



# Support Mechanisms to Conduct Empirical Studies in Software Engineering: a Systematic Mapping Study

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## ABSTRACT

**Context:** Empirical studies are gaining recognition in the Software Engineering (SE) research community, allowing improved quality of research and accelerating the adoption of new technologies in the software market. However, empirical studies in this area are still limited. In order to foster empirical research in SE, it is essential to understand the resources available to aid these studies. **Goal:** Identify support mechanisms (methodology, tool, guideline, process, etc.) used to conduct empirical studies in the Empirical Software Engineering (ESE) community. **Method:** We performed a systematic mapping study that included all full papers published at EASE, ESEM and ESEJ since their first editions. Were selected 891 studies between 1996 and 2013. **Results:** A total of 375 support mechanisms were identified. We provide the full list of mechanisms and the strategies that uses them. Despite this, we identified a high number of studies that do not cite any mechanism to support their empirical strategies: 433 studies (48%). Experiment is the strategy that has more resources to support their activities. And guideline was the most used type of mechanism. Moreover we observed that the most mechanisms used as reference to empirical studies are not specific to SE area. And some mechanisms were used only in specific activities of empirical research, such as statistical and qualitative data analysis. Experiment and case studies are the strategies most applied. **Conclusions:** The use of empirical methods in SE has increased over the years. Despite this, many studies did not apply these methods and do not cite any resource to guide their research. Therefore, the list of support mechanisms, where and how they were applied is a major asset to the SE community. Such asset can encourage empirical studies aiding the choice regarding which strategies and mechanisms to use in a research, as well as pointing out examples where they were used, mainly to novice researchers. We also identified new perspectives and gaps that foster other research for the improvement of empirical research in this area.

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## Categories and Subject Descriptors

A.0.1 [Cross-computing Tools and Techniques]: Empirical Studies.

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Measurement, Experimentation, Verification.

## Keywords

Empirical Software Engineering, Systematic Mapping Study, Empirical Strategies, Support Mechanisms.

## 1. INTRODUCTION

In recent years, researchers have been emphasizing the importance of using empirical methods to evaluate technologies proposals and research results in software engineering (SE). These methods provide consistent and systematic approaches to evaluate, improve and validate phenomena (technologies, processes, models, tools, etc.), as well as identify problems and propose solutions in this area. Thus, empirical strategies became indispensable instruments to the SE scientific advancements, allowing us to point out reliable evidences about a certain technology and to aid the decision-making process on whether or not using it [1, 2, 3, 4].

The need to perform empirical studies in SE is not new [5]. Many initiatives arose to improve and disseminate the adoption of empirical strategies in SE in the last decades. In this context, some researchers proposed environments, guidelines, methodologies, tools, and other resources to support conducting empirical studies [3, 5, 6, 7]. However, experiments in this field are still limited, which hinders its progress as science and delays the adoption of new technologies in software industry [2, 8].

In order to improve research quality and to increase the use of empirical strategies in SE, it is necessary to understand research designs, philosophies, and methods available, as well as mechanisms used to support the researchers in these studies. In this sense, it is important conduct research to gather this knowledge systematically and develop environments supporting the planning and execution of such studies.

This scenario motivated us to investigate which support mechanisms are used as reference to plan, conduct, and analyze empirical studies in the SE context. We focused our investigation

in the most well-known venues of the ESE community: the International Conference on Evaluation and Assessment in Software Engineering (EASE), the International Symposium on Empirical Software Engineering and Measurement (ESEM), and the Empirical Software Engineering Journal (ESEJ). Since people involved in publishing and/or peer-reviewing in these vehicles are well-established researchers in the ESE field, we expect that studies published on these venues can reflect a considerable spectrum of ESE community. As such, we believe that gathering these studies can provide a great knowledge base and give a considerable view of this area.

Therefore, we carried out a systematic mapping study to identify which mechanisms have been used to support empirical studies on research published on EASE, ESEM, and ESEJ. The research protocol was based on Kitchenham et al.'s guidelines [9]. The studies are all full papers published in EASE, between 1997 and 2013; ESEM, between 2002 and 2013; and, ESEJ, between 1996 and 2013. As a matter of fact, regarding ESEM, from 2002 and 2006, we collected studies from the ISESE (International Symposium on Empirical Software Engineering), which joined with the Metrics Symposium in 2007 resulting on ESEM. We collected 891 papers, among primary, secondary, and tertiary studies. A total of 375 support mechanisms were found. As a secondary goal, we categorized the empirical strategies employed. Among our results, we observed that the most used support mechanisms are related to experiments [3], case studies [13], and systematic literature reviews [9]. We also identified that the most reported empirical strategies are experiments and case studies.

The main contribution of this research is providing a list of support mechanisms available to the SE community interested in empirical studies. Thus, it is possible to know which resources are being used as reference to plan and to support empirical studies and in which contexts they are applied. Such list may be a reference to the SE researchers in the decision regarding which empirical strategies and support mechanisms to use in a specific research. This is a valuable asset, mainly to newcomer and less experienced researchers, but also to the ESE community that can use this asset as a centralized source of information. Furthermore, it was possible to map other relevant evidence for the SE area, such as the empirical methods most widely used in the ESE community. We also identified new perspectives and gaps that foster the development of mechanisms to aid empirical studies.

This paper is organized as follows: Section 2 describes the research method applied and its steps; Section 3 reports the results, while Section 4 discusses the findings and limitations of this mapping; finally, Section 5 concludes and presents some future work.

## 2. METHOD

We conducted a systematic mapping study to identify methodologies, processes, guidelines, and tools employed to support empirical research strategies in SE, at EASE and ESEM conferences, and also ESEJ. The mapping study procedure was performed in four main steps: (1) Research Planning, (2) Search Strategy, (3) Data Extraction, and (4) Data Analysis. The protocol used to guide this research execution was based on the guidelines defined by Kitchenham et al. [9]. We summarize the research protocol in the following subsections. The complete protocol is available elsewhere (<http://bit.ly/1rem6j2>).

### 2.1 Research Questions

The research questions were defined based on the scope of this mapping. It is important to emphasize that they were divided into one main research question and two secondary questions. Thus, to provide an overview about support mechanisms for empirical studies, in addition to research strategies applied, we defined the following research questions:

- **RQ 1:** *Which are the support mechanisms used to conduct empirical studies in the research published in EASE, ESEM, and ESEJ?*
- **RQ 1.1:** *Which are the most used empirical strategies in the research published in EASE, ESEM, and ESEJ?*
- **RQ 1.2:** *What is the evolution of the use of support mechanisms in the research published in EASE, ESEM, and ESEJ?*

### 2.2 Search Strategy

Since our systematic mapping intends exclusively to make analyses of EASE, ESEM, and ESEJ proceedings, no search string and automatic search were necessary, hence, the search process used to map the studies only involved manual searches. All studies from these vehicles, since their first editions until 2013, were obtained.

Considering that only manual search was done, most of the articles found were considered relevant to the research. Despite that, three exclusion criteria were adopted: (1) short papers, (2) non-technical research studies (tutorial, keynote, industrial presentation, etc.), and (3) duplicate papers. We decided to exclude short papers and non-technical research studies because they, in general, either do not follow an empirical strategy or do not have space to specify in details their strategy. In cases of duplicate articles, we adopted the strategy of excluding the older and / or less complete version, unless they have additional information.

### 2.3 Data Extraction

After collecting and selecting the studies from EASE, ESEM, and ESEJ, we initiated the process of data extraction. Eight researchers participated in this process, four PhD and four MSc students. In order to avoid an error-prone data extraction, each paper was read by at least two researchers. Thus, the participants were divided in pairs, each comprised by one PhD and one MSc student. In order to organize the data extraction, all studies received a unique identifier. For instance, PS01 means study one. The instrument used to make data extraction was a spreadsheet detailed in Subsection 2.3.1.

