Guidelines for including the grey literature and conducting multivocal literature reviews in software engineering

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Abstract:
Context: A Multivocal Literature Review (MLR) is a form of a Systematic Literature Review (SLR) which includes the grey literature (e.g., blog posts and white papers) in addition to the published (formal) literature (e.g., journal and conference papers). MLRs are useful for both researchers and practitioners since they provide summaries both the state-of-the-art and –practice in a given area. MLRs are popular in other fields and have recently started to appear in software engineering (SE).

Objective: There are several guidelines to conduct SLR studies in SE. However, given the facts that several phases of MLRs differ from those of traditional SLRs, for instance with respect to the search process and source quality assessment. Therefore, SLR guidelines are only partially useful for conducting MLR studies. Our goal in this paper is to present guidelines on how to conduct MLR studies in SE.

Method: To develop the MLR guidelines, we benefit from three inputs: (1) existing SLR guidelines in SE, (2), a literature survey of MLR guidelines and experience papers in other fields, and (3) our own experiences in conducting several MLRs in SE. We took the popular SLR guidelines of Kitchenham and Charters as the baseline and extended/adopted them to conduct MLR studies in SE. All derived guidelines are discussed in the context of three examples MLRs as running examples (two from SE and one MLR from the medical sciences).

Results: The resulting guidelines cover all phases of conducting and reporting MLRs in SE from the planning phase, over conducting the review to the final reporting of the review. In particular, we believe that incorporating and adopting a vast set of experience-based recommendations from MLR guidelines and experience papers in other fields have enabled us to propose a set of guidelines with solid foundations.

Conclusion: Having been developed on the basis of three types of solid experience and evidence, the provided MLR guidelines support researchers to effectively and efficiently conduct new MLRs in any area of SE. The authors recommend the researchers to utilize these guidelines in their MLR studies and then share their lessons learned and experiences.

Keywords: Multivocal literature review; state-of-the-evidence review; grey literature review; guidelines; systematic literature review; systematic mapping study; literature study; grey literature; evidence-based software engineering
1 INTRODUCTION

Systematic Literature Reviews (SLR) and Systematic Mapping (SM) studies have become common in software engineering (SE) and other fields, such as medical and social sciences. SLR and SM studies systematically collect evidence and structure a given research area, respectively. Many SLRs and SMs appear regularly in various SE venues (journals and conferences) each year, e.g., [1, 2].

SLR or SM studies are valuable and can provide many benefits to practitioners and researchers. They can help young researchers and PhD students be aware of existing works and find the gaps in a research area, e.g., [3-5]. They can also help practitioners get a summary of the large body of knowledge in a research area [6, 7]. Since most practitioners do not have the time resources to study a large number of papers (e.g., more than 200) in given area, they would much prefer to review a summary/ review paper which would serve as an “index” to the large body of knowledge in that area [8]. For example, after conducting an SLR on testing embedded software [8], we found that in addition to researchers industry also benefited from the study and one practitioner mentioned: “There are a lot of studies in the pool of this review study, which would benefit us. I think this idea is a major benefit for companies like ours.”
While SLR or SM studies are valuable, we can do more to serve the industry. SLR or SM studies focus mainly on research contributions [9] and do not include the “grey” literature (non-published, nor peer-reviewed sources of information), which are constantly produced by SE practitioners in a great scale. Thus, those studies cannot provide enough insights into the “state of the practice” in SE. For a practical (practitioner-oriented) field such as SE, synthesizing and combing both the state-of-the-art and practice is very important. Unfortunately, a large majority of software practitioners do not publish in academic forums [10], meaning we must include grey literature (GL) if we want to “hear the voice” of the practitioners in regular SE studies or review (survey) papers.

SLRs which include both the academic (formal) and the GL were termed as Multivocal Literature Reviews (MLR) in other fields, e.g., educational research [11, 12], in the early 1990’s. The main difference between an MLR and an SLR or an SM is the fact that, while SLRs and SMs use as input only academic peer-reviewed papers, MLRs in addition also use sources from the GL, e.g., blogs, white papers and web-pages [9]. Furthermore, multivocal synthesis is highly recommended as an appropriate tool for investigations for fields “characterized by an abundance of diverse documents and a scarcity of systematic investigations” [13]. Researchers also have reported that: “another potential use of multivocal literature reviews is in closing the gap between academic research and professional practice” [14].

