials.

- **RQ1.3: How ESE instructors make the course study materials available to their students?**. Thinking about the student learning, course planning is essential—as well as providing students with a way to organize their studies. Study guides, for instance, can aid instructors and students to follow in a concrete way the progress of the course and its activities to be carried out. Thus, the availability of materials to students is also fundamental in this process.
- **RQ1.4: What teaching and learning practices are adopted in ESE courses?**. In this question, we seek to understand what and how teaching and learning practices are used or adopted in ESE courses. This is a valuable information, as such practices may impact directly the outcomes of the course.
- **RQ1.5: What are the assessment methods used to measure student performance in ESE?**. As each student has particular learning characteristics and instructors have different skills to transfer knowledge, we want to identify what are the learning assessment methods used by ESE instructors in this question.

4 METHODOLOGY

This section presents how we applied the guidelines for Survey from Linåker et al. [12].

4.1 Target Audience

Our target audience is the set of instructors who teach ESE in higher education (undergraduate or graduate level). Such target audience is characterized as dependent on data collection, as the study questions require pedagogical knowledge of the respondents.

4.2 Sampling

Sampling was carried out as an invitation sent by e-mail to instructors in the Software Engineering field. We obtained such information from CSIndex.br[3], the ESELAW 2020 TPC[4], the ISERN network [5], the ESEM TPC[6], and the EASE TPC[7]. From the names of possible participants, we looked for their personal webpages online to obtain their contact data.

Even knowing the amount of emails sent, the sampling was non-probabilistic, as its randomness cannot be guaranteed and the sample calculation cannot be carried out in relation to the error and the level of significance as the population size is not known. For this study, we obtained 31 responses from approximately 400 invitation emails sent (response rate of ~7.75%), from 14-Apr-2020 to 30-May-2020. The data collection process took place at the time of the COVID19 pandemic, which may have affected the number of responses.

[3]https://csindexbr.org
[4]https://cibse2020.ppgia.pucpr.br/
[5]https://isern.iese.de/
[6]https://eseiw2020.di.uniba.it/esem_conf
[7]https://www.ntnu.edu/ease2020

Most respondents (20 – 64.5%) are Brazilian, whereas the other 35.5% (11) are from Uruguay, Germany, Ecuador, Sweden, Netherlands, and United States. Among the participants, 28 (90.23%) reported that they teach the concepts of ESE in public institutions and only three (9.7%) in private institutions or in both private and public institutions.

Most respondents reported they teach ESE concepts in Master's courses (22 - 71%), as well as in undergraduate and doctoral programs. An interesting point when analyzing the results is that none of the instructors indicated that such knowledge is included in *lato sensu*/MBA courses, thus demonstrating an opportunity to be explored.

The sample obtained is composed of respondents with different levels of experience in teaching ESE. The majority (19 – 61.3%) have five years or less of experience in teaching empirical studies or experimentation, nine (29%) have 6 to 10 years, one indicated having 14 years of experience, and two have more than 15 years of experience. These data provide us a relatively mature instructors of ESE.

4.3 Study Design

We chose an exploratory research, as our goal is to discover the methods, teaching practices, materials used, among other pedagogical processes used by instructors that may support the teaching of ESE [22].

4.4 Instrument

The instrument developed was an online questionnaire to reach geographically dispersed potential instructors, as the target audience has Internet access. The questionnaire was designed with a common vocabulary for the audience.

The initial design of the research was discussed within the authors to understand teaching ESE and generate the initial version of the questionnaire. Subsequently, we included the questions in a Google Forms [8], which we sent to the potential participants.

The questionnaire was designed following an approach based on understanding the teaching-learning process applied by the instructors, guiding what we wanted to explore with this survey. The type of questionnaire, the method of execution, the duration of the survey, and the sequence of the research questions were taken into consideration. We discussed all of these factors with invited researchers to evaluate and obtain greater assertiveness in the research, as well as having easy and objective questions, thus not generating fatigue or lack of motivation to answer the survey. Therefore, we defined that the questionnaire could be answered in a maximum of 15 minutes.

The questionnaire contains nominal, multiple choice and open-ended questions. All information contained in the survey is in English, with simple language, short texts, without vague or biased sentences and containing a relationship with the study proposal.