Before the actual data extraction, we performed an extraction pilot. Ten papers were randomly selected from the studies set, and all participants performed the data extractions on these papers. After that, a meeting was organized in order to resolve the conflicts and mitigate the mistakes. This pilot was necessary to calibrate the extraction instrument, to reinforce the extraction strategies, and to avoid misunderstandings among the participants. For example, in some articles were observed divergences in the definition of the type of empirical strategy, so we decided to extract the information exactly as the authors mentioned in the paper. Was also possible to analyze the average time necessary to evaluate each article, therewith it was possible planning the data extraction steps. In fact, this is a procedure that we strongly suggest to be performed in systematic literature reviews in

general, which is not suggested in the Kitchenham et al. guideline [9]. By doing so, we could early mitigate bias among different pairs and also conflicts among researchers of a pair.

During the data extraction, papers were analyzed considering abstract, introduction, methodology, results, and conclusion. In some cases, a meticulous reading of the paper was necessary. This process was organized in cycles in order to avoid errors. Each cycle lasted two weeks, in which each pair was responsible for data extraction from twenty papers. By the end of each cycle, the teams performed the results compilation. In addition, after each cycle, a meeting with all participants was organized, with the intent of resolving the remaining conflicts and to evaluate the current state and plan the next steps of the extraction process. A senior researcher supervised the process. The experience gained in this research suggests that in research involving many articles and different teams, perform the extraction process in cycles allows a constant realignment in the understanding of the criteria as research evolves, and previously mitigate a possible bias in the data extraction.

As mentioned, we extracted the information exactly as the authors mentioned in the paper. Any conflicts were discussed and resolved internally by the pairs. If there was no consensus, they were discussed with all participants, in general meetings. It is important to mention that a high level of agreement between researchers was reached (76%). Just a few divergences needed to be discussed at general meetings. This is due to our decision to extract the information exactly as the authors mentioned in the paper. Besides, we have performed the extraction pilot and realized many meetings among the researchers.

In the final stage of extraction, two researchers were responsible for integrating the final spreadsheets from all teams. Data standardization was needed, because even having an extraction pilot to avoid misunderstandings among the participants, we found deviations from the expected results. For instance, a paper that the authors reported that performs a focus group strategy and one of us classified the empirical strategy naming “Focus Group”. In this example, the correct was considering the strategy classification as “Others”, and records the focus group strategy in a field of the spreadsheet exclusive for this kind of observation. Other disagreements were related with formatting of the bibliographical reference of the mechanisms, and also with the names of authors and institutions. The result of this process was a spreadsheet with all data extracted from studies included in this mapping study.

### 2.3.1 Instrument

The instrument used to make data extraction is described in Table 1. As usual, each research question motivates some data extraction. In particular, the instrument was a spreadsheet, where each column represents a piece of information that had to be extracted from the studies.

We consider that a mechanism is any resource cited as reference to support empirical strategies, such as tools, methodologies, processes, guidelines, etc. We also consider any resources used to analyze the study results (qualitative and quantitative) or used only to guide the study validation. However, we are not accounting the mechanisms used for a specific domain other than ESE. For instance, assuming a study that performs a case study in an agile project, and uses a guideline to support the case study and another to support the agile methodology. In this example, we

extracted as mechanism only the guideline to perform the case study, since the guideline for the agile methodology is specific to the domain of the study, so it is not specific to the ESE domain.

**Table 1. Data extraction instrument**

Information	Description
<b>General Information</b>	Title; Authors; Institution; Publication Year.
<b>Support Mechanism</b>	<b>Bibliographical Reference.</b>
	<b>Mechanism Type:</b> Framework, Guidelines, Lessons Learned, Method, Paradigm, Process, Technique, Template, Checklist, and Tool.
	<b>Mechanism Domain.</b>
<b>Empirical Strategy</b>	<b>Empirical Strategy Type:</b> Experiment, Case Study, Survey, Ethnography, Action Research, Systematic Literature Study, Mixed Methods, Others, or Not Identified.

A fundamental remark is that all extracted pieces of information have to correspond strictly to the authors’ words in the paper. We adopted this policy in order to avoid subjectivity and allow easier the replication and verification of our study. Therefore, the type of a support mechanism is defined based only on the paper’s content. The same approach was followed for the empirical strategy classification. If the author does not state the empirical strategy applied or does not perform an empirical study, the study was classified as “Not Identified”. In general, these kinds of paper are theoretical study or perform a dataset analysis.

The empirical strategy classification adopted is the one provided by Easterbrook et al. [10]. These authors define empirical strategy as a set of organizing principles around which the empirical data are collected and analyzed. We believe that empirical studies provide consistent and systematic ways to validate phenomena. For the sake of simplicity, we are considering systematic literature studies as empirical strategies. We classify systematic review, systematic mapping, and tertiary studies as “Systematic Literature Study”. Besides, all studies that adopt more than one empirical strategy were classified as “Mixed Methods” [10]. Easterbrook et al. and Dyba et al. [12] makes detailed discussion about the distinction of each empirical strategy.

Another important observation is the difference between “Others” and “Not Identified” in the classification presented in Table 1. The studies classified as Not Identified are those where their authors did not state the empirical strategy employed or did not perform an empirical study, for instance, dataset analysis. The studies that specify an empirical strategy that do not match any of the strategies presented in Table 1 are classified as Others, for instance, focus group, cross validation, and qualitative study.

To illustrate the Not Identified category, we randomly selected from the set of papers classified as Not Identified a paper by Jørgensen [14]. In this study, the author specified the method as “... *Method: The hypothesis is tested by analyzing a dataset of 4,791,067 bids for 785,326 small-scale projects registered at a web-based marketplace connecting software clients and providers...*”. In the remainder of the paper, the author defines the measures, datasets, and analyses, however he does not specify explicitly which empirical strategy was adopted. Therefore, this study was classified as Not Identified.

## 2.4 Data Analysis

In this step, the data collected from studies were organized in tables and graphics, which allow better visualization. Since the amount of extracted information is also large, we developed a tool to automate the data extraction from spreadsheets and to organize the results by counting and graph plotting. The source code of our tool is available on-line (<http://bit.ly/1jEAZE>). From this, we performed analyzes and comparisons of data. In the next section, we present the results of this systematic mapping study.

## 3. RESULTS

This section presents the results of our systematic mapping. In Section 3.1, we present some general information. Section 3.2 outlines the mechanisms found (RQ 1). Section 3.3 presents a classification of the studies based on the empirical method adopted (RQ 1.1). Finally, Section 3.4 shows the evolution of the studies published in EASE, ESEM, and ESEJ regarding with the adopted empirical strategy and the support mechanisms (RQ 1.2).

Unlike other systematic mappings, we cannot detail each study collected, since our systematic mapping included 891 articles. Among the selected studies, this research found relevant evidence to answer the main research question, and the secondary questions.

### 3.1 General Information

We gathered the studies from the conference websites, and also some search engines (IEEE, ACM, Springer Link, Science Direct, Scopus, and Google Scholar). When the paper was not available, we contacted the authors. However, even with these efforts, we did not found 15 papers. In the collection process were retrieved 1,323 studies from the chosen scientific vehicles. Table 2 summarizes some numbers about this process.

After collect the studies, we excluded some them through the exclusion criteria. As can be seen in the Table 2, 235 short papers, and 164 non-technical papers were excluded. Moreover, we identified 18 duplicate studies. These studies were approved on EASE or ESEM, and later versions were published in ESEJ. In these cases, we excluded the versions of the conferences, since publications in journals tend to be more complete and bring additional results. Fifteen articles were not found. Thus, this process results in 891 relevant papers, 198 (22%) from EASE, 377 (42%) from ESEM, and 316 (36%) from ESEJ.

Figure 1 presents the number of full papers gathered by year. Since its first edition, EASE published papers had a smooth oscillation in its growth, with a mean of 12 papers per year. On the other hand, ESEM, since the first editions, has a larger number of publications. In the last 4 editions of ESEM, we can observe a mean of 26 papers per year. Making another observation, in the last eight years of ESEJ, the high number of publications is almost constant.

