The Educational Value of Mapping Studies of Software Engineering Literature

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ABSTRACT
We identify three challenges related to the provenance of the material we use in teaching software engineering. We suggest that these challenges can be addressed by using evidence-based software engineering (EBSE) and its primary tool of systematic literature reviews (SLRs). This paper aims to assess the educational and scientific value of undergraduate and postgraduate students undertaking a specific form of SLR called a mapping study. Using a case study methodology, we asked three postgraduate students and three undergraduates and their supervisor to complete a questionnaire concerning the educational value of mapping studies and any problems they experienced. Students found undertaking a mapping study to be a valuable experience providing both reusable research skills and a good overview of a research topic. Postgraduates found it useful as a starting point for their studies. Undergraduates reported problems undertaking the study in the required timescales. Searching and classifying the literature was difficult.

Categories and Subject Descriptors
K.3 Computers and Education, D.2 Software Engineering

General Terms
Human Factors.

Keywords
Systematic literature review, education, mapping studies, evidence-based software engineering.

1. INTRODUCTION
Software engineering is in principle at least, a subject where our knowledge should be underpinned by a solid corpus of evidence about our concepts, practices and procedures. Unfortunately, this is not so, and much of our basic material is largely dependent upon expert knowledge [1]. This in turn presents a problem for an instructor, in that they may themselves lack deep experience of practice or research, and hence in their teaching have to address the following three challenges:

- Where can they find well-founded support material and hence have confidence in the verity of what they are teaching?
- What are the sound research practices that can help provide such material?
- How can they teach students the skills needed to critically appraise both experience and empirical data?

Our paper addresses all three of these challenges, and provides some answers that are derived from a systematic assessment of our own experiences. We suggest that Evidence-based Software Engineering (EBSE) and systematic literature reviews (SLRs) provide the means to address the first two points. Using the basic systematic literature review process, we evaluate the use of student mapping studies to address the third point.

In a series of three papers Kitchenham, Dybä and Jørgensen suggested that software engineers (both practitioners and academics) should adopt evidence-based practice, as pioneered in the fields of medicine and sociology ([2], [3], [3]). They proposed a framework for EBSE, derived from medical standards, that relies on aggregating best available evidence to address software engineering questions posed by practitioners and researchers. The most reliable evidence is considered to be that which comes from aggregating all empirical studies on a particular topic. EBSE, as proposed by Kitchenham, Dybä and Jørgensen, therefore follows five steps:

1. Convert a problem or information need into an answerable question.
2. Search the literature for the best available evidence to answer the question.
3. Critically appraise the evidence in the literature
4. Integrate the evidence with practical experience and the circumstances to make decisions about practice.
5. Evaluate the performance in steps1-4 and seek ways to improve it.

The methodology for aggregating the results of empirical studies recommended by medical researchers and social scientists is the

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systematic literature review (SLR) (see for example [5], [6], [7]). Kitchenham adapted the medical guidelines for SLRs to software engineering [8], and later updated them to include insights from sociology research [9][1]. SLRs have subsequently been undertaken for a wide range of topics [10].

In the context of education, Jørgensen et al [3] suggested that training in the procedures of Evidence-based Software Engineering was useful for undergraduates. To support this view, they presented lessons learnt from teaching EBSE to students at Hedmark University College in Rena, Norway, and suggested the following reasons for teaching EBSE:

- To help software industry to adopt EBSE concepts.
- To give software engineering students training in critical and systematic evaluation of arguments.
- To train students to collect and evaluate information from various sources.
- To improve University provision with respect to training on how to acquire new skills.
- To alert students to the dangers of "hype" in the software industry.

Since that paper there have been several papers reporting experiences in teaching EBSE in general and systematic reviews in particular ([11], [12], [13], [14], [15]). In this paper we report experiences of three postgraduate and three undergraduate students performing mapping studies. A mapping study is a special type of SLR that concentrates on locating and classifying the literature, but usually only provides aggregation against the various study categories, and usually does not address the quality of individual studies. Our overall research question is:

> *What educational value does undertaking a mapping study provide?*

We addressed this research question using Yin's case study methodology, as discussed in Section 3.1 [16].

Section 2 discusses previous related research. Section 3 describes our methodology. Our results are reported in Section 4 and discussed in Section 5. We present our conclusions in Section 6.