We evaluated the study instrument with three instructors of ESE in higher education. We considered their teaching experiences and analyzed whether respondents made any comments about their structure or semantics. Two instructors made indications about asking participants for more detailed information on the reference texts used and about the possibility of sharing files. Taking into

[8]A version is available at https://doi.org/10.5281/zenodo.6372914

account the opinions and notes of the evaluators, we addressed such indications, thus we applied the instrument.

4.5 Data Sharing

Data of this study are publicly and permanently available at https://doi.org/10.5281/zenodo.5106333.

5 RESULT ANALYSIS

This section presents the results of the survey based on our predefined research questions from Section 3.

5.1 RQ1.1: Material Creation, Licensing, and Main References

Most of the instructors (17 – 54.8%) adopt both third-party materials and create their own. A subset (11 – 35.5%) prefer preparing their own material, whereas three (9.7%) adopt third-party materials.

With regard to the licensing, 67.7% (21) of the instructors confirm that the use materials they use do not follow any common licenses for distribution or use, whereas five (16.1%) indicate some licensing and five (16.1%) indicated that some of the materials are provided under some license.

Regarding basic/reference materials, from 29 responses (two did not respond this question), we observed books and book chapters (18 – 58.1%) are most cited, whereas books and articles are mentioned by eight (25.8%) and (9.7%) mentioned only articles. It is noteworthy that some of the authors/literature most mentioned by the instructors are Wohlin et al. [22] (16 – 51.61%), followed by Juristo and Moreno [9] (five – 16.12%). Thus, this demonstrates these reference texts are relevant to the teaching of ESE. We provide a list of references provided by our respondents in supplementary materials.[9]

> ***Answering RQ1.1:*** *Most of the materials used by ESE instructors are a mix of third-party and own material, and most of them do not follow any licensing policy. Books and book chapters are the main basic references for ESE courses, especially Wohlin et al.'s [22] and Juristo and Moreno's [9].*

5.2 RQ1.2: Materials Organization and Teaching Guidance

Instructors organize their materials for teaching ESE concepts mainly using slides (26 – 83.87%), papers (23 – 74.19%), class notes (7 – 22.58%), and discussion on book chapters (5 – 16.12%).

As a teaching guidance for ESE concepts, most instructors provide study guides (5 – 16.12%) using different types of Learning Management Systems (LMS) (e.g., Moodle), whereas the remaining mentions are to instructor's Website, guidelines prepared by the instructor, Canvas software, Google Classroom, shared slides (all of them with 1 mention each – 3.22%). It is worth to note that 15 instructors (48.4%) do not provide any study guide to support teaching ESE to their students.

[9]https://doi.org/10.5281/zenodo.5106333

> ***Answering RQ1.2:*** *A small group of ESE instructors organize their ESE teaching materials using slides, paper, and class notes. Almost 50% of the instructors do not provide any study guide to their students.*

5.3 RQ1.3 Materials Availability

All instructors make their materials available to students in some way. Eighteen (58.1%) provide the study materials throughout a Learning Management System (LMS) such as Moodle, whereas seven (22.6%) make it available by email or other methods, three (9.7%) on their personal websites, and three (9.7%) in other means such as virtual drivers.

With regards to the used materials, eight (25.8%) instructors provided us the URL where their materials used in their classes can be found.

> ***Answering RQ1.3:*** *ESE instructors provide students their materials mainly via a Learning Management System and e-mail. A few of them provide open URL with materials used to teach ESE.*

5.4 RQ1.4 Teaching and Learning Practices

Regarding the way an ESE course is taught, most of the instructors teach in a course dedicated exclusively to ESE (19 - 61.3%), whereas nine teach ESE spread out in one or more different courses (9 - 29%), and three (9.7%) instructors teach in both ways.

Regarding the learning practices, 14 instructors (45.16%) mentioned that they adopt student practical participation, such as designing experiments, elaboration of research projects, continuous delivery, group work, and replication of experiments. Twelve instructors (38.7%) mentioned they present ESE concepts in regular lectures. Nine (29.03%) require students seminar and paper presentations, whereas seven (22.58%) use some active learning technique, such as Project-Based Learning (PBL) and Learning Objects. Writing essays, such as exams or papers, are required by six (19.35%) of the instructors.