EASE's edition with higher publication number was EASE 2012 with 22 papers, and the lower was its first edition with only five papers. ESEM 2005, the edition with higher publication number, had 50 papers, while ESEM 2002 had only 20 papers. In ESEJ, the year with higher number of publication was 2013, with 31 publications, and the lower was its second volume, in 1997, with only eight papers.

Table 2. Results of collecting process

Year	Collected Studies	Short Papers	Non-Technical	Duplicate Papers	Not Found	Total of Included Studies
1996	10	0	1	0	0	9
1997	35	1	21	0	0	13
1998	30	4	9	0	0	17
1999	41	4	12	0	1	24
2000	36	0	9	6	1	20
2001	44	7	17	2	3	15
2002	60	3	11	0	3	43
2003	69	0	6	4	1	58
2004	63	0	6	0	5	52
2005	82	1	4	0	1	76
2006	96	20	4	4	0	68
2007	100	17	4	1	0	78
2008	106	29	8	0	0	69
2009	107	31	4	1	0	71
2010	101	30	5	0	0	66
2011	108	23	12	0	0	73
2012	116	33	14	0	0	69
2013	119	32	17	0	0	70
<b>Total</b>	<b>1323</b>	<b>235</b>	<b>164</b>	<b>18</b>	<b>15</b>	<b>891</b>

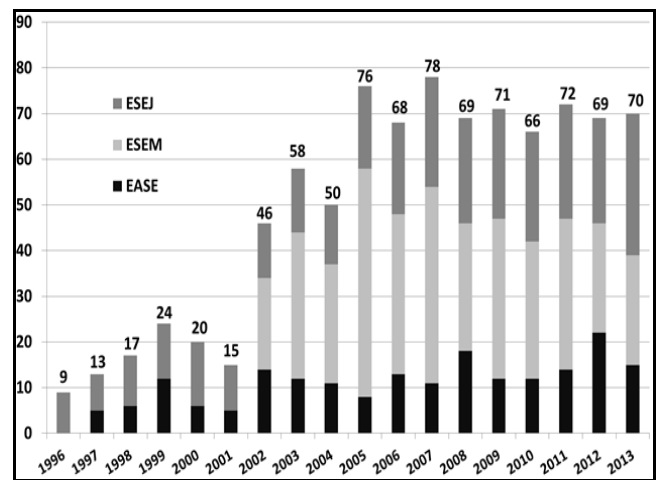


Figure 1. Distribution of full papers by year

In our mapping we identified 1,972 authors that had at least one study published at these vehicles. About 60% (1,212 authors) of them published at least two papers. Figure 2 presents the authors that most have studies published at those venues. Emilia Mendes, Claes Wohlin, and Barbara Kitchenham are the most active authors; they published 29, 26, and 22 studies, respectively.

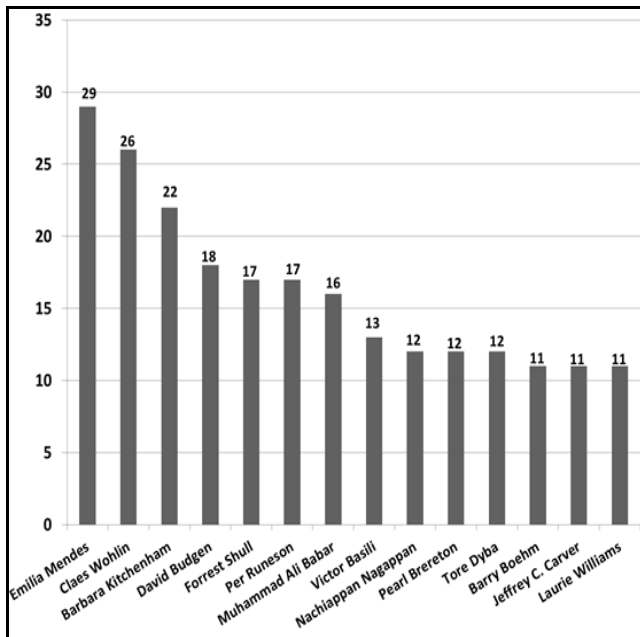


Figure 2. Most active authors

We also made a geographic analysis of our data, through the countries of the institutions, as show in the Figure 3. The research originated from 53 different countries. It is important to mention that some studies have been developed in cooperation between two or more researchers from institutions located in different countries. The country that most contributes to ESE community is the United States of America (USA), that is involved in 215 publications, followed by United Kingdom (UK), with 130 articles. Other countries that have an important role as contributor are Sweden (88), Germany (79), Italy (71), Canada (67), Norway (66), Australia (55), and Brazil (49).

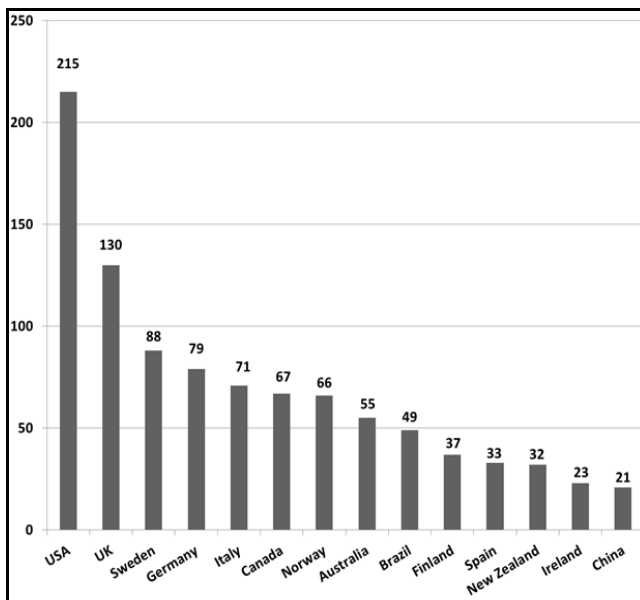


Figure 3. Country distribution

Figure 4 depicts the institutions that most contributed with published studies. Highlight to The Lund University (40 studies) and Blekinge Institute of Technology (40 studies), both located in Sweden. We can observe that, despite being the country with the highest number of articles published at these vehicles, USA has no institutions among the top five in the rankings. This can be motivated by the distribution of the studies in different institutions in USA. In addition to Maryland (30 studies) and California (27 studies), there are several other institutions with good numbers of contributions.

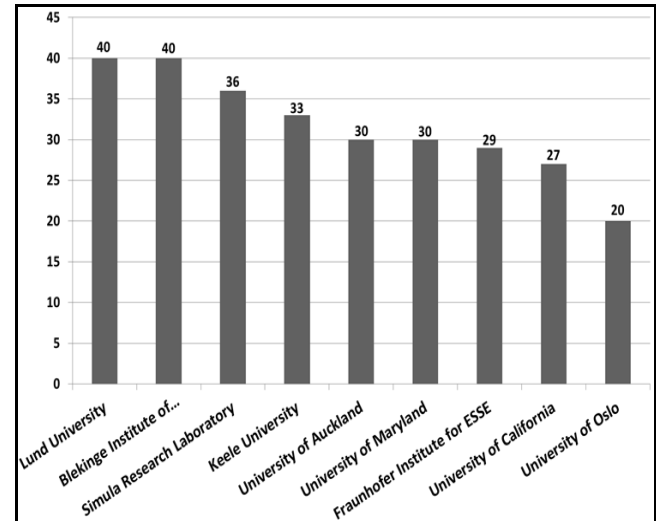


Figure 4. Institution distribution

Finally, it is important to highlight that are 1,972 researchers, 348 institutions and 53 countries involved in research published in the main scientific vehicles of ESE community. This factor may be an indication that the use of empirical studies has been gaining importance in the ES community, since there is a wide range of researchers and institutions involved in research in this area. The increase in research published in the last decade in the ESE area also corroborates with this hypothesis.