2. PREVIOUS RESEARCH

In 2006, Rainer et al. [11] reported on the use of EBSE by 15 final year undergraduates taking a module on empirical evaluation in Software Engineering at the University of Hertfordshire. Students were asked to use EBSE to evaluate a technology of their own choice. The authors found that students had problems with each of the 5 EBSE stages. However, the student marks suggested that Step 1 was the easiest and step 5 was the hardest. In a follow-up study, Rainer and Beecham [12] reported on a coursework assessment for 37 final-years undergraduates that required them to evaluate a requirements management tool using EBSE. 12 students completed a feedback form and reported that they found steps 1 and 4 to be the easiest and steps 2 and 3 the hardest. Overall students found EBSE challenging, particularly undertaking SLRs.

Baldassarre et al. [13] reported how the concept of systematic review has been integrated into the Empirical Software Engineering module course taught at the University of Bari. Students received training in the systematic literature review process and undertook a series of exercises within the context of a systematic review of statistical process control that allowed them to try out processes such as searching digital libraries, extracting data from papers, and aggregating results. The students were asked their opinion of the course. 95% of the students felt the mixture of theory and practice was important for understanding the tasks. In addition, 98% of the class agreed that the lessons gave them a good understanding of the topic of the SLR. Baldassare et al. reported that many students expressed an interest in undertaking a systematic review on another topic.

Oates and Capper [14] report the results of introducing EBSE into a module on research methods for computing-related MSc students at the University of Teeside. They found that introducing systematic reviews and EBSE guidance can improve students' literature handling skills and enables supervisors to provide improved feedback to students. The results suggested that students found evaluating the quality of studies found in a systematic review particularly problematic, but, in contrast to Rainer and Beecham [12], students found the search process to be the easiest task. The authors suggest that the guidelines for systematic reviews [8] need to be revised to give more assistance to students and novice researchers.

Janzen and Ryoo [15] take a different approach. They are concerned with summarizing individual empirical studies. They suggest the need for an online database of evidence-based studies populated in a decentralized fashion by the software engineering community as a "kind of structured Wiki". They discuss a prototype database call "SEEDS[2]. The database was populated with summaries of 216 empirical software engineering papers produced by graduate students. Summaries selected at random and viewed by software professionals were found to be at least as good as professionally-written summaries. However, from an EBSE point of view, using a decentralized process to populate such a database raises questions about how to evaluate completeness of any set of papers addressing a specific topic. Furthermore, the authors have not used a structured format for the summaries, which could result in missing information needed for aggregation of studies ([17], [18]). It is also important for EBSE purposes to have a reliable method of evaluating the quality of individual empirical studies before aggregating results.

3. METHOD

In this study we obtained opinions from the six students and their supervisor regarding the value of, and problems associated with, undertaking mapping studies. We used a qualitative case study methodology because we were particularly interested in the viewpoint of the students themselves. Each mapping study represents a single case, and we have collected information about each mapping study as a whole. Thus we regard this study as a multi-case holistic case study [16].

We used an open-question style questionnaire (see Appendix A) because, given our enthusiasm for EBSE and SLRs, there was a risk that a semi-quantitative opinion survey with closed questions would impose our own viewpoint on the students. For the same reason, we regarded semi-structured interviews as an unsuitable means of data collection.

[1] These reports can be found at http://www.ebse.org.uk

[2] http://www.evidencebasedse.com

3.1 Study Research Question and Propositions

Yin [16] suggests that case studies, other than those used for exploratory purposes, need to derive and evaluate propositions (which are similar to "hypotheses" in experiments) in order to address a research question. In this section we consider existing research related to EBSE and systematic reviews to identify a number of "a priori" propositions relating to the educational value of mapping studies.

A mapping study uses a generic research question of the type "What do we know empirically about topic X?" and only aggregates the identified literature against a set of categories such as the type of empirical study. Furthermore, it addresses only step 2 of the EBSE process. In terms of the motivation for EBSE-based education specified by Jørgensen et al [3], the educational value of mapping studies is likely to be restricted to training students how to collect and evaluate information from various sources and indirectly to help industry to adopt EBSE concepts. Thus, our initial proposition is:

> *P1: Mapping studies teach students how to search the literature systematically and organize the results of such searches.*

Mapping studies are intended to be a preliminary stage in evaluating the literature. They can be used prior to undertaking a conventional systematic review to establish whether there are sufficient studies for a full SLR, and as the starting point for a research activity to address deficiencies in existing empirical research. Thus, we would expect postgraduate research students to find mapping studies both a useful initial starting point for their research and a useful transferable skill. In contrast undergraduates would be expected to value mapping studies only as a useful transferable skill. This leads to two propositions

> *P2: Postgraduate PhD students will find a mapping study a valuable means of initiating their research activities.*
>
> *P3: Postgraduate students and undergraduate students will find undertaking a mapping study provides them with transferable research skills.*

Compared with conventional systematic literature reviews, mapping studies have a broader research question, so the number of relevant papers is likely to be relatively large. The organization of the literature depends on identifying and applying a useful classification schema. However, aggregation and reporting should be correspondingly easier for mapping studies. This suggests two further propositions:

> *P4: Problems students find with mapping studies will primarily be concerned with the search and study classification processes.*
>
> *P5: Students should find mapping studies relatively easy to document and report.*

In the context of our research question, P1, P2 and P3 are the main propositions while P4 and P5 are secondary propositions. Furthermore, the view of the students and supervisor will be assessed to establish whether there are other educational advantages or problems not identified within the context of the preliminary propositions.

