



Research synthesis in software engineering: A tertiary study

Daniela S. Cruzes^{a,*}, Tore Dybå^b

^a NTNU, NO-7491 Trondheim, Norway

^b SINTEF, NO-7465 Trondheim, Norway

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ABSTRACT

Context: Comparing and contrasting evidence from multiple studies is necessary to build knowledge and reach conclusions about the empirical support for a phenomenon. Therefore, research synthesis is at the center of the scientific enterprise in the software engineering discipline.

Objective: The objective of this article is to contribute to a better understanding of the challenges in synthesizing software engineering research and their implications for the progress of research and practice.

Method: A tertiary study of journal articles and full proceedings papers from the inception of evidence-based software engineering was performed to assess the types and methods of research synthesis in systematic reviews in software engineering.

Results: As many as half of the 49 reviews included in the study did not contain any synthesis. Of the studies that did contain synthesis, two thirds performed a narrative or a thematic synthesis. Only a few studies adequately demonstrated a robust, academic approach to research synthesis.

Conclusion: We concluded that, despite the focus on systematic reviews, there is limited attention paid to research synthesis in software engineering. This trend needs to change and a repertoire of synthesis methods needs to be an integral part of systematic reviews to increase their significance and utility for research and practice.

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* Corresponding author.

E-mail addresses: dcruz@idi.ntnu.no (D.S. Cruzes), tore.dyba@sintef.no (T. Dybå).

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1. Introduction

Developing software engineering (SE) knowledge is a cooperative enterprise of accumulating empirical evidence in an orderly and accurate fashion. The evidence of a particular research study cannot be interpreted with any confidence unless it has been considered together with the results of other studies addressing the same or similar questions. Comparing and contrasting evidence is necessary to build knowledge and reach conclusions about the empirical support for a phenomenon. An accurate combination of study outcomes in terms of research syntheses is, therefore, at the center of the scientific enterprise in the SE discipline. Still, it was only half a decade ago when software researchers began to pay serious attention to how to systematically locate, evaluate, synthesize, and interpret the evidence of past research studies [18,32].

Research synthesis is a collective term for a family of methods that are used to summarize, integrate, combine, and compare the findings of different studies on a specific topic or research question [7,13,39]. These methods embody the idea of making a new whole out of the parts to provide novel concepts and higher-order interpretations, novel explanatory frameworks, an argument, new or enhanced theories, or conclusions. Such syntheses can also identify crucial areas and questions for future studies that have not been addressed adequately with past empirical research. Research synthesis is built upon the observation that no matter how well designed and executed, empirical findings from single studies are limited in the extent to which they may be generalized [5]. It is, thus, a way for drawing conclusions from a *collection* of studies [39].

The key objective of research synthesis is to analyze and evaluate multiple studies and select appropriate methods for integrating [7] or providing new interpretive explanations about them [39]. If the primary studies have similar interventions and quantitative outcome variables, it may be possible to aggregate them through meta-analysis, which uses statistical methods to combine effect sizes. However, in SE, primary studies are often too heterogeneous to permit a statistical summary and, in particular, for qualitative and mixed methods studies, different methods of research synthesis are needed [17].

Although research is underway in other disciplines (e.g., [13,41,50]), there is a number of methodological questions about the synthesis of qualitative and mixed-methods findings. There are technical challenges, such as inter-rater reliability in abstracting qualitative data from individual studies or from diverse study type analyses for producing a cross-study type synthesis. There are also challenges related to the epistemological and ontological commitments underlying qualitative research, the methods of qualitative synthesis, and to methods for integrating qualitative synthesis with meta-analysis.

The aim of this article is to contribute to a better understanding of these challenges and their implications for the progress of empirical and evidence-based SE research by examining the types and methods of research synthesis employed in systematic reviews (SRs) in SE. More specifically, we seek to answer the following research questions:

1. What is the basis, in terms of primary study types and evidence that is included, in SE systematic reviews?
2. How, and according to which methods, are the findings of systematic reviews in SE synthesized?

3. How are the syntheses of the findings presented?

The remainder of this article is organized as follows: Section 2 describes the theoretical background and examines the concept of research synthesis along with an overview of synthesis and appraisal methods. Section 3 provides an overview of the research methods that were used, while Section 4 presents findings related to the research questions. Finally, Section 5 provides a discussion of the findings and the implications for research and practice. Section 6 provides the conclusions of the study.

This article is an extension of a conference paper [10], which was extended in three respects. First, Section 2 is broadened and considerably expanded to provide a much fuller account of the concept of research synthesis and its role within systematic reviews. Additionally, there is extended coverage of emerging synthesis methods as well as new material on appraisal methods. The results in Section 4 are considerably expanded with new material related to the number of studies that were included and with respect to the topics that were covered. Finally, Section 5 is expanded with a deeper discussion of the findings, their implications for theory and practice, and opportunities for future research.

2. Theoretical background

In this section, we provide the theoretical background of SRs and their relationship to evidence-based software engineering (EBSE) by contrasting the reviews to traditional literature reviews and scoping studies. Furthermore, we present definitions of research synthesis and provide an overview of the most relevant methods for synthesis of qualitative and mixed-methods evidence, followed by an overview of different ways of appraising the quality of such evidence for inclusion in SRs.

2.1. The role and definition of systematic reviews

Along with several other domains, such as healthcare, public policy, education, and management, the evidence-based paradigm has also been proposed for SE research [32], practice [18], and education [25]. The goal of this paradigm is:

to provide the means by which current best evidence from research can be integrated with practical experience and human values in the decision-making process regarding the development and maintenance of software [32].

In this context, evidence is knowledge obtained from findings derived from analysis of data obtained from observational or experimental procedures that are potentially repeatable and that meet the currently accepted standards of design, execution, and analysis (e.g., [26,49]). Depending on how the evidence was obtained, it can vary greatly in terms of strength. The strongest empirical evidence is obtained from rigorous methods incorporated into a study designed to have a clear, unequivocal supporting or refuting outcome. However, the evidence can be weakened by the possibility of other explanations for the results or due to weaknesses in the methods. Because the opportunity for independent assessment of the strength of evidence is a key component in any empirical study, the methods used to obtain the evidence must

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