We also asked the instructors about which learning practices worked and which did not (in their perception). Note most of instructors mentioned what did work rather than what did not, as follows:

- **Learning Practices that Worked:** active preparation for the class; reproduction of experiments (design and statistics); providing data sets for practical activities; teaching tools as R; ask students to apply the concepts and perform a quantitative analysis on their theses' subjects; group discussions and evaluations; instructor as a stakeholder is beneficial and help to manage risk; delegate to students to define scope and technology; motivate publishing their experiments; invite guest lectures on ESE from industry; use of active learning and learning objects.
- **Learning Practices that did not Work:** students do not read required contents for a given class; focus on theory (mainly, statistics and probability); discussions of articles may be boring.

Answering RQ1.4: *ESE instructors tend to teach ESE in courses dedicated exclusively for the subject with practical assignments (e.g., designing or reproduction of experiments). The instructors also have claimed many positive takeaway learning practices, whereas a few of negative ones.*

5.5 RQ1.5 Learning Assessment Methods

As a way to assess the ESE learning performance, most of the instructors have adopted different methods. Most of them assess theirs students carrying out seminars (21 - 67.74%).

Practical projects are required by 16 (51.61%) instructors, written essays/exams by 14 (45.16%), technical reports by 10 (32.25%), articles by nine (29.03%), and active discussions by one (1.41%).

Answering RQ1.5: *ESE instructors have adopted seminars, practical projects, written essays/exams, technical reports, articles, and active discussions to assess ESE learning.*

6 DISCUSSION OF RESULTS

In this section we provide a discussion on the observed results by providing assumptions that might be prospectively investigated to contribute to the teaching of ESE research topic.

6.1 Discussing RQ1.1

As we expected, the classic books of Wohlin et al. [22] and Juristo and Moreno [9] are adopted as reference texts by several instructors who teach ESE. However, we did not expect that more than one third of instructors prefer to create their own materials. We believe that this might occur because: (i) experimentation has evolved in the software engineering context mainly in the last years with a diverse set of ways to apply statistical techniques, the experience in strengthening discussions of threats to validity, and the power of reproducibility; (ii) we need brand new versions of existing classic texts to tackle such ESE evolution; and (iii) instructors want to provide students with their own examples and excerpts of experiments. These assumptions might bring light to invest in ESE open educational resources, which might be shared to our community.

Also related to ESE materials, we surprisingly observed the lack of license applied to produced materials. This might be because of reasons like: (i) instructors do not have the culture of sharing materials among their colleagues, thus they will not do for the whole community; (ii) instructors want to keep the copyright for their materials, thus they do not open to other people; and (iii) instructors are not aware of the benefits of providing licensed materials, for instance, based on the Creative Commons initiative. Therefore, it is worth investigating the benefits of promoting licensed ESE materials. An exemplary use of licensing is the open source research topic, which might straightforward contribute to employ this culture to ESE teaching materials.

6.2 Discussing RQ1.2

As expected, ESE instructors have used common types of materials in their classes (slides, papers, class notes, and book chapters). However, only a few instructors worry about providing guides to teach ESE, beyond using Learning Management Systems and their own or universities' websites. Study guides are an essential learning object to provide directions on how to handle teaching materials and related artifacts. We understand a conceptual model would be of great value to define teaching and learning ESE concepts, learning objects, and learning outcomes to be instantiated by instructors to properly guide students in ESE courses.

Another interesting result is that a few instructors provided us their ESE course syllabus. We understand this might happened as the syllabus could be available only for the students in, for instance, an LMS. Such conceptual model might also aid at establishing common syllabus for teaching ESE.

6.3 Discussing RQ1.3

Instructors provide their students teaching materials as we already expected. However, most of them do this by using an LMS, which is usually neither public or open. This might threat sharing such materials with other instructors and students, thus reducing the chances to allow materials evolution.

We understand that adopting open repositories, such as Zenodo or FigShare (or even GitHub repositories), might increase materials openness and their exchange towards benefiting both instructors and students. This would strengthen the ESE body of knowledge and the dissemination in our community, seeding the culture of Open Science. In addition, as teaching materials evolve they could be assigned certification badges as reference materials, thus motivating instructors and students to produce quality-based materials.