3.2 Study Context and Participants

All three undergraduates were in their third year of study, and were registered for an 'integrated' module that had elements drawn from both the Physics and Computer Science programmes. Part of the Computer Science element was a strand of lectures on empirical software engineering including a lecture on SLRs. These three students also came from two different cohorts. Assessment for the module was in the form of a number of tasks, of which this was one, and this one was intended to equate to 50 hours of *Student Learning Activity Time* (SLAT). Since mapping studies have the potential to become a 'run-away' form of assessment, the students were asked to maintain a log of the time spent on different activities, and if necessary to curtail their searching or data extraction (in fact, none actually had to do so).

For supporting materials they were provided with: two of the original papers on EBSE; an example research protocol used for an earlier study; both the full *Guidelines* document as well as supplementary guidelines on student use of EBSE [19] and any relevant benchmark review papers on their topic. The choice of software tools and recording formats were left to them. The two students in the second cohort also had access to some of the material that had been produced by the student in the previous one.

The topics for the mapping studies were agreed between student and supervisor and were chosen as being ones that:

- addressed a topic that was reasonably familiar to the student, making for easier identification of suitable search terms and easier classification;
- were unlikely to produce an excessively large number of papers to be reviewed (whether relevant or not);
- were likely to be of interest to others who might help extend the review for eventual publication.

This was obviously quite tightly tailored, and the use of such a mapping study was only felt to be practical because very few students took this module. All three students actually worked with relatively minimal supervision after some initial meetings with the supervisor, and after having written (and agreed) a research protocol for the study. Where questions did arise, these were mostly addressed by an exchange of e-mails.

The studies for the postgraduate students arose from a rather different context. Part of departmental practice is for research students to produce a literature review and thesis plan at the end of their first year, which is then the subject of an oral examination which needs to be passed to permit progression. All three of these students undertook to perform their literature review as a mapping study.

For the postgraduate studying OO design patterns, this proved to be a larger task than had been expected, partly because the searches made use of terms that led to many irrelevant papers being found. This student also opted to go beyond the use of electronic searching and performed a manual search on major journals as well as a 'snowball' search (that followed up the references in the included papers). This mapping study was also later extended to include 'observational' papers as well as experiments. Collectively, this delayed the internal assessment

process by about a year, but did result in a literature review that was considered as outstanding by the examiners, as well as a conference paper on one aspect of the study, and a journal paper submission on another. With hindsight, it would have been better to have submitted interim results for the internal assessment process since the one eventually produced was felt to form a substantial part of the PhD. A valuable outcome was that the plan for the remainder of the PhD was easily agreed, the main problem being one of restricting the scope!

For the postgraduate studying software architecture, the mapping study was again used as the basis of an initial literature review. The topic chosen was one that the student had identified as being of interest. The study had a tighter form than that for the OO design pattern study (which may partly have reflected the experience gained by the supervisor from the OO design pattern study) and also addressed a topic which had emerged relatively recently, which also restricted the search period.

The outcome was a very thorough literature review that subsequently formed the basis of a workshop paper and a journal paper submission. Again, the student passed their internal oral examination very successfully. However, the use made of this review was different to that of the case of the OO design pattern study, in that student and supervisor concluded that the results did not provide enough confidence for the student to continue with the original goal, and a modified goal was adopted. So in both cases, the mapping study performed a valuable, if quite different, role in giving a focus to their studies.

In the case of the postgraduate studying Web service composition, the mapping study was also used to undertake an initial literature review. Searching was thorough, and found a reasonable number of papers. However, classification did prove to be quite a problem, at least, beyond a fairly basic level, setting something of a challenge for analysis of the outcomes. As in the case of the software architecture study, the outcomes also changed ideas about how to address the topic (but in this case, didn't cause the topic to be changed). In particular, it led to a decision that the student would employ a simulation framework as the most effective way of comparing the effects of different forms. The postgraduate and supervisor are currently working on a paper based on the mapping study.