### 3.2 Mechanisms to Support Empirical Studies in SE

This section answers the main research question of this mapping, RQ1: “Which are the support mechanisms used to conduct empirical studies in the research published in EASE, ESEM, and ESEJ?” We identified 375 mechanisms used to support the conduction of empirical strategies. All mechanisms received a unique identifier. For instance, SM01 stands for Support Mechanisms 01. Due to space constraints, we only discussed the most relevant mechanisms. As additional information, we provide a list of the 40 most cited support mechanisms in the Appendix A. And the complete list comprising all mechanisms, organized by ID, is available on-line (<http://bit.ly/1rem6j2>).

Initially, we present information of the support mechanisms most cited as reference by the analyzed empirical studies. Table 3 summarizes such information. The first column presents the ID of the mechanism, the second column shows the bibliography reference, the third shows the count of studies that used each mechanism, and the fourth shows which empirical strategy or specific empirical activities the mechanism aims to support.



**Table 3. Most used support mechanisms**

Mechanism ID	Reference	Number of Citation	Empirical Strategy
SM38	[3]	101	Experiment
SM35	[13]	52	Case Study
SM81	[9]	30	Systematic Study
SM41	[16]	28	Experiment
SM08	[15]	28	Experiment Goals (GQM)
SM16	[21]	25	Quantitative and Qualitative Approaches
SM57	[18]	23	Qualitative Data Analysis
SM28	[20]	21	Experiment
SM56	[19]	21	Grounded Theory
SM65	[23]	20	Qualitative Data Analysis
SM100	[2]	20	Experiment
SM58	[17]	18	Systematic Literature Study

The most used support mechanism was SM38, cited by 101 studies. This mechanism is a guideline to experiment planning and execution, as well as threats to research validity. Other guidelines for experiments with many citations were SM41 (28 studies) and SM100 (20 studies). We also identified a web-based framework to support SE experiments activities (SM80). Many other mechanisms were used in experiment studies, as can be seen in the complete catalogue available at the research's website. It is important to mention that 32% of the experiment studies (95 studies) do not cite any support mechanism to support their empirical process.

Cited by 52 studies, the second most used support mechanisms was SM35. In this mechanism, Yin presents methods to aid case study researches, supporting the research design, evidence collecting, and evidence analysis. Other 14 case studies used SM14, 11 studies used SM88, and seven used SM69. All these mechanisms are guidelines for planning and conducting case study research. In spite of this, 110 studies (51% of the case studies) do not cite any support mechanism.

Besides experiment and case study, another empirical strategy that has many support mechanisms is systematic literature study. Cited by 30 studies, the third most used support mechanism was SM81. It is a set of guidelines used to plan and guide systematic literature reviews and systematic mappings. Other guideline for systematic studies with a high number of citations was SM58 (18 studies). The most remarkable result about the systematic literature studies, when compared with other strategies, is the fact that all studies that applied this kind of empirical strategy use at least one support mechanism to guide their research.

The remaining mechanisms presented in Table 3 are:

- **SM41** – 28 citations. This mechanism is a preliminary set of research guidelines aimed to assist SE researchers in designing, conducting, and evaluating their empirical studies. The mechanism focuses on experiment, however it can be adopted by studies in any empirical strategy, including systematic reviews;

- **SM08** – 28 citations. This mechanism specifies the approach called the goal-question-metric (GQM) [15]. It is being used to define and evaluate a set of goals, using measurement. It represents a systematic approach for tailoring and integrating goals with SE products, based upon the specific needs of a project;
- **SM16** – 25 citations. This mechanism provides a route-map of the various steps needed to carry out a piece of applied research. It brings together materials and approaches from different disciplines, valuing both quantitative and qualitative approaches, as well as their combination in multiple method designs;
- **SM57** – 23 citations. This mechanism presents some technical advice to aid researchers in making analysis of their collected data. It is full of definitions and illustrative examples, concluding with chapters that present criteria for evaluating qualitative research;
- **SM28** – 21 citations. This mechanism is a framework for organizing related sets of experiments in order to building up a complete picture with results of a wide range of contexts, organized around the GQM goal template. It is used in experiment studies, mainly to the definition of goal and objectives of the experiment. It is also applied in the threats to validity of the research;
- **SM56** – 21 citations. This mechanism is not specific to SE community; it is a guideline to grounded theory [19]. Its authors suggest meanings to discovery theories from data systematically obtained and analyzed;
- **SM65** – 20 citations. This mechanism presents several qualitative methods for data collection and analysis, and describes them in terms of how incorporate them into empirical studies of software engineering, in particular to combine them with quantitative methods. It was more used in case studies and surveys;
- **SM100** – 20 citations. This mechanism presents a guideline for perform experiment in SE. It reports many concepts related with empirical research in software engineering. Researchers follows recommendations provided by this mechanism to plan and conduct SE experiments;
- **SM58** – 18 citations. This mechanism presents a general guideline for undertaking systematic reviews. It uses meta-analysis to perform rigorous synthesis of empirical evidences;

We also identified some mechanisms to support surveys. SM68, the most used (nine studies), consist in a set of principles to plan and to conduct a survey. SM22 and SM46 present handbooks for survey, while SM130 present practical experiences in the design and conduct of surveys in empirical software engineering. SM110 (Lime Survey <http://limesurvey.org>) and SM231 (Survey Monkey <https://pt.surveymonkey.com>) are web-tools to create survey questionnaires and perform data analysis. Besides, SM229 present survey research methods. Other mechanisms to support survey strategy could be seen in the complete list of evidences.

Related with ethnography and action research, we found few references. SM44 presents principles, while SM45 discusses lessons learned in the application of ethnography. SM123 presents step-by-step to perform ethnography. In SM124, Passos et al. [31] presents challenges of applying ethnography to study software practices. Two guidelines to conduct action research strategies were found: SM127, and SM129.

The following are presents some support mechanisms that do not address a specific empirical strategy, in other words, resources that are used to guide specific activities of empirical studies, such as statistical analysis and qualitative data analysis:

**Statistical Data Analysis:** many mechanisms related with statistical analysis were found. SM03 and SM15 present principles and techniques to perform statistical data analysis, and they were used in seven and 17 studies, respectively. The ANOVA variance analysis model (SM64) was also used in some researches for this same purpose. Cohen (SM55) presents another widely used statistical model to perform data analysis. S-PLUS (SM26) is a statistical tool that allows manipulating experiment data, performing statistical analysis, and creating graphs. Another tool found was R (SM107), an environment for statistical computing and graphics (<http://www.r-project.org>). It is important to mention that were found 68 mechanisms specific to support statistical data analysis, 18% of the total of support mechanisms found in this mapping study.

**Qualitative Data Analysis:** besides the main mechanisms cited in Table 3 (SM56, SM57, and SM65), we identified other mechanisms to support qualitative data analysis. SM72 was used in 11 studies and it provides guidelines to perform data analysis and synthesis. SM264 recommended steps for thematic synthesis in SE.

**Replication:** we also identified mechanisms to support research replication. SM11 presents a replication approach to empirical software engineering research. It was used by four studies, two surveys and two experiments. SM142 and SM181 originally are guidelines to replication of experimental studies, but they were applied in survey studies. SM244 shows some good practices to for SE experiments replication.

**Validity of the Research:** SM38 is the mechanism most used to the threats to validity. It was explicitly cited for this purpose in 23 studies.

Another remarkable result in this research is regarding to the studies that do not use any mechanism to support their empirical strategies: 433 studies (48% of the total). In this sense, 458 studies use support mechanisms, in three domains: i) planning and conducting the empirical strategy; ii) data analysis; iii) and / or research validity. It is important to mention that 76 of these 458 studies use support mechanisms only to data analysis and research validity, without applying any mechanisms to guide the planning and the conducting of empirical strategy. Therefore, if we consider the studies that use at least one as reference to aid planning and conducting the empirical strategy, we have only 382 studies, in other words, only 43% of the full papers published in EASE, ESEM, and ESEJ apply guides to their empirical methods.

We also evaluate the type of each support mechanism (Figure 5). The mechanisms were classified as: framework, guidelines, lessons learned, method, paradigm, process, technique, template, checklist, and tool. The most common type is guideline, with 145 (39%) occurrences. This kind of mechanism was usually applied to plan and guide the empirical methods adopted in the studies analyzed in this work. Other most frequent types are method (97 occurrences, 26%) and technique (36 occurrences, 10%).

