- ORIGINAL ARTICLE -

Educational Value of Systematic Mapping Studies: A Replication Study

Valor Educativo de los Estudios Sistemáticos de Mapeo: una Replicación de un Estudio

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Abstract

The goal of this study is to validate the results of a prior study on the educational value of systematic mapping studies (SMS) and evaluate the possibility of generalizing those results to similar contexts. Since the inception of the Evidence Based Software Engineering (EBSE) paradigm in 2004, few studies have aimed at evaluating their impact in the academic field, and the educational values that SMS can offer to the students. In 2010, three renowned researchers presented an article on this subject at ICSE'10. The study made interesting contributions. We believe that, after 8 years, a replication of that study can be useful to assess the original findings and to guide future educational interventions. As a research method, we did a replication of the original multi-case holistic study. This replication confirms all but two of the results from the original work. The differences may be due to slight variations in the context. The experience of undertaking an SMS provided the students with both research skills and a broad understanding of a research area. We encourage other researchers to replicate this study, to gain further insights into the educational value of this method.

Keywords: Educational value, Evidence Based Software engineering, Replication Studies, Systematic Mapping Studies.

Resumen

El objetivo de este estudio es el de validar los resultados de un estudio anterior sobre el valor educativo de los estudios sistemáticos de mapeo (SMS), y evaluar la posibilidad de generalizar aquellos resultados a contextos similares. Desde la aparición del paradigma de Ingeniería del Software Basada en Evidencias (EBSE) en 2004, pocos estudios se han dirigido a evaluar su impacto en el ámbito académico, y el valor educativo que los SMS pueden ofrecer a los estudiantes. En 2010 tres reconocidos investigadores presentaron un artículo sobre éste asunto en ICSE'10. El estudio hizo interesantes contribuciones. Creemos que, después de 8 años, una replicación de ese estudio puede ser útil para comprobar los hallazgos originales y, para guiar futuras intervenciones educativas. Como método de investigación, hicimos una replicación del estudio holístico multi-caso original. Esta replicación confirma todos los resultados, menos dos, del estudio original. Las diferencias pueden deberse a pequeñas variaciones en el contexto. La experiencia de realizar un SMS proporcionó a los estudiantes tanto destrezas para la investigación como un amplio conocimiento de su área de investigación. Animamos a otros investigadores a replicar este estudio, para conseguir mayor información sobre el valor educativo de éste método.

Palabras claves: Estudios sistemáticos de mapeo, Ingeniería de Software Basada en Evidencias, Replicación de estudios, Valor educativo.

1. Introduction

When teaching a scientific discipline, teachers face two important challenges: to convey theoretical concepts, while at the same time, endowing students with requisite practical skills. The theoretical ideas are grounded in the fundamentals of the discipline, organized into what is referred to as the theoretical framework. On the other hand, students must be able to assimilate this framework sufficiently to apply the techniques and tools related to the common practice in the field.

There is a host of problems associated with both challenges. A frequent problem of the theoretical framework, especially in recent disciplines and with a very high turnover, is to find valid data empirically. We call these data evidence. The other great challenge, associated with the practice of a discipline, is the technical training of apprentices, that is, the acquisition of the skills necessary to realize practical experiences. These skills include the use of methods, techniques, and tools. Frequently, the main success factor in transmitting theoretical and practical skills is associated with the instructor's experience. Therefore, new teachers find it difficult to obtain solid evidence and to help students acquire the necessary skills to critically evaluate such evidence.

The area of software engineering is no stranger to such drawbacks. Evidence in this technological field is scarce because it is relatively new (born

around 1968) and the tools available for critical evaluation are constantly evolving. The EBSE (Evidence-Based Software Engineering) paradigm [1] and two principal research tools, systematic literature review (SLR) [2] and systematic mapping studies (SMS) [3], offer a solution to the proposed problems [4], [5].

The main objective of EBSE is to identify and aggregate the best available evidence in a given research field. By "best available evidence", we mean the one that has been validated and contrasted greater number times by empirical studies. SLRs seek to provide an objective, unbiased mechanism for identifying and selecting relevant primary reference from previous studies. They are designed to help formulate new information by answering questions posed by previous research [6]. On the other hand, an SMS - also known as scope study - is a secondary study that aim to identify and classify the existing set of publications on a given research topic [7]. The SMS is useful for detecting evidence gaps, highlighting the need for more primary studies, or "evidence clusters", which can be used to perform an SLR [1].