3.3 Roles and responsibilities

One of the authors (Budgen) was the supervisor of all the students. He completed the supervisor form for each mapping study and was responsible for circulating the questionnaire to the students. The responses were returned to the supervisor who forwarded them to the other two authors. The other two authors were responsible for collating and analyzing the questionnaires.

3.4 Data Collection and Analysis

The study results are based on questionnaires completed by the students after competing their mapping study (see Appendix A). The supervisor also completed a questionnaire for each study (see Appendix B). The responses from the students and the supervisor were interpreted in terms of the support they provided for the proposition and other issues. This was done initially by one of the authors (Kitchenham) and then reviewed by another (Brereton). During the exercise we identified that there was an overlap between P1 and P3. For example, if participants said "I learnt how to do a mapping study" we could not be sure whether they meant they learnt the techniques of searching and aggregating the literature, or they found that mapping studies were a useful transferable skill. We decided to treat such a response as providing support for both P1 and P3. Another issue was that one undergraduate mentioned learning about time management for research. Such a question could be related to the nature of undergraduate assignments rather than mapping studies, but since mapping studies begin with a protocol (i.e. a plan), we decided to identify this as support for P3. Discussion of the classification of student responses continued until we reached full agreement,

4. RESULTS

The data gathered from each of the sources are summarized below. None of the students had undertaken previous mapping study, so all were equally unfamiliar with the methodology.

All tables apart from Table 1, can be cross indexed by student identified (PG1, PG2, PG3 for postgraduates; UG1, UG2, UG3 for undergraduates). Table 1 only identifies the student type (P for postgraduate, U for undergraduate) to avoid linking the answers provided to specific students by identifying the authors of published mapping studies on specific topics.

4.1 Educational goals

For the undergraduate students the goal was to undertake a research-led project that allowed them to demonstrate appropriate analytical skills as part of their degree programme. All obtained high marks for their work. For the postgraduates the goal was to produce a 'state of the art' review as part of the the initial stages of their PhD and to help with formulating a research plan for the rest of the PhD.

The opinions of the students and supervisor with respect the achievement of education goals are summarized in Table 1, which also identifies the topics of the mapping studies and the elapsed time required for the activity.

Problems noted by the supervisor were the number of irrelevant studies and the large number of relevant papers. In the case of PG2, the results were too diffuse to form a sound basis for a PhD and the topic was revised.

Points raised by the students are shown in Table 2. The table also indicates whether the comments relates to any of the propositions defined in Section 3.1 and whether it provides supports (+) or contradicts the proposition (-). The issues not covered by the specified propositions are that mapping studies:

- Are challenging (I1)
- Are enjoyable/rewarding (I2)
- Provide a broad understanding of the topic area. (I3)
- Can absorb too much effort for an undergraduate assignment. (I4)

Table 1 The achievement of education goals

Student type	Topic	Elapsed months	Achieved educational goals	
			Student view	Supervisor view
P	Web Services	7	Yes	Yes

	Composition			
U	Chidamber & Kemerer OO metrics	2.2	Mostly	Yes
P	OO design Patterns	13.5	Yes	Yes
U	Software Visualization	5	Mostly	Yes
U	Models and forms used in the UML	2	Yes	Yes
P	Software architecture	5	Yes	Mostly
U	Software Visualization	5	Mostly	Yes

The supervisor was also asked whether there has been any follow-on work resulting from the mapping studies. Two of the undergraduate studies are being followed up by other researchers. Two of the postgraduate mapping studies are being followed-up with further research undertaken by the postgraduate student.

Table 2 Issues influencing the achievement of educational goals

Subject	Comment	Prop / Issues
UG1	The project was actually very enjoyable overall **(I2)**. However, as with many projects, it was very absorbing and demanded a lot of time **(I1)**. I found it very difficult not to exceed the (I believe 50 hour) time set for the work. **(I4)** I think this is because we were actually producing useful and meaningful work and something you can be proud of. **(I2)**. It did mean however that this component required far more time and effort than other parts of my course this year, yet only carried a small (I believe 25%) weighting. **(I4)** I think it would be difficult to reduce the size of the project while keeping it useful, but I do think it would benefit from carrying a greater weight in the module (obviously in this case, the module and course is in its final year). **(I4)**	I1 I2 I4
UG2	The process was frustrating at times, especially when reading poor abstracts **(P4)** but overall it taught or reinforced a lot of 'soft' skills such as how to word searches **(P1)** and present results **(P3)**.	P4 (+) P1 (+) P3(+)
UG3	It provided good insight into the methods of independent research, specifically into tertiary studies. **(P3)** It was challenging as it was something that had not previously been attempted. **(I1)** Nevertheless, it was engaging **(I2)** as I could plan my protocol and subsequent study independently. The fact that it was just a mapping study and not a complete literature review made it manageable and rewarding at an undergraduate level **(I2)**.	P3(+) I1 I2
PG1	This experience brought me a very broad view about the field of design patterns. **(I3)**	I3
PG2	The experience was quite satisfactory and it helped in understanding the depth and breadth of the area. (**I3)**	I3
PG3	Yes, it gave me wide knowledge about what have been done toward development of service composition (tools and techniques). **(I3)** Also it assisted me to gain and build up my ideas to present a proposal for service composition. **(P1)**	I3 P1