6.4 Discussing RQ1.4

Positive experiences are reported by instructors in terms of learning practices. We can see that most instructors have required the students practical participation in ESE classes. Designing experiments and replicating them are very interesting activities that contribute to the students immersion on ESE.

Although other classic practices are still used, such as, written essays, we understand alternative ones, as reported by few instructors, such as active learning might make the difference in the students performance. For instance, Problem-Based Learning (PBL) is an interesting and straightforward way to make students proposing experimental-based solutions.

Instructors also reported successful practices for teaching ESE. Among such practices, we understand creation of open data sets, use of open tools as R, and motivating students to publish their experiments report in open repositories (e.g., arXiv) are essential to prospectively evolve experimentation, thus contributing to our community with new findings and data. Once again, we believe that employing open science practices would benefit the community growth, by spreading good practices and sharing results.

6.5 Discussing RQ1.5

Although we agree with instructors that seminars, practical projects, written essays, and active discussions are interesting to assess students performance in ESE courses, we straightforward understand motivating such students to share their experiments and all instruments (e.g., documents, data, scripts) is vital for effectively evolve ESE education. For instance, giving extra course credits for each experiment published in high impact conferences or journals seems

a motivational and practical strategy. When it is not possible, fostering the sharing culture via other means would make the case.

We also envision registered reports could be a way of pre-assessing the design of experiments, thus guiding their conduction and reporting. Such reports might be stored in open repositories. The ESEM conference encourages the submission of this kind of artifact[10].

Another strategy might be creating a network of ESE courses and organizations in which students open peer review experiments conducted by other groups or even other institutions. This might encourage students to reflect on solid experimentation concepts to provide this kind of review. To do so, student experiments might be published in open repositories, thus receive such reviews from other students or researchers.

6.6 Open Science to Support ESE Education

By discussing the results of this survey, we understand that Open Science principles [13, 14] can be adopted to effectively support promoting ESE education. Principles, such as, Open and FAIR Data, Open Repositories, Open Access, and Open Source are widely disseminated in the literature of different research areas, which motivates us to apply to software engineering.

As we understand ESE education must be open for our community, we further encourage instructors to adopt them, according to their convenience. Starting by licensing materials and publishing experiments data are a great effort and might motivate our community to gradually do this. In addition, open educational resources might be taken into account for producing ESE educating materials towards amplifying their sharing with the community. With interesting examples we strengthen the community towards improving ESE education.

7 THREATS TO VALIDITY

Despite we have evaluated our instrument (Section 4.4), one threat to this survey is the level which instructors teach ESE as we did not provide any "industry set" options, as certain instructors have provided training courses or practical activities in the industrial environment, as in Continuous Experimentation.

In the evaluation method question, we find we could have provided other options, such as, teaching assistant activities, extra class tasks, and actual projects in a company.

Another threat might be we create our instrument based on our experience at teaching ESE. This occurs as no other survey on this matter could be found and we are confident on our research questions.

8 RESEARCH AGENDA FOR PROMOTING TEACHING ESE

Based on the discussion of results in Section 6, we provide a research agenda for teaching ESE, as follows:

(1) map teaching elements of ESE using conceptual models or formalizing them with ontology;
(2) investigate practices for producing open educational resources and/or Massive Open Online Courses (MOOC) for disseminating ESE teaching materials;
(3) produce state of the practice teaching materials;
(4) investigate improving the sharing of ESE materials with open registered reports, open repositories, and open and FAIR data practices;
(5) promote licensing of ESE materials;
(6) investigate how active learning can contribute to improve students performance in ESE courses;
(7) create a network of organizations and universities to foster sharing, open reviews, and idea exchange to create a community-level effort.

[10]https://conf.researchr.org/track/esem-2021/esem-2021-registered-reports

9 FINAL REMARKS

This paper presented emerging results from a survey with ESE instructors guided by five research questions. From these results we envisioned a research agenda for teaching ESE.

As future work we intend to establish and test hypotheses based on the discussions and the provided research agenda, thus contributing to the evolution of teaching ESE.