The contribution of this paper is the validation of the results obtained by previous work on the educational value of an SMS [8], and the identification of the effects produced by small changes in the context. The rest of this paper is structured as follows: section 2 describes related work with a brief analysis of their results; section 3 presents the research method used for this study; section 4 provides the results, and section 5 discusses the findings. Section 6 details the key limitations and, finally, in section 7, we offer some conclusions and future work proposals.

2. Related work

In 2010, Kitchenham et al. [8] carried out a case study to answer the following research question: "What educational value does a mapping study provide?". Six university students were asked to conduct an SMS, under the direction of a supervisor. Both the study subjects, three undergraduate students and three graduate students, as well as the experiment supervisor, responded to a final questionnaire, asking about the educational value of SMS and the problems that arose during its implementation. The conclusions of the study indicated that the development of SMS was a positive experience; the students emphasized the acquisition of skills for the search of information as well as obtaining a general vision of the research area of interest. In the specific case of postgraduate students, the SMS was seen as a good tool to start their doctoral studies, and to identify the state of the art, detecting possible "evidence gaps" that could offer possible research opportunities. The problems reported by the students affected the search and classification activities.

In 2013, Catal [9] studied the effect of a single class session (two-hour duration) aimed at students in a master's degree course. The contents of the lesson included an introduction to EBSE and the technique for conducting SMS. Two months later, the participants delivered an SMS on the specific theme of the course (software architecture). The percentage of this SMS on the final grade was 50%, the students were highly motivated and submitted medium to high-quality work. All students stated that they had acquired basic skills in SMS (search, selection, and classification of relevant primary studies), and that the experience had a positive impact on their career.

Also in 2013, Castelluccia and Visaggio [10] conducted an experiment with Master students. A full semester course on empirical and experimental research methods was offered to participants. The final product was a collaborative SMS on the topic of adoption of OSS (Open Source Software) in companies. From questionnaires administered after the completion of the course, students stated that both the EBSE paradigm and the SMS were valuable assets for their professional growth. The authors reported a positive impact on student participation and their attitude toward teamwork.

In 2014, Lavallée et al. [11] presented a new approach to conducting systematic literature reviews. The main feature of their method is an iterative process for collecting relevant evidence. The process, called iSR (iterative systematic review), was designed for novice researchers with very little experience in the review process or the research domain. During four semesters, four systematic reviews were developed, using a variable number of participants. In two of the reviews, the process suggested by Biolchini et al. [12] was used, and in two others, the iSR process was applied. The results showed that the iterative process is suitable for beginners. As the review progresses, knowledge about the domain expands, and the design of the review itself needs to be revised and adjusted accordingly. In each iteration, the results are more accurate and the participants' knowledge increases, both in the domain and in the revision process itself.

Finally, in 2015, Pejcinovic [13] conducted a pilot study on the possibility of applying iSR [11] to the context of a specific course on problems, rather than general contexts, as is often done in research method courses. The duration of the experiment was ten weeks. The conclusions of the study are that iSR is an adequate approach to teach students both the methodology of the systematic reviews and the relevant knowledge of their specific area of research. The students said that the process of selection of primary articles is a time-consuming task, although what is complex is the formulation of appropriate research questions. It was also suggested that the

method should be applied during a full semester (15 weeks).

Almost all the conclusions from the reviewed works are consistent and indicate that there is agreement among the researchers that teaching EBSE and SLR to university students is advisable. However, it is still necessary to validate the results, because the reported contexts are quite diverse, as well as the number of subjects participating in the studies, or the duration of the experience. Therefore, we replicated one of these studies [8] and checked whether small changes in the context affected the original results or not. A summary of data provided for the original related works and those added by our study is presented in Table 4 and Table 5 in Appendix I.

3. Method

Here, a qualitative case study methodology was used. The purpose was to gather student's opinions regarding the educational value of undertaking an SMS procedure. Because each SMS represents a single sample, this can be regarded as a multi-case holistic study [14]. We reused the propositions and issues, as well as the "open-ended" questionnaires used in [8]. A full description of these items and other complementary material can be found online in [15].