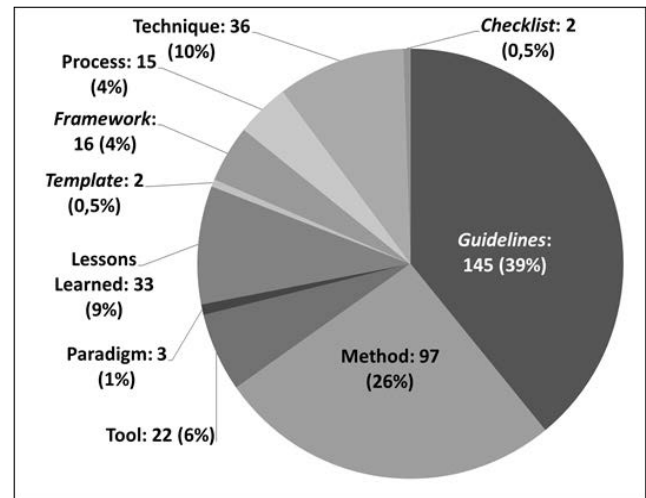


Figure 5. Support mechanisms type distribution

### 3.3 Empirical Methods Applied

This section answers a secondary question of this mapping, RQ1.1: “Which are the most used empirical strategies in the research published in EASE, ESEM, and ESEJ?”. Figure 6 presents the distribution of empirical strategies among the studies published in EASE, ESEM, and ESEJ.

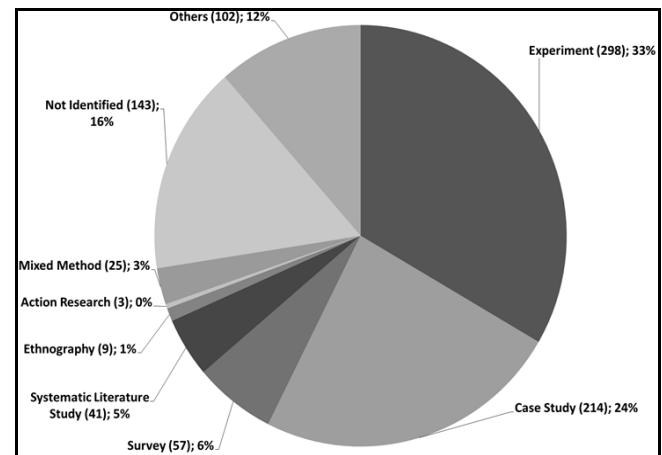


Figure 6. Empirical strategies distribution

Experiment is the empirical strategy more commonly adopted, with 298 studies, 33% of the total. Moreover, considering strictly the extracted information, this group of studies can be decomposed into: experiments (181 studies), controlled experiments (107 studies), and quasi-experiments (10 studies). In fact, Wholin et al. [3] considers experiment and controlled experiment as synonyms. A quasi-experiment has all the same elements as an experiment, however it typically lacks random selection and/or random assignment of participants [3].

Case study is the second strategy more adopted, with 214 studies, 24% of the total. The third most frequently reported strategy is survey, with 57 studies (6% of the total). This strategy is most frequent in combination of empirical strategies, as will be discussed in the finally of this subsection.

Systematic literature study composes a group of 41 studies, where 31 are systematic literature reviews, eight are systematic mapping studies, and just two are tertiary studies. It is important to remind that we made this distinction because we classified the empirical strategy based only on authors' specification in the paper.

Considering the studies classified as Others (102 studies), the authors classified their studies as: empirical study, focus group, empirical investigation, qualitative study, qualitative research, quantitative analyses, empirical analysis, meta-analysis, grounded theory, empirical validation, correlational study, and cross validation.

Finally, 25 studies were classified as Mixed Methods. The most used combination was survey and case study, with 13 studies. The most frequent strategy adopted in mixed methods is survey, appearing in 92% of mixed methods studies (23 occurrences). Case study was also frequently used in mixed methods studies, with 15 occurrences. So, any studies that adopted mixed methods uses at least one of them (survey or case study).

It is important to mention that we identified a high number of the *Not Identified* studies, 16% (143 studies). These studies are present in almost all editions of the venues.

### 3.4 Evolution of Mechanisms Usage and Empirical Strategies

This section answers another secondary question of this mapping, RQ1.2: “What is the evolution of the use of support mechanisms in the research published in EASE, ESEM, and ESEJ?”. Figure 7 presents the evolution of the support mechanisms usage throughout the vehicles editions. For each year, the total amount of published studies are reported, and the number of studies that using at least one support mechanism. In all venues there are studies that not cite at least one mechanism to guide their empirical strategies. In the last decade, the worse performance was in 2009, only 30 studies (42% of the 71) cited any support mechanisms, in other words 41 of 71 studies did not use any guidelines to aid their empirical strategy. However, in the last four years the rate of studies that cited support mechanisms maintained an average of 68%.

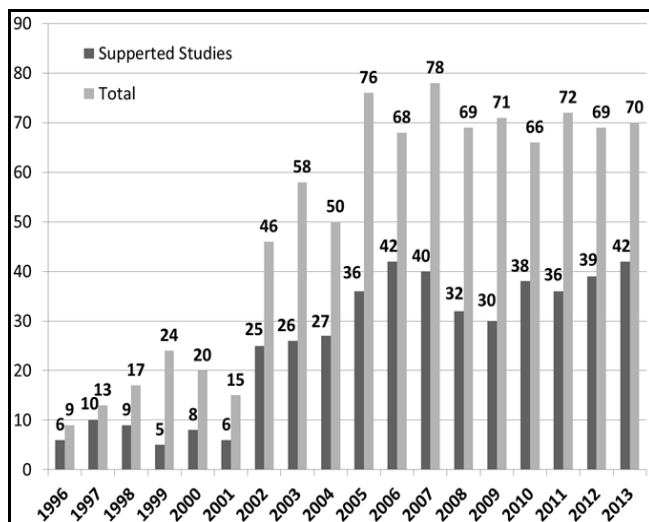


Figure 7. Support mechanisms usage evolution

We also show the evolution along the years of empirical strategies more commonly adopted: experiment (Figure 8), case study (Figure 9), survey (Figure 10), and systematic literature study (Figure 11).

As depicted by Figure 8, since the its first editions, experiment is one of the mostly used empirical strategies. In the last six years, we have an average of 12 experiments published per year. Its climax was on 2007 with 24 published experiments. Only on 1998 no experiment was published.

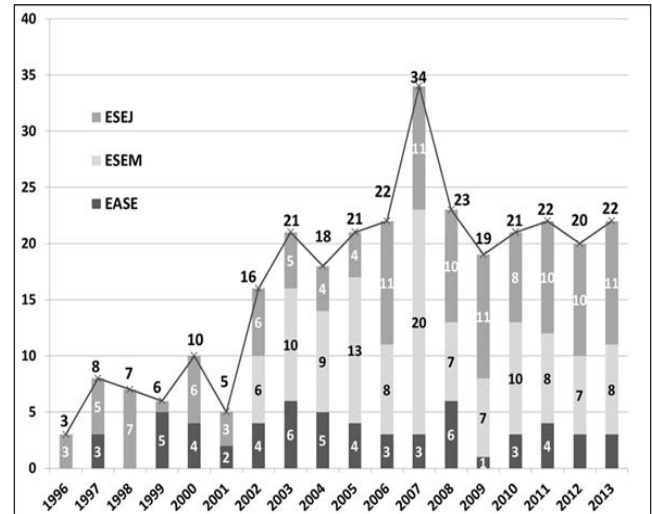


Figure 8. Experiments evolution

The case study evolution is similar to experiment evolution, almost ever with a high number of published case studies. Observing the Figure 9, we can notice the case study evolution has an ascendant phases between 2009 and 2011, followed by a descendant phases in the last two years. Only in the first two editions of EASE there was not a case study published. As a matter of fact, the majority of case studies were published at ESEM and ESEJ.