REFERENCES

[1] Nergiz Ercil Cagiltay. 2007. Teaching software engineering by means of computer-game development: Challenges and opportunities. *British Journal of Educational Technology* 38, 3 (2007), 405–415.
[2] Jeffrey C Carver, Letizia Jaccheri, Sandro Morasca, and Forrest Shull. 2010. A checklist for integrating student empirical studies with research and teaching goals. *Empirical Software Engineering* 15, 1 (2010), 35–59.
[3] Deepak Dahiya. 2010. Teaching software engineering: A practical approach. *ACM SIGSOFT Software Engineering Notes* 35, 2 (2010), 1–5.
[4] A. Fabijan, P. Dmitriev, H. H. Olsson, and J. Bosch. 2017. The Evolution of Continuous Experimentation in Software Product Development: From Data to a Data-Driven Organization at Scale. In *ICSE*. 770–780.
[5] David Forsyth. 2018. *Probability and Statistics for Computer Science* (1st. ed.). Springer Publishing Company, New York, NY.
[6] Michael Gnatz, Leonid Kof, Franz Prilmeier, and Tilman Seifert. 2003. A practical approach of teaching software engineering. In *CSEE&T*. IEEE, 120–128.
[7] Jesús M. González-Barahona and Gregorio Robles. 2012. On the reproducibility of empirical software engineering studies based on data retrieved from development repositories. *Emp. Soft. Eng.* 17, 1 (2012), 75–89.
[8] M. Host. 2002. Introducing Empirical Software Engineering Methods in Education. In *CSEE&T*. 170–179.
[9] Natalia Juristo and Ana M Moreno. 2010. *Basics of Software Engineering Experimentation*. Springer Publishing Company.
[10] M. Kuhrmann. 2017. Teaching Empirical Software Engineering Using Expert Teams. In *15th Workshop on Software Engineering*. 20–31.
[11] Marco Kuhrmann and Jürgen Münch. 2018. Enhancing software engineering education through experimentation: an experience report. In *ICE/ITMC*. 1–9.
[12] Johan Linåker, Sardar Muhammad Sulaman, Rafael Maiani de Mello, and Martin Höst. 2015. *Guidelines for Conducting Surveys in Software Engineering*. Technical Report 1.1. Lund University, Sweden.
[13] Daniel Mendez, Daniel Graziotin, Stefan Wagner, and Heidi Seibold. 2020. *Open Science in Software Engineering*. Springer International Publishing, 477–501.
[14] National Academies of Sciences, Engineering, and Medicine. 2018. *Open Science by Design: Realizing a Vision for 21st Century Research*. National Academies Press (US), Washington (DC).
[15] Sofia Ouhbi and Nuno Pombo. 2020. Software Engineering Education: Challenges and Perspectives. In *2020 IEEE Global Engineering Education Conference (EDUCON)*. 202–209. https://doi.org/10.1109/EDUCON45650.2020.9125353
[16] D Rodriguez. 2005. Empirical software engineering research: epistemological and ontological foundations. In *ONTOSE*.
[17] Halil Ibrahim Saglam. 2011. An Investigation on Teaching Materials Used in Social Studies Lesson. *Turkish Online J. Educ. Tech.* 10, 1 (2011), 36–44.
[18] A. Santos, O. S. Gomez, and N. Juristo. 2018. Analyzing Families of Experiments in SE: a Systematic Mapping Study. *IEEE Trans. Soft. Eng.* 46, 5 (2018), 566–583.
[19] Rodrigo Santos, Cláudia Werner, Heitor Costa, Ramon Abílio, and Hudson Borges. 2012. Managing reusable learning objects and experience reports in EduSE portal. In *International Conference on Information Reuse Integration*. 631–638.
[20] Dag IK Sjøberg, Jo Erskine Hannay, Ove Hansen, Vigdis By Kampenes, Amela Karahasanovic, N-K Liborg, and Anette C Rekdal. 2005. A survey of controlled experiments in software engineering. *IEEE Trans. Soft. Eng.* 31, 9 (2005), 733–753.
[21] Claes Wohlin. 2007. *Empirical Software Engineering: Teaching Methods and Conducting Studies*. Springer Berlin Heidelberg, Berlin, Heidelberg, 135–142.
[22] C. Wohlin, P. Runeson, M. Höst, C. Ohlsson, B. Regnell, and A. Wesslén. 2012. *Experimentation in software engineering* (2nd. ed.). Springer.