Twelve postgraduate students participated in our study. All the students work as instructors in the Faculty of Exact, Physical and Natural Sciences, at the National University of San Juan (Argentina), and are pursuing a Ph.D. in Computer Science. Each student is in the first year of a two-year Ph.D. program and, as a departmental practice, they are required to produce a literature review and thesis plan at the end of this first year. We performed a one-month (60 hours) course on EBSE, Systematic Reviews and SMS, specifically designed to help the students fulfil that requirement. Appendix II highlighted the key context differences between the original work and this study.

Due to time limitations, the students were asked to produce a brief report of their work using an SMS approach, including the complete protocol and descriptions of the search, selection, and data extraction processes. This study was related to their thesis topic. Therefore, the SMS report constitute the formal protocol to conduct a "future, complete SMS, reporting the state of the art, and identifying research gaps. Afterwards, the full SMS will be evaluated by their thesis tutor.

The roles assumed in this study were chosen to produce unbiased results, consistent with the standard practice of SMS procedures. The roles were: supervisor, reviewers, and students. The first author (Barros-Justo) assumed the role of "supervisor" of all the students in the study. He was responsible for writing the "supervisor form" for each SMS and administered the questionnaire to the students. The students sent their responses back to the supervisor who redirected them to the reviewers (i.e., the other three authors), who took on the role of carrying out integration and analysis tasks. Importantly, none of these reviewers had direct contact with the students participating in the study. In addition, the supervisor did not participate in the analysis, only in data collection.

The work of the "reviewers", of collecting and analysing data, was distributed amongst the other authors of this work. In particular, one of the reviewers (i.e., the second author) was responsible for coding/scoring the students' "raw" comments. The other reviewers (i.e., the third and fourth authors) studied the coding, extracted the data, and completed the analysis.

The student's opinions regarding set of propositions were collected. For convenience, the propositions (originally stated in [8]) are summarized as follows:

P1: An SMS is a useful literature search tool and helpful for organizing results,

P2: An SMS is helpful for initiating research activity, particularly when beginning a Master or PhD thesis,

P3: An SMS provides research skills that can be applied to a wide set of contexts,

P4: The most frequent problems are those related to search and classification.

P5: The results or an SMS are easy to document and report

In addition, we collected opinions about whether the SMS were perceived as challenging (I1) or enjoyable (I2), if they provide a general understanding of the research area (I3) or require too much effort (I4).

4. Results

In this section, we summarized all the data collected from each of the sources. Additional information, including tables with all the original student responses, is available online at [15].

None of the students had prior experience in performing an SMS, nor did they have previous knowledge about EBSE procedures. The goal of the participants, as they were PhD students, was to produce a review of the state-of-the-art, which serves as a valuable educational experience and foundation for the initial stage of their research plan. It is not surprising that all students responded affirmatively to the question: Do you consider that you have achieved your educational goals with this work? Based upon the actual written responses, the supervisor scored the student answers as "Yes" and "Mostly" (Figure 1).

Figure 1 Goal's achievement (Scores from the supervisor)

On the other hand, Figure 2 shows the elapsed time, i.e. the time students needed to complete the production of their SMS.

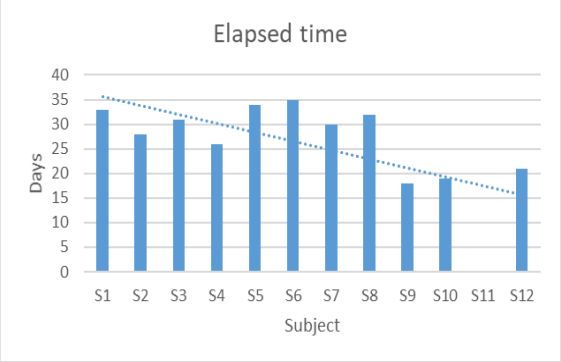

Figure 2 Time needed for the students (S1..S12) to complete their assignment (S11 did not report this information)

Ten students rated SMS positively as a useful tool for carrying out systematic searches of the literature and organizing the results found (Proposition P1). Only three students mentioned that an SMS was useful for initiating their research activities (Proposition P2). Eight students highlighted the usefulness of the SMS to provide research skills (Proposition P3). As expected, the combination P1 and P3 was the most frequent (86%). Figure 3 shows the relevant percentages.