For the metrics mapping study, while the results were valuable, the student was concerned that the process of inclusion and exclusion had been hindered by poor reporting in the abstracts of many of the papers (a tendency by authors to use vague terms such as 'using a number of…"). As a result, it was concluded that extending this study would be a substantial task, although possibly one to return to in the future.

The visualization mapping study has subsequently been extended with the aid of other researchers who were interested in the topic, and the preliminary results from this have been submitted as a conference paper.

For the UML study, the project resulted in a conference short paper that was produced by the supervisor and the student together, and presented by the student. Work is now proceeding within our research team to extend this study (as it proved to have interesting results) with the aim of producing a full journal paper.

For the post graduates, as indicated above, the studies have led in two cases to conference/workshop papers with journal papers also having been submitted and in the third case to a journal paper that is currently in preparation. In all cases, although differently, the mapping study also helped focus the further development of their PhD plan.

4.2 Learning outcomes

Students were asked to identify what they had learnt from the experience of undertaking a mapping study. As documented in Table 3 they reported an increased knowledge both of the topic area and of the process of systematic reviews. All three postgraduate students were positive about the benefits of starting a PhD research programme with a mapping study.

Table 3 Lessons learnt from a mapping study

Subject	Comment	Prop/ Issue
UG1	I have a much better understanding of empirical work and literature and my knowledge of the work covered in the evaluation lectures this year has been	P3(+)

	refreshed and improved. **(P3)**	
UG2	I've learnt more about the C&K metrics **(I3)** and also how to conduct a mapping study. **(P1 & P3)**	P1(+) P3(+) I3
UG3	How to approach literature in an analytical manner and then draw points together from several studies to reach and convey conclusions. **(P1)** The importance of structuring search strings in the best possible way. **(P1)** It provided useful practice in time-management for research. **(P3)**	P1(+) P3(+)
PG1	From the experience I have learnt the process of mapping study, **(P1 & P3)** and how to extract information from it and also how to find research gaps. **(P3)**	P3(+) P1(+)
PG2	It was good to start literature review with mapping study. **(P2)** It helped in creating the clear picture of the area **(I3)** and gave some level of confidence. Also it helped in understanding how to conduct a systematic literature review. **(P1&P3)**	P1(+) P2(+) P3(+) I3
PG3	How to perform un-biased research. **(P3)** How to extract the related papers from the search outcomes. **(P1)** How to classify the outcomes. **(P1)**	P1(+) P3(+)

4.3 Problems with the mapping study process

Students were asked to report whether they had any problems with the mapping study process. Their answers are shown in Table 4 and include problems with search engines, the quality of abstracts and the classification of papers.

Table 4 Problems with Mapping study process

Subject	Re-sponse	Comment	Prop / Issue
UG1	Yes	The project planning and writeup were both interesting and enjoyable. **(I1) (P5)** The actual process of retrieving studies however was slow and often difficult. Many of the search engines were clearly not designed with mapping studies in mind and often restricted the searches or made searching too complicated (eg. WOS[3]). IEEExplore was definitely the easiest to work with. **(P4)**	I1 P5(+) P4(+)
UG2	Yes	Abstracts of some papers difficult to classify – so took a long time. **(P4)**	P4(+)
UG3	Yes	Time management of specific tasks. Much more time was spent on tasks than had been planned for.**(I4)**	I4
PG1	No	N/A	
PG2	Yes	Classification of papers. **(P4)**	P4(+)
PG3	Yes	The number of papers is very big and it takes a long time to perform my study. **(I4)**	I4 (but for a PG)

[3] Web of Science

With respect to the use of systematic review guidelines three of the students reported using the Kitchenham and Charters guidelines [9], two reported using the Rainer and Beecham guidelines [19], and one reported using the Petticrew and Roberts text [7], one did not identify specific guidelines but comments that guidelines were used as supplementary reading. Two students reported problems with the guidelines because they were not well-suited to mapping studies.

4.4 Recommendations to other students

The students were asked if they would recommend doing a mapping study to other students. Their responses are shown in Table 5. They make it clear that a mapping study is useful if the individual undertaking it has a clear need for the type of skills that a mapping study teaches i.e. how to undertake research activities.