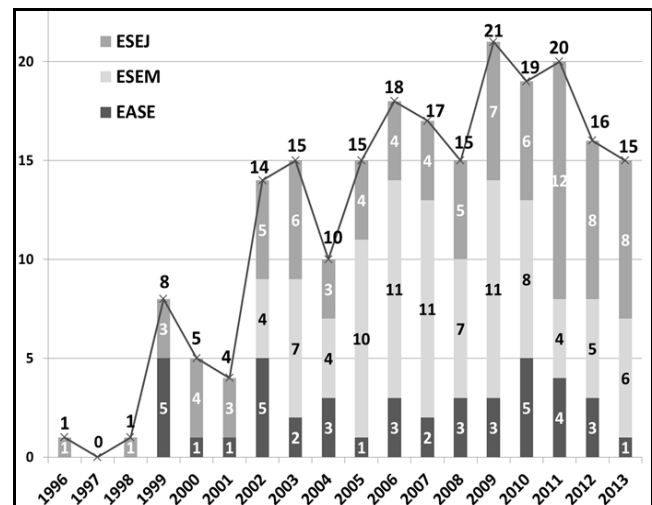


Figure 9. Case studies evolution

Surveys evolution (Figure 10) has a smooth ascendant. In particular, since 2006 there is an average of four study that performed a survey. We can observe that they have few variation, except in 2005 (10 survey studies published).



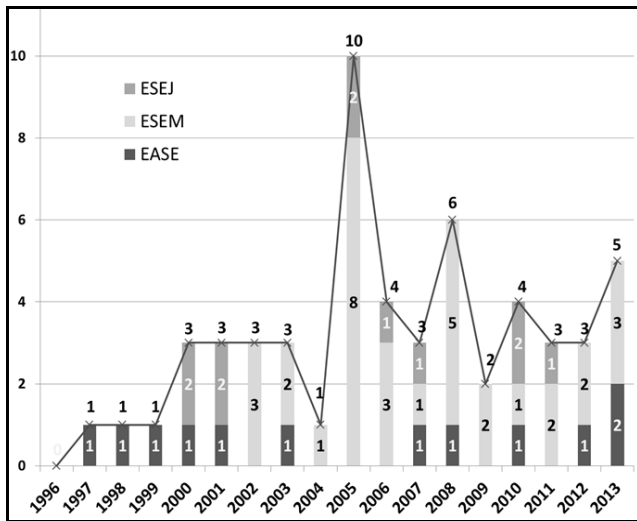


Figure 10. Surveys evolution

The systematic literature study evolution line has a singular behavior. We can clearly see an ascendant trajectory from 2005 (Figure 11). This evidences that studies involving this kind of strategy are still recent. However, this evolution depicts the relevance of this particular method has been acquiring recently, proving that such strategy is a trend. The period between 2011 and 2012 was its apogee, with 9 and 11 systematic literature studies published, respectively. We can also observe that the majority of this kind of study was published in EASE conference (60%). Few systematic literature studies were published in ESEM (13 occurrences) and only four in ESEJ.

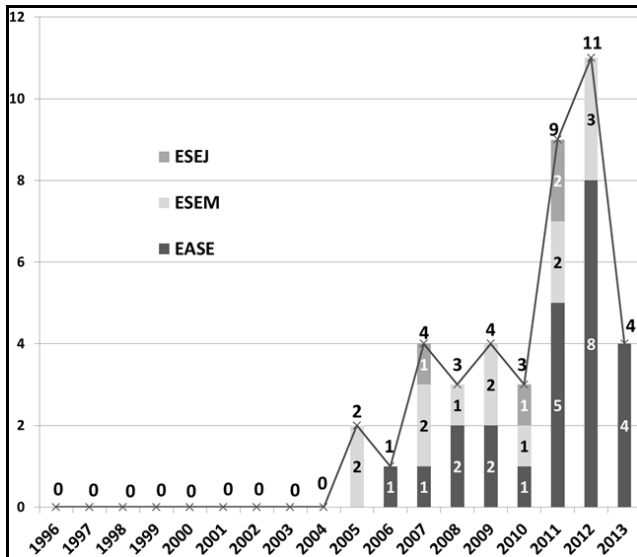


Figure 11. Systematic literature studies evolution

## 4. DISCUSSION

This section discusses the results found by this systematic mapping study. Based on these results, in the following sections we present some new perspectives and opportunities for future improvements. Each section focuses on answering each research question. In the end, we discuss the limitations of this study.

### 4.1 Support Mechanism Usage

Maybe the most remarkable results about the support mechanism usage is regarding to case studies. Even being one of the most used empirical strategies, a few support mechanisms was found. Moreover, the most commonly used guideline (SM35) is cited only by 52 of 214 case study papers (24% of all case studies). To complete this scenario, 49% of the studies that performed a case study (105 studies) did not cite any support mechanism. This fact corroborates with Per Runeson et al. [24], suggesting that there is still a misunderstanding on what is a case study. Since such studies can range from very ambitious and well-organized studies in a real life environment (in vivo) to small toy examples in university lab (in vitro). This variation creates confusion, which should be addressed by increased knowledge about case study methodology.

The most frequently used support mechanism SM38 is a guideline for experiments. The results regarding to support mechanisms usage in experiment studies is also not satisfactory: 37% of experiments (112 of 298 studies) do not cite any mechanism to guide their empirical research. So, this percent of experiment studies that do not cite any mechanism is a high amount. Some can argue that these studies do not cite their support mechanisms, since they are a common sense in the community. However, Jedlitschka et al. [22] say that the quality of an experiment report is decreased when it does not cite adopted guidelines, tools, etc. Considering only controlled experiment, the percentage of studies that not cited empirical support mechanisms decreases to 16% (17 of 107 controlled experiment studies). Maybe this lower percentage is due to all control required by the experiment execution, which maybe easy achieved if based on mechanisms like guidelines. Moreover, there is a larger number of support mechanisms available contributing to this result.

Other notable result regards systematic literature studies. Even this strategy being relatively new in SE, the studies with this type of empirical strategy are a significant amount of all collected papers (5% of total). Besides, 78% (30 of 41 studies) of them make reference at least to a SM81, the third most used mechanism. Several also cite SM41, other guideline used for systematic literature reviews. All systematic literature studies use at least one support mechanism. It can be due to the systematic nature required by such type of study, so that a guideline is required.

Surveys play an important role in ESE, often being used in conjunction with other empirical methods. We found some mechanisms widely used to support surveys, like guidelines [25] and tools [26]. Several mechanisms specific to survey were also applied in studies that used other empirical strategies, like Plfeeger et al. [25], that was also used in experiment studies.

We cannot make any accurate conclusion about ethnography or action research due to the small number of findings. However, we know that there are guides to ethnography [27, 28] and action research [29]. Most of references used to ethnography are not specific to SE area. To the best of our knowledge, we do not know a guideline of action research strategy that is specific for SE, which could characterize as an open issue in ESE.

We also notice that some studies are using auxiliary techniques in order to support their researches, in particular, SM08, SM16, SM56, SM57, and SM28. At same time, several studies use empirical environments, statistical tools (such as Mat-Lab and

SPSS), and statistical models however their sources are not being cited. Some can argue that such concepts and techniques are a common sense in ESE. Jedlitschka et al. [22] say that the quality of experiments reports is decreased when tools and statistical instruments adopted are not mentioned. We believe this is also true for any empirical strategy.

Finally, we analyzed if the support mechanisms identified are specific to SE area. Only 38% of the mechanisms used as a reference to guide empirical studies are specific to research in SE. This is evidence that this research area also reuses many resources from other scientific areas. Many times the SE researchers must adapt guides to other areas in their research, especially for methods like survey, ethnography and action research.

## 4.2 Empirical Strategy Adoption

The two most used empirical strategies are Experiment and Case Study, together they were used at 57% of all studies collected from EASE, ESEM, and ESEJ. Runneson et al. [24] say that experiments usually have an explanatory purpose, while case studies usually have an exploratory purpose. Our findings suggest a characteristic both explanatory and exploratory to these research strategies.