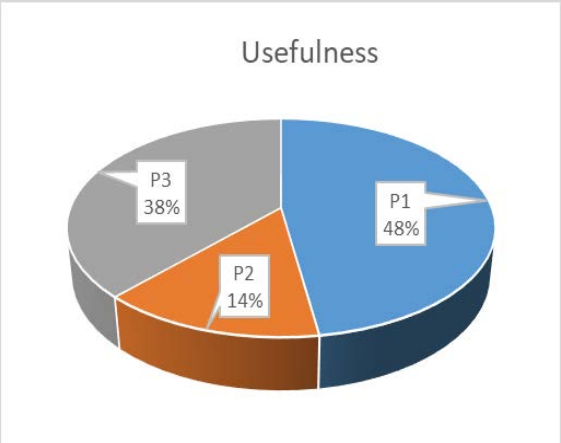

Figure 3 Opinions about the usefulness of SMS for propositions P1, P2 and P3.

The problems related to the search and classification of results (Proposition P4) were the most reported (5 students), followed by effort demands (3 students) and difficulty for documenting and reporting the SMS (Proposition P5, 2 students). None of the students reported that SMS are challenging (Issue I1), while eight mentioned that the SMS is enjoyable (Issue I2). These percentages are reflected in Figure 4.

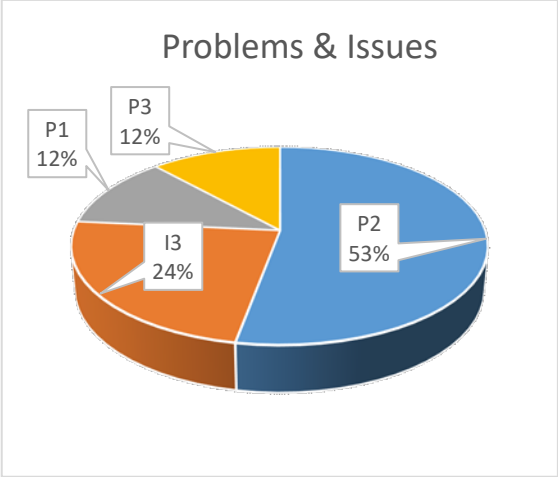

Figure 4 Observed Problems (P4) and Issues (I2, I4)

When asked if they would recommend an SMS to other students, all the participants answered affirmatively, highlighting the usefulness of an SMS to initiate research activities (P2). Four students specifically mentioned the issue of gain a broad knowledge of the research area (Issue I3). Eight students expressed additional comments. The topics ranged from very positive comments on the value of an SMS to complaints about the effort required (Issue I4), especially on the rigor to be applied. Figure 5 summarize these data.

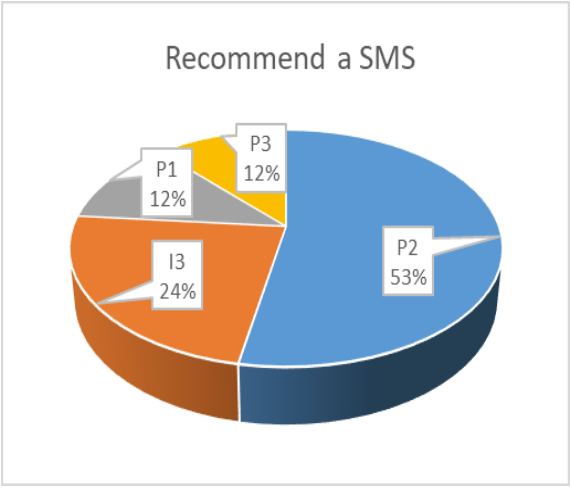

Figure 5 Recommend a SMS to other students

Finally, the partial results concerning the achievement of the educational goals, learning outcomes, problems, and recommendations, were

integrated into two sets. The results from the set of propositions supported by each student are shown in Table 1 and mentions to the issues (second set) in Table 2. All the original responses are available online in reference [15].

Table 1 Support for Propositions

Propo-sitions	Subjects											
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
P1	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
P2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
P3	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	
P4			✓		✓			✓	✓		✓	
P5				✓								×

Table 2 Issues

Issues	Subjects											
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
I1												
I2	✓	✓	✓		✓	✓	✓	✓	✓			
I3			✓			✓		✓				✓
I4	✓							✓	✓	✓	✓	

5. Discussion

In this section, we comment on the extent to which propositions are supported by the original results in [8] and those of our study. We also report the limitations of the replication (this study). Previous works demonstrated that undergraduates and master students are able to conduct SMS. This study is the first that includes only PhD students.