Table 5 Suitability for other students

Subject	Re-sponse	Comment	Prop/ Issue
UG1	In some circum-stances	As above, I really enjoyed the work. **(I1)** However I feel that the project work greatly interfered with revision for other modules **(I4)** and because of the addictive nature of the project, I gave it priority and my exam marks have probably suffered for it. I would definitely recommend the work if the marks carried more weight.	I1 I4
UG2	In some circum-stances	I don't think this type of project is relevant to all students but where it is it is definitely worth undertaking if only to stress the importance of clear abstracts. **(P4)**	P4(+)
UG3	Yes	I feel this is a very useful exercise to undertake as an undergraduate. It provides a useful insight into research and all its technicalities in a way that is manageable, but	I1 P3(+)

		challenging at the same time. **(I1)** It forces one to structure one's thoughts and convey it in a concise, meaningful and logical manner. **(P3)** It also allows one to understand Evidence Based Software Engineering from personal experience. **(P3)**	
PG1	Yes	It is very useful for science students who are taking their first stage of the research. **(P2)** Although there are some differences on technique issues, science students can borrow some experiences about mapping study from this type of project. **(P3)** As we know in Question 7, this type of project can be seen as a successful experience based on these guidelines	P2(+) P3(+)
PG2	Yes	It's a good starting point for PhD **(P2)** which not only helps in selection of research papers but also guides how to analyze papers. **(P1)**	P2(+) P1(+)
PG3	In some circum-stances	I think it is very useful for doing wide-range literature review, **(P1&P3)** also when a researcher addresses a new area for the first time. **(P2)**	P1(+) P3(+) P2(+)

4.5 Other issues

The students were asked if they had any further comments about their experiences. Four of the students responded to this question as shown in Table 6.

Table 6 Other comments

Subject	Comment	Prop/Issue
UG1	The web tool suggested for the project was a nice idea, however it would have required a lot of work to be anywhere near as useful and flexible as a common database tool. Perhaps providing students with a universal parser just to extract the data from the libraries to a common bibtex or database format would be more useful. **(P4)**	P4(+)
UG2	The search engines available leave quite something to be desired. They have confusing syntax and errors in their output, such as returning fewer results for an (A OR B) search than just an (A) search. It would be good if the entities behind the search engines got together and standardized input syntax and the way searches are handled. **(P4)**	
UG3	It was a valuable experience, which with hindsight proved useful during my final year project in Physics. This indicates the skills learnt were transferrable across subjects and which I'm sure will be of benefit in the future. **(P3)**	P3(+)
PG1	During process of the mapping study we should combine the characteristic of our research field with the guidelines of mapping study.	N/A

4.6 Summary

Table 7 shows the propositions supported by each student. Table 8 shows the issues mentioned by each student.

Table 7 Support for propositions

Student	Propositions				
	P1	P2	P3	P4	P5
UG1			√	√	√
UG2	√		√	√	
UG3	√		√		
PG1	√	√	√		
PG2	√	√	√	√	
PG3	√	√	√		

Table 8 Issues

Student	Issues			
	I1	I2	I3	I4
UG1	√	√		√
UG2			√	
UG3	√	√		√
PG1			√	
PG2			√	√
PG3			√	

5. DISCUSSION

In this section we discuss the extent to which the propositions are supported by the results. We also point out the limitations of our study.

5.1 Propositions

The results show that overall the three main propositions identifying the value of mapping studies were supported:

- P1 states that "Mapping studies teach students how to search the literature and organize the results of such

searches. Five of the six students made comments supporting this proposition.

- P2 states that "Postgraduate PhD students will find a mapping study a valuable means of initiating their research activities." All three postgraduate students made comments supporting this proposition.
- P3. States that "Postgraduate students and undergraduate students will find undertaking a mapping study provides them with transferable research skills." All the students made comments supporting this proposition.

In addition to the three propositions, three other positive issues were found:

- Two undergraduate students found the mapping study challenging (I1).
- Two undergraduate students found the mapping study enjoyable (I2).
- One undergraduate and all three postgraduates mentioned that the exercise gave them a good overview of the topic area (I3).

Overall these issues are consistent with the results reported by Baldassare et al. [13], although they used a conventional systematic review rather than a mapping study. Given that mapping studies concentrate mainly on categorizing the literature it is important to find that they are still valuable with respect to understanding the topic area.

With respect to the problems students find with mapping studies (P4), as anticipated three students mentioned problems with searches and/or classification. However, in addition two undergraduates mentioned that it was difficult to do the work with the effort specified (in SLAT hours) and one postgraduate also commented on the time and effort needed for a mapping study (I4).