We thus believe that, in a practical field such as SE, MLRs should be conducted in addition to SLRs. A few MLRs have appeared in the SE community, e.g., [15-23]. In our previous work [24], we presented initial ideas in this direction, that we extend in this paper to a set of guidelines for conducting MLRs in SE. While there are guidelines for SLR and SM studies in SE, e.g., [2, 25, 26], those guidelines cannot be easily adopted for conducting MLRs since MLR studies include and synthesize the GL in addition to the academic (formal) literature. This guidelines paper aims at complementing the existing guidelines for SLR and SM studies in SE as we are observing an emerging need for MLRs in SE. Researchers who plan to conduct MLRs should benefit from this paper. An existing guidelines paper for working with GL in systematic reviews in the field of management and organizational studies [27] highlighted that “more specific guidelines for scholars on including grey literature in reviews are important as the practice of systematic review in our field continues to mature”. We share the same belief for SE.

This guidelines paper is structured similar to two previous related papers: the guidelines for SLR studies [26], and the other ones for SM studies [2], in that we provide guidelines for three phases: (1) planning the review, (2) conducting the review, and (3) reporting the review results. The remainder of this guidelines paper is structured as follows. Section 2 provides a review of background and related work. Section 3 discuss the methodology applied in this papers to derive the MLR guidelines for SE, which is based on a survey on MLR guidelines and experience papers in other fields. Section 4 presents guidelines on planning an MLR, Section 5 on conducting an MLR, and Section 6 on reporting an MLR. Finally, in Section 7, we draw conclusions and suggest areas for further work.

2 BACKGROUND AND RELATED WORK

We review the following topics as background and related work in this section:

- Emergence and impact of GL in the scientific community
- Introduction to MLRs
- The need for utilizing GL and MLRs in SE
- Adopting a model for differentiating types of sources in the GL
- Reviewing existing guidelines for SLR and SM studies in SE

2.1 EMERGENCE AND IMPACT OF GL IN THE SCIENTIFIC COMMUNITY

We review the state of GL by reviewing its emergence, definition and impact as discussed in other fields. The issue of the GL in the research community has gained popularity in many fields. There is an annual conference on the topic of GL (www.textrelease.com) and an international journal on the topic (www.emeraldinsight.com/toc/ijgl/1/4). There is also a Grey Literature Network Service (www.greynet.org) which is “dedicated to research, publication, open access, education, and public awareness to grey literature”.

Various definitions of GL have been offered in the literature. We review next some of those definitions. The so-called “Luxembourg definition”, discussed and approved at the third International Conference on Grey Literature in 1997 in Luxembourg, defined grey literature as “that which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers”. In 2004, a postscript was added for purposes of clarification: grey literature is “…not controlled by commercial publishers, i.e., where publishing is not the primary activity of the producing body” [28]. This definition has since been used extensively and is widely accepted. The Cochrane handbook for systematic reviews of interventions [29] defines GL as “literature that is not formally published in sources such as books or journal articles”.

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The study in [30] defined the GL as “studies with limited distribution, i.e., those not included in computerized bibliographic retrieval systems”. Entitled “Finding the hard to finds: searching for grey (gray) literature”, the study in [31] grouped the traditional GL sources into 10 types as follows: (1) Theses and dissertations, (2) Census, economic and other related data sources, (3) Databases of ongoing research, (4) Statistics and related data sources, (5) (non-peer reviewed) Conference proceedings and abstracts, (6) Newsletters, (7) Research reports (completed and uncompleted), (8) Technical specifications, standards, and annual reports, (9) Informal communication, i.e., telephone conversations, meetings, etc., and (10) Translations.

The study in [32] defined GL as “studies with limited distribution (i.e., those not included in computerized bibliographic retrieval systems), unpublished reports, dissertations, articles in obscure journals, some online journals, conference abstracts, policy documents, reports to funding agencies, rejected or unsubmitted manuscripts, non-English language articles, and technical reports”). It is quite bold to observe that, in the opinion of [32], articles in “obscure” journals are considered as part of GL.

The source in [33] mentioned that: “More often than not, grey literature is not indexed in databases and so can be a puzzle to find. Locating grey literature can be a very different process than locating scholarly articles”.

Entitled “On the quality of grey literature and its use in information synthesis during systematic literature reviews”, the source in [34] mentioned that: “The grey literature, as opposed to white literature, is non-peer reviewed scientific information that is not available using commercial information sources such as IEEE or ACM, but available in Google Scholar. Google Scholar indexes both white and grey literature published around the web from peer-reviewed journal articles to lecture notes and documents published through universities”.