Our results are consistent with those from the originally reported work [8]. An SMS provide students with transferable research skills that are a useful first step to initiate their thesis work using a systematic literature review. Since we performed a replication of the study in [8], but with a subject group having different conditions, we compared responses corresponding to propositions and issues.

With respect to the propositions, our results agree with those of [8] P1, P2 and P3. Recalling, these propositions refer to the effect of mapping studies, such that (P1) they will help to organize search results, (P2) they prove to be important first steps for initiating research, and (P3) the students obtain concrete and transferable research skills. After the conclusion of such studies, all students (100%) in the original study [8] answered the questionnaire supporting these three propositions. In our study, we found that answers were P1 (92%), P2 (100%) and P3 (83%).

However, with respect to proposition P5, related to the ease of documenting and reporting the findings of a mapping study, we obtained contradictory responses. This may be because students did not narrow their queries to a specific question, as suggested in [8].

When comparing our results of issues with those from [8], we found that issue I1 (an SMS is challenging) was not mentioned by any student, in agreement with the original work. However, concerning issue I2 (an SMS is enjoyable/rewarding), our results differ. In the original work, none of the students answered positively to issue I2, while we got eight positive mentions (67%). Perhaps this is because our students only had to submit a draft at the end of the course, which allowed them to "enjoy" the learning experience and be satisfied with what they had achieved.

For issue I3 (an SMS provides a broad understanding of the topic area), all three postgraduate students from the original work [8] made comments supporting this issue. In our study, there were responses from only four students (⅓ of total). Since all students supported the P2 proposition and, found that an SMS was useful for initiating research and carrying out a review of the state of the art, we believe that the lack of support for I3 is due to a failure in the questionnaire. By including a specific question about this topic, we expect support can be similar to the one for P2 (100% positive comments).

In the original work, only one student supported the claim of issue I4 (an SMS can absorb too much effort). In our study, five students made comments about this issue. If we only consider the number of comments, both studies agree (a third of the participants commented on I4). However, if we review the comments from both studies, they coincide in mentioning the lack of time to perform the SMS. The same conclusions can be drawn for proposition P4 (students will find problems associated with the process of an SMS search/study classification) since the data fully match those of issue I4.

Table 3 shows, as a final summary, a comparison between the original study and this one.

Table 3 Summary of both studies

Study	Items to compare								
	P1	P2	P3	P4	P5	I1	I2	I3	I4
Original	✓	✓	✓	✓	×	✓	×	✓	✓
This study	✓	✓	✓	✓	✓	✓	✓	---	✓

6. Limitations

The limitations of this study reflects the ones in the original work [8], as follows:

- It is based only on the experiences of twelve postgraduate students that were all

supervised by the same person. Although this limits the generality of the results, the data supports the same set of propositions when combined with previous studies. In particular, data from the original work, as well as those from other studies included in related works section, show that the comments of all participants are quite similar.

- Researchers with a clear bias in favour of EBSE undertook the original work. This is not the case in our study; only the first author has experience in EBSE and SMS. Since he did not intervene in the analysis of the data, we believe that the influence of bias is very low. Furthermore, in this work, we provide all the "raw" responses [15] and, how we interpret them so the readers can extract their own opinions.
- As in the original work, the responses were requested from and returned to the supervisor. There is a chance that students have been tempted to report only positive aspects, or what they thought the supervisor wanted to hear. As we reported previously, the student's responses were verbatim. In this way, these responses could be re-evaluated. Additionally, the students did not know the propositions of our work, so they were not able to build up their responses to suit up our purposes.

7. Conclusions

Previous works, reported in the previous research section, demonstrated that undergraduates and master students are able to conduct SMS. This study is the first including only PhD students and confirms that they are able to conduct this type of studies and fulfil the education goals. We observed that the students learned a lot by "making mistakes". Therefore, "education goals" were achieved, the students learned. However, the resulting SMS were not good enough to be considered for publication in highly ranked journals.

The results of this study support the conclusion that through the practice (writing a SMS), and by example (reading other SMS), students can acquire the skills to find and organize the necessary research material, obtaining a good view of the state of the art in their area of interest. We think that both studies (the original and this one) demonstrated that an SMS could be a very good starting point for Ph.D. students.

We hope that other researchers, in academia, will be encouraged to replicate experiments like this, with the aim of increasing knowledge about the effects of research tools such as SMS and SLR, and the best methods to teach them to students. A project, involving five Latin American universities, is underway to evaluate the potential of undergraduate students, in the first courses, to carry out a simple SMS.