With respect to the relative ease of reporting (P5), only one student mentioned that reporting was interesting and enjoyable. The limited support might be because we failed to ask a specific question about what parts of the process the students found particularly easy.

5.2 Limitations

The obvious limitations of this study are that:

- It is based only on the experiences of six students (three undergraduates and three postgraduates), all supervised by the same person. This clearly limits the generality of the results.
- It is being undertaken by researchers with a clear bias in favour of EBSE, systematic literature reviews, and mapping studies. This may have influenced our interpretation of the students' responses. However, we present all their responses and how we interpreted them so the reader can draw their own opinions. We can, also, confirm that we have not "cherry-picked" results reported in this paper to include only the ones that support our positive view of EBSE and systematic reviews. All undergraduates and postgraduates who were undertaking mapping studies, with Budgen as their supervisor, in the time period 2007-2009, were included.
- The responses were requested from and returned to one of the authors of this paper who was also the student's supervisor. It is possible, therefore, that the students might have been tempted to report what they thought their supervisor wanted to hear. This is always an issue when academics seek feedback from students. We hope that, reporting the students' responses verbatim will give the reader the opportunity to decide for themselves whether the responses reflect the genuine views of the student. In addition, the students were not aware either of our case study propositions or of our intended analysis so they were not in a position to construct their responses to suit our purposes. Furthermore, their supervisor was not involved in the analysis process, so did not have opportunity to directly influence the final results.

6. CONCLUSIONS

Previous studies have confirmed that undergraduates and masters students are able to do systematic reviews ([11], [12], [14]) and this study confirms that undergraduates and PhD candidates are equally able to do systematic mapping studies. The results also confirm that, as expected, mapping studies provide students with useful and transferable research skills and are a useful first step for postgraduate PhD candidates. As expected there were problems with the search and classification process.

However, this study also suggests that in spite of mapping studies being more limited in terms both of coverage of the five EBSE steps and the establishing the research question and aggregation steps of a systematic literature review, they do provide a means of integrating research into a broad understanding of specific topic areas. Furthermore, as an undergraduate project, they are enjoyable although it may be difficult to do the required work within the allocated effort. The basic difficulties of mapping studies relate to searching the literature which is a general problem with any type of systematic literature review and the issue of classifying empirical studies which is specific to mapping studies. However, several students mentioned the problem that current guidelines for systematic reviews do not provide sufficient information about how to undertake mapping studies.

With respect to the first challenge identified in the Section 1, we have shown that both undergraduate students and postgraduate students can contribute to the provision of educational support material. Students can publish the results of their mapping studies and, particularly in the case of undergraduates, their mapping studies can provide the basis for other researchers to undertake more detailed summaries of the research literature. With respect to the second challenge, we have demonstrated that systematic mapping studies provide a means of organizing the research literature and give a good overview of software engineering topics. With respect to the third challenge, we have demonstrated that systematic mapping studies are suitable projects for some undergraduates and are very useful starting point for postgraduate PhD students.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Kitchenham B., Budgen, D., Brereton, P., Turner, M., Charters, S., and Linkman, S. 2007. Large-scale software engineering questions –expert opinion or empirical evidence? IET Software 1 (5), 161-171.

[2] Kitchenham, B.A., Dybå, T. and Jørgensen, M. 2004. Evidence-based Software Engineering. Proceedings of the 26th International Conference on Software Engineering, (ICSE '04), IEEE Computer Society, Washington DC, USA, pp 273 – 281.

[3] Dybå, T., Kitchenham, B.A. and Jørgensen, M. 2005. Evidence-based Software Engineering for Practitioners, IEEE Software, 22 (1), pp 58-65.

[4] Jørgensen, M., Dybå, T. and Kitchenham, B.A. 2005. Teaching Evidence-Based Software Engineering to University Students, 11th IEEE International Software Metrics Symposium (METRICS'05), p. 24.

[5] Khan, Khalid, S., Kunz, Regina, Kleijnen, Jos and Antes, Gerd. 2003. Systematic Reviews to Support Evidence-based Medicine, The Royal Society of Medicine Press Ltd.,

[6] Fink, A. 2005. Conducting Research Literature Reviews. From the Internet to Paper, Sage Publications, Inc.

[7] Petticrew, Mark and Helen Roberts. 2005. Systematic Reviews in the Social Sciences: A Practical Guide, Blackwell Publishing.

[8] Kitchenham, B.A. 2004. Procedures for Undertaking Systematic Reviews, Joint Technical Report, Computer Science Department, Keele University (TR/SE-0401) and National ICT Australia Ltd (0400011T.1)

[9] Kitchenham, B.A. and Charters, S. 2007. Guidelines for performing Systematic Literature Reviews in Software Engineering Technical Report EBSE-2007-01.