After experiment and case study, the third most frequently reported empirical strategy is survey, 6% of total. We cannot consider this rate insignificant. Moreover, such empirical strategy is most frequent in combination of empirical strategies, appearing in 92% of mixed method studies found. One explanation to low survey adoption is the lack of control for sampling bias [9]. Sampling bias causes problems in generalizing the survey results, since usually few subjects of the target population answer a survey, and the respondents to the survey may not be representative. Such fact can also explain the why this strategy is being used together with others, since surveys can be a mean to confirm the results provided by other empirical strategies.

Another frequently used strategy is systematic literature studies, 5% of total. Such rate is notable, since this strategy is relatively new in SE, mainly if we compare with experiment and case study. The results of this work show the increase of the relevance of this particular method in the last five years.

The empirical strategy ethnography was rarely used. In fact, authors of other ethnographical studies argue that such empirical strategy is hard to use [31]. Another method with low adoption is action research, we find only one study that had used only such empirical strategy. This strategy was also adopted together with other two strategies (see Section 3.3). In Information Systems [30] action research is being widely used, however such strategy is relatively new in SE. It is possible that the ESE Community is waiting for more mature results from studies that use this strategy. We also can argue that action research involves more complex environments and settings than other methods.

The studies that perform an empirical strategy that does not fit in our classification are 12% (102 of 891) and that we did not identify its strategy are 16% (143 of 891) of all collected full papers. In spite of all evolution of the ESE, we believe that normalization and dissemination of empirical strategies are still open issues. One action to address these issues could be made by the researchers of this area in elaborating a catalog with some recommendations of support mechanism.

## 4.3 Evolution of Empirical Strategies and Mechanisms Usage

Analyzing our data about the usage of case study and experiment over the conference editions, we note that studies that adopt these strategies have been constantly published in the conferences. In fact, these strategies are widely adopted by the sciences in general [2, 13]. It can be a sign that the ESE community is open for studies of any strategies, allowing their development.

Regarding systematic literature studies, we noticed that such empirical strategy is a trend. Besides, we find that all systematic studies use some guideline to support their research. In this sense, since SM81's debut, this mechanism has been cited by almost every (73%) systematic studies (30 of 41 studies).

Maybe the most critical result from our work is the fact that the "Not Identified" studies and the "Other" studies are present in almost all editions of the conference. As discussed, the studies in which the use of empirical strategies was not identified constitute 16% (143 studies) of all analyzed papers. Between 2010 and 2013, were identified 40 studies (15% of the studies of this period analyzed). Therewith, it is possible observe that such kind of study is not increasing along the years, however we also can say they are slowly decreasing. In spite of all efforts to evolve the ESE, we consider these results as a sign of misunderstandings on the usage of ESE methodologies, which could be mitigated by increased knowledge about the empirical strategies and their support mechanisms.

The results regarding evolution of mechanism usage confirm our previous conclusion. In fact, comparing with earlier conferences editions, the number of studies that do not cite any support mechanism is decreasing. However, we can also notice that this reduction is slow, with trend to a constant in last editions of EASE, ESEM and ESEJ.

## 4.4 Study Limitations

An important limitation is regarding to the not available studies. The majority was studies published in early EASE editions, so in EASE 2001's website (<http://www.scm.keele.ac.uk/ease/ease2001>) here is the following message: "... we are unable to make all files available for copyright reasons, additionally not all authors in the early years of EASE could make electronic copies of their papers available...". In ESEM, we had fewer problems with this issue, while in ESEJ all studies were available. We believe that our conclusions cannot be invalidated by this lack, since such studies correspond only to 1.1% (15 studies) of all candidate studies (some of them could be excluded) for our SMS.

Due to the larger size of our study set when compared to other systematic mappings, one possible threat to this work is the inaccuracy in data extraction. To mitigate this threat all extracted information process was performed by pairs of researchers, as described in Section 2.2, and all disagreements were resolved collectively in the research group. Besides, we performed an extraction pilot to avoid misunderstandings among the participants. Since the amount of extracted information is also large, we developed a tool in order to automatically consume and analyze them (Section 2.3). Moreover, we conducted a review strategy in order to evaluate if the information presented by the tool is accurate. In particular, two researchers manually extracted part of the information presented in this paper and we compare with the tool. No disagreements were found.

## 5. CONCLUDING REMARKS

In the SE context, empirical methods allow a vaster examination of proposed resources (technologies, processes, models, tools, etc.), facilitating their acquisition by the industry. Moreover, it enables evaluating research results and conducting researches with greater scientific value, thus contributing to the advancement of the field. The purpose of this systematic mapping was to investigate the mechanisms used as reference to support empirical methods in studies published by EASE, ESEM, and ESEJ, representing the ESE community, and also the usage of empirical strategies by these studies.

Among our findings, we highlight: (i) the most used support mechanisms are Wohlin et al. [3], for experiments, and Yin et al. [9], for case study; (ii) the types of mechanisms more common are guidelines, method, and technique; (iii) experiments and case studies are the most adopted empirical strategy in the ESE community, (iv) systematic literature studies are a trend, (v) support mechanisms to systematic studies [7, 12] are well established, and (vi) the remainder of empirical strategies are not widely used in SE, besides have few specific resources to guide its activities in the context of SE.

Regarding to the scientific vehicles, we noticed a slight difference in quality, when considered the amount of studies that explicitly use empirical methods and support resources to guide the empirical activities. It can be said that among the three analyzed vehicles, the journal (ESEJ) has a higher level of quality, in other words, has the highest average of research that make use of guides and references to empirical studies. This result can be attributed to a higher rigidity required by the journal, as well as a greater maturity of the research submitted to this, which in general have been published previously in any conference, which tends to raise the quality of work.

The list of support mechanisms found, where and by whom they were used, is a major contribution of this work to the SE community interested in empirical studies. It is possible to use the gathered knowledge to develop an environment to support the decision-making process regarding strategies and what support mechanisms to use in a specific research, also pointing out examples where they were used. This can serve mainly to newcomers and less experienced researchers of the SE community to have access and to choose approaches to conduct research, and so popularize further the adoption of empirical studies.

We believe that our results can reflect a significant spectrum of the empirical study community in SE. However, we plan to perform other similar systematic mapping considering more general conferences, comparing our results with other communities in SE, such as ICSE. Such study could improve the accuracy of our results, confirming or refuting them.

In fact, despite a greater effort made an analysis of EASE, ESEM, and ESEJ papers, further research is necessary to investigate other characteristics, such as the quality of the studies presented these conferences. We can make a study to assess if the authors properly classified the empirical strategies they used. And also expand this research, aiming to investigate a specific empirical method, considering the strategies and mechanisms available. Besides, an investigation to analyze with more details the mechanisms found could be a good contribution to the topic. Other research could be made in order to develop new mechanisms (framework, guide, process, tool, etc.) aimed to support planning and conducting

empirical studies on ES, according to the gaps observed throughout this work. Finally, conduct a research to identify reasons that aid to understand the high rates of researchers who perform empirical studies without citing references to guide its activities.

## 6. ACKNOWLEDGMENTS

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## 8. APPENDIX A: SUPPORT MECHANISMS

- [SM38] **Title:** Experimentation in software engineering. **Author(s):** C. Wohlin, P. Runeson, M. Hst, M. C. Ohlsson, B. Regnell, and A. Wessln. **Number of citation:** 101 studies. **Empirical strategy:** Experiment.
- [SM35] **Title:** Case study research: Design and methods. **Author(s):** R. K. Yin. **Number of citation:** 52 studies. **Empirical strategy:** Case Study.
- [SM81] **Title:** Guidelines for performing Systematic Literature Reviews in Software Engineering. **Author(s):** Kitchenham, B., and S. Charters. **Number of citation:** 30 studies. **Empirical strategy:** Systematic Study.
- [SM41] **Title:** Preliminary guidelines for empirical research in software engineering. **Author(s):** B. A. Kitchenham, S. L. Pfleeger, L. M. Pickard, P. W. Jones, D. C. Hoaglin, K. El Emam, and J. Rosenberg. **Number of citation:** 28 studies. **Empirical strategy:** Systematic Study.
- [SM08] **Title:** The goal question metric approach. **Author(s):** V. R. B. G. Caldiera and H. D. Rombach. **Number of citation:** 28 studies. **Empirical strategy:** Experiment Goals (GQM).
- [SM16] **Title:** Real world research: A resource for social scientists and practitioner-researchers. **Author(s):** C. Robson. **Number of citation:** 25 studies. **Empirical strategy:** Quantitative and Qualitative Approaches.
- [SM57] **Title:** Basics of qualitative research: Techniques and procedures for developing grounded theory. **Author(s):** J. Corbin and A. Strauss. **Number of citation:** 23 studies. **Empirical strategy:** Qualitative Data Analysis.
- [SM28] **Title:** Building knowledge through families of experiments. **Author(s):** V. R. Basili, F. Shull, and F. Lanubile. **Number of citation:** 21 studies. **Empirical strategy:** Experiment.
- [SM56] **Title:** The discovery of grounded theory: Strategies for qualitative research. **Author(s):** B. G. Glaser and A. L. Strauss. **Number of citation:** 21 studies. **Empirical strategy:** Grounded Theory.

- [SM65] **Title:** Qualitative Methods in Empirical Studies of Software Engineering. **Author(s):** Seaman, C. B. **Number of citation:** 20 studies. **Empirical strategy:** Qualitative Data Analysis.
- [SM100] **Title:** Basics of software engineering experimentation. **Author(s):** N. Juristo and A. M. Moreno. **Number of citation:** 20 studies. **Empirical strategy:** Experiment.
- [SM58] **Title:** Procedures for performing systematic reviews. **Author(s):** Kitchenham, B. **Number of citation:** 18 studies. **Empirical strategy:** Systematic Literature Review.
- [SM15] **Title:** Nonparametric Statistics for the Behavioral Science. **Author(s):** S. Siegel; N.J. Castellan. **Number of citation:** 17 studies. **Empirical strategy:** Statistics Data Analysis.
- [SM53] **Title:** Experimental and Quasi-Experimental Design for Research. **Author(s):** D. T. Campbell; J. C. Stanley. **Number of citation:** 17 studies. **Empirical strategy:** Experiment.
- [SM01] **Title:** Experimentation in software engineering. **Author(s):** V. Basili; R. Selby; D. Hutchens. **Number of citation:** 14 studies. **Empirical strategy:** Experiment.
- [SM14] **Title:** Case Studies for Method and Tool Evaluation. **Author(s):** B. Kitchenham, L. Pickard, S. L. Pfleeger. **Number of citation:** 14 studies. **Empirical strategy:** Case Study.
- [SM72] **Title:** Qualitative Data Analysis: An Expanded Sourcebook. **Author(s):** M. B. Miles; A. M. Huberman. **Number of citation:** 11 studies. **Empirical strategy:** Qualitative Data Analysis.
- [SM88] **Title:** Guidelines for conducting and reporting case study research in software engineering. **Author(s):** P. Runeson; M. Host. **Number of citation:** 11 studies. **Empirical strategy:** Case Study.
- [SM157] **Title:** Quasi-Experimentation Design and Analysis Issues for Field Settings. **Author(s):** T. D. Cook; D. T. Campbell. **Number of citation:** 11 studies. **Empirical strategy:** Experiment.
- [SM55] **Title:** Statistical Power Analysis for the Behavioral Sciences. **Author(s):** J. Cohen. **Number of citation:** 10 studies. **Empirical strategy:** Statistics Data Analysis.
- [SM92] **Title:** Reporting guidelines for controlled experiments in software engineering. **Author(s):** Andreas Jedlitschka; Dietmar Pfahl. **Number of citation:** 9 studies. **Empirical strategy:** Experiment.
- [SM47] **Title:** Using students as subjects – a comparative study of students and professionals in lead-time impact assessment. **Author(s):** M. Host; B. Regnell; C. Wohlin. **Number of citation:** 8 studies. **Empirical strategy:** Experiment.
- [SM68] **Title:** Principles of Survey Research. **Author(s):** Shari Lawrence Pfleeger; Barbara A. Kitchenham. **Number of citation:** 8 studies. **Empirical strategy:** Survey.
- [SM75] **Title:** Questionnaire Design, Interviewing and Attitude Measurement. **Author(s):** A.N. Oppenheim. **Number of citation:** 8 studies. **Empirical strategy:** Survey.
- [SM03] **Title:** Statistical Principles in Experimental Design. **Author(s):** B.J. Winer; D.R. Brown; K.M. Michels. **Number of citation:** 7 studies. **Empirical strategy:** Statistics Data Analysis.
- [SM17] **Title:** Design and Analysis of Experiments. **Author(s):** D. Montgomery. **Number of citation:** 7 studies. **Empirical strategy:** Experiment.
- [SM50] **Title:** What accuracy statistics really measure. **Author(s):** B.A. Kitchenham; L.M. Pickard; S.G. MacDonell; M.J. Shepperd. **Number of citation:** 7 studies. **Empirical strategy:** Statistics Data Analysis.
- [SM51] **Title:** Issues in using students in empirical studies in software engineering education. **Author(s):** J. Carver; L. Jaccheri; S. Morasca; F. Shull. **Number of citation:** 7 studies. **Empirical strategy:** Experiment.
- [SM69] **Title:** Building Theories from Case Study Research. **Author(s):** K. M. Eisenhardt. **Number of citation:** 7 studies. **Empirical strategy:** Case Study.
- [SM71] **Title:** A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. **Author(s):** H. K. Klein; M. D. Myers. **Number of citation:** 7 studies. **Empirical strategy:** Field Study.
- [SM156] **Title:** Experimental Models for Validating Technology. **Author(s):** M.V. Zelkowitz; D.R. Wallace. **Number of citation:** 7 studies. **Empirical strategy:** Experiment.
- [SM171] **Title:** Qualitative Evaluation and Research Methods. **Author(s):** M. Q. Patton. **Number of citation:** 7 studies. **Empirical strategy:** Qualitative Data Analysis.



[SM214] **Title:** Practical Nonparametric Statistics. **Author(s):** W. J. Conover. **Number of citation:** 7 studies. **Empirical strategy:** Statistics Data Analysis.

[SM259] **Title:** Research design: Qualitative, quantitative, and mixed methods approaches. **Author(s):** J. W. Creswell. **Number of citation:** 7 studies. **Empirical strategy:** Empirical Research.

[SM303] **Title:** Statistical Methods for Meta-Analysis. **Author(s):** Hedges, L. V.; Olkin, I. **Number of citation:** 7 studies. **Empirical strategy:** Statistics Data Analysis.

[SM34] **Title:** SPSS Reference Guide **Author(s):** SPSS Inc.. **Number of citation:** 6 studies. **Empirical strategy:** Statistics Data Analysis.

[SM59] **Title:** Evidence-based software engineering. **Author(s):** B.A. Kitchenham; T. Dyba; M. Jorgensen. **Number of citation:** 6 studies. **Empirical strategy:** Systematic Literature Study.

[SM66] **Title:** Studying Software Engineers: Data Collection Techniques for Software Field Studies. **Author(s):** T.C. Lethbridge; S.E. Sim; J. Singer. **Number of citation:** 6 studies. **Empirical strategy:** Field Study.

[SM79] **Title:** Conducting Realistic Experiments in Software Engineering. **Author(s):** D. I. K. Sjoberg; B. Anda; E. Arisholm; T. Dyba; M. Jorgensen; A. Karahasanovix; E. F. Koren; M. Vokac. **Number of citation:** 6 studies. **Empirical strategy:** Experiment.

[SM80] **Title:** A Web-based Support Environment for Software Engineering Experiments. **Author(s):** E. Arisholm; D. I. K. Sjoberg; G. J. Carelius; Y. Lindsjorn. **Number of citation:** 6 studies. **Empirical strategy:** Experiment.