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Competing interests

The authors have declared that no competing interests exist.

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Appendix I: related work

Table 4 The original work's previous research

Papers in the original work	Process	Results
[Rainer et al. 2005]	Use of EBSE, to evaluate a technology of their own choice, by 15 final year undergraduates. A module on Empirical Evaluation in SE. University of Hertfordshire.	Students had problems with EBSE stages. They found that stage 1 was the easiest and stage 5 the hardest.
[Rainer and Beecham 2008]	Coursework assessment for final year undergraduates. To evaluate a requirements management tool using EBSE. Twelve students completed a feedback form.	They found steps 1 and 4 the easiest and steps 2 and 3 the hardest.
[Baldassarre et al. 2008]	Integration of systematic review in the "Empirical Software Engineering Methods" course taught at the University of Bari.	95% of the students said that the mixture of theory and practice was essential for understanding the tasks. 98% agreed that the lessons gave them a good understanding of SLR.
[Oates and Capper 2009]	Introducing EBSE into a module on research methods. University of Teesside.	Students found evaluating the quality of studies found in a SLR problematic, but found searching the easiest process.

Table 5 Related research added by this study

Papers added by this study	Process	Results
[Catal 2013]	A single lecture (two hours) in a master course. Each student delivered a SMS report related to software architecture (the topic of the course) two months later.	As the percentage of the SMS for grading was 50%, the students were highly motivated and delivered a medium to high-quality works. They learned the basic skills and reported a positive impact of this project in their degree.
[Castelluccia and Visaggio 2013]	Students of a master degree in Computer Science. A semester-long course including empirical and experimental methods. They produced a collaborative SMS on Open Source Software (topic) adoption.	Students came to appreciate EBSE and SMS as a precious asset in support of their professional growth. As a side effect, the experience had a positive impact in terms of student's participation, teamwork attitude and professional interest in OSS.
[Lavallee et al. 2014]	They performed four SLR, over four different semesters (60 hours) of a software engineering graduate course. For each SLR all the students of the class worked as a single team. The last two SLR were performed using an iterative method (iSLR).	An iterative approach to perform a SLR can be beneficial when working with novices. The approach should produce better and more accurate results with each iteration. The first SLR achieved partial success, the second was a failure and the last two (with the iterative approach) reports success.
[Pejcinovic 2015]	iSLR method, implemented in a Solid-State Electronics I graduate course (10 weeks, MS and PhD students). Seven students, divided into three teams (2+2+3), took the course.	Students found that Selection and Analysis were the two most time consuming stages and Question formulation was the most challenging one. Easiest to learn were Search and Selection process, while Analysis and Synthesis were the most difficult ones.

Appendix II: context of the study

Table 6 Differences in Context

	Original work	This study
Participants	Six students (3 undergraduates, 3 postgraduates) and one supervisor.	Twelve postgraduate students and one supervisor.
Duration	50 hours of Student Learning Activity Time	60 hours (45 hours for lectures plus 15 hours of homework).
Supporting materials	1. Two original papers on EBSE. 2. Guidelines. 3. Supplementary Guidelines. 4. Relevant benchmark review papers on their topic.	The same material for 1, 2 and 3. Relevant benchmark studies (we kept the spirit) but for different topics (see Table 4).
Software Tools and recording formats	Free choice.	Free choice.
Topics for the mapping studies	Predefined by the student and his/her thesis tutor.	Predefined by the student and his/her thesis tutor.
Previous research protocol	Yes.	Yes.
Elapsed time	Range from 2 to 13.5 months	Students were given a maximum of 30 days to produce an evaluable draft of the SMS.

Although students were free to choose software tools, they all chose to use the following:

- Electronic Data Sources: SCOPUS[1], IEEE Xplore[2] and Google Scholar[3].
- References manager: Mendeley[4] (one student used JabRef[5]).
- Recording and analysing: MS-Excel spreadsheet.
- Word processing: MS-Word.

While in the original work, the students should produce a complete SMS, in this study they were asked to produce only a draft, including the complete protocol and the search, selection and data extraction processes. The need to evaluate the course independently of their thesis projects was the reason for requiring this draft of the SMS, while the tutor of each student assumed responsibility for evaluating the final work, a review of the state of the art in the form of a full SMS.

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