[10] Kitchenham, B.A., Brereton, O.P., Budgen, D., Turner, M., Bailey, J., and Linkman, S.G. 2009. Systematic Literature reviews in Software Engineering – A systematic Literature review. Information and Software Technology, 51, pp 7-15.

[11] Rainer, A., Hall, T. and Baddoo, N. 2006. A Preliminary Empirical Investigation of the Use of Evidence Based Software Engineering by Under-graduate Students, 10th International Conference on Evaluation and Assessment in Software Engineering, Keele University, UK, April 2006.

[12] Rainer, A. and Beecham, S., 2008. A follow-up empirical evaluation of evidence based software engineering by undergraduate students, 12th International Conference on Evaluation and Assessment in Software Engineering, University of Bari, Italy, June 2008.

[13] Baldassarre M.T., Boffoli N., Caivano D., Visaggio G. 2008. A hands-on approach for teaching systematic review, LNCS 5089, pp. 415-426.

[14] Oates, B.J. and Capper, G. 2009. Using systematic reviews and evidence-based software engineering with masters students, 13th International Conference on Evaluation and Assessment in Software Engineering, Durham University, UK, April 2009

[15] Janzen D.S., Ryoo J. 2009. Engaging the net generation with evidence-based software engineering through a community-driven web database, Journal of Systems and Software, 82(4) pp. 563-570.

[16] Yin, Robert K. 2003. Case Study Research: Design and Methods, 3rd Edition, Sage Publications.

[17] Budgen, D., Kitchenham, B.A., Charters, S.M., Turner, M., Brereton, P., Linkman, S.G. 2008. Presenting software engineering results using structured abstracts: A randomised experiment, Empirical Software Engineering, 13 (4), pp. 435-468.

[18] Kitchenham, B.A., Brereton, O.P., Owen, S., Butcher, J., Jefferies, C. 2008. Length and readability of structured software engineering abstracts, IET Software, 2 (1), pp. 37-45.

[19] Rainer, A. and Beecham, S. 2008. Supplementary Guidelines, Assessment Scheme and evidence-based evaluations of the use of Evidence Based Software Engineering. University of Hertfordshire Technical Report, Version 2.0 Draft.[4]

APPENDIX A

Debrief Questionnaire for Students who Undertook Mapping Studies

Please note you will not be referred to by name in any report using information in this questionnaire. Please continue on the other side of the questionnaire if you have any additional comments you want to make.

Your name:

1. Have you ever done a mapping study (or something similar) before: Yes/No

If yes please answer the two following sub-questions (other wise proceed to question 2)

1.1 Please describe briefly the previous study.

1.2 Please identify all the ways that the previous study assisted the current study.

- Understanding the basic principles of mapping studies: Yes/No
- Experience producing protocols: Yes/No
- Experience using search strings and search engines: Yes/No
- Experience writing-up results: Yes/No
- Other (please specify)

2. When did you perform your mapping study:

Start Date: dd/mm/yyyy

End Date: dd/mm/yyyy

[4] http://www.dur.ac.uk/ebse/resources/guidelines/EBSE_supplementary_guidelines_v2.0_DRAFT.pdf

3. What was the topic of the mapping study?

4. Was this a satisfactory educational experience? Yes/Mostly/Somewhat/No

Please explain your answer

5. What (if anything) have you learnt from the experience?

6. Did you find any aspect(s) of the project particularly troublesome? Yes/No

If Yes, please specify

7. Did you use any standards/guidelines/text books to explain the review process? Yes/No

If Yes, please specify which ones

8. Were there any particular problems with the standards/guidelines? Yes/No

If Yes, please specify

9. Would your recommend this type of project to other students? Yes/No/In some circumstances

Please explain your answer

10. If you have any further comments/observations, please add them here

APPENDIX B

Debrief Questionnaire for Supervisors whose Student Undertook a Mapping Study

Please complete for each student project. Note the student will not be referred to by name in any report using information in this questionnaire.

Name:

Name of student:

1. What was the topic of the mapping study?

2. What were the education goals of the study?

3. Was any follow-up study planned, or is it in progress, or completed? No/Yes- Not started/Yes –in progress/Yes completed.

4. Were there any problems with the project from the supervisor viewpoint? Yes/No

If Yes please specify all problems:

- Quality of project outcome? Yes/No
- Difficulty with current standards as applied to mapping studies? Yes/No
- Study topic? Yes/No
- Other? Please specify

5. Were the education goals achieved? Yes/Mostly/Somewhat/No