The study in [31] discussed the newer types of GL (which are mostly technology-based): (1) e-prints, preprints; (2) electronic networked communication; (3) blogs and podcasts (audio) or video on the web; (4) repositories; (5) listserv archives (6) digital libraries; (7) spatial data (e.g., Google Earth); (8) meta-searching, federated searching, portals; and (9) Wikis, Twitter, and other social media. The study in [31] grouped the producers of GL as follows: (1) Government departments and agencies (i.e., in municipal, provincial, or national levels); (2) Non-profit economic and trade organizations; (3) Academic and research institutions; (4) Societies and political parties; (5) Libraries, museums, and archives; (6) Businesses and corporations; and (7) Freelance individuals, i.e., bloggers, consultants, and web 2.0 enthusiasts. The study [31] further positioned the GL between the ‘white’ and ‘black’ literature and showed the spectrum as shown in Table 1. In this terminology, the ‘white’ literature refers to formal (published) sources and ‘black’ literature refers to very informal sources of information (e.g., ideas and thoughts).

| 'White' literature | 'Grey' literature | 'Black' literature |
|-------------------|------------------|-------------------|
| Books             | Preprints         | Ideas             |
| Published journal papers | e-Prints        | Concepts          |
| Conference proceedings | Technical reports | Thoughts          |
|                   | Lectures          |                   |
|                   | Data sets         |                   |
|                   | Audio-Video (AV) media |       |
|                   | Blogs             |                   |

As a paper in the field of management and organization studies, the source in [27] suggested that the GL, as “the diverse and heterogeneous body of material that is made public outside, and not subject to, traditional academic peer-review processes”, can be used to increase the relevance and impact of management and organization studies.

Usefulness of GL has been recognized in other fields. We searched for GL in Scopus and found that the search string “grey literature” (targeted to title, abstract, and keywords) resulted in 3,853 hits (as of this writing, May 2017). Some of those papers have had high citations, such as the paper titled “Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review” [35] (with 2,137 citations in Scopus as of May 2017) whose aim was “to perform the most thorough literature search possible” and included GL. We also identified papers that had analyzed the number of citations made to GL, for example, the study in [36] studied six journals in various domains of health sciences and found that 33% to 83% of the articles made references to GL and that 11% to 20% of the citations in total were to GL sources.

Drawing on an analysis of 140 systematic reviews published in the field of management and organization studies (MOS), an MLR guidelines paper [27] reported that: “A significant number of management and organization studies scholars already assert that grey material has relevance to their research questions and objectives” [27]. A number of reviewers (authors of SLR studies) from the sample considered in [27] who excluded the GL because of its challenges and the time required also believed that “their conclusions may be poorer for its absence” [27]. On the basis of those observations, [27] argued that “there is strong justification for greater consideration of including the GL in future MOS systematic reviews”.

Other studies such as [37-39] have measured and reported the online impact of GL using tools such as Google Scholar. Among the findings are that [38]: “… grey literature tends to be cited primarily by other grey literature. Although digital alerting
and access tools are increasing in number and coverage, a reliance on grey literature as the primary means of publication continues to pose hurdles for influencing scientific research, public policy, and public opinion. While grey literature is common to [many] organizations, the impact of this literature can be muted because of the limitations of its dissemination and perceptions of its quality”.

### 2.2 Introduction to Multivocal Literature Reviews

In this section, we review the concept of MLRs and their emergence in other fields and in SE.

#### 2.2.1 What are multivocal literature reviews?

SLRs which include both the academic (formal) and the grey (informal) literature were termed as Multivocal Literature Reviews (MLR) in other fields, e.g., educational research [11, 12], in the early 1990’s. The main difference between an MLR and an SLR or an SM is the fact that, while SLRs and SMs use as input only academic peer-reviewed articles, MLRs in addition also use sources from the GL, e.g., blogs, white papers and web-pages [9].

The source [11] entitled “Towards rigor in reviews of multivocal literatures: applying the exploratory case study method” defines MLR as follows: “Multivocal literatures are comprised of all accessible writings on a common, often contemporary topic. The writings embody the views or voices of diverse sets of authors (academics, practitioners, journalists, policy centers, state offices of education, local school districts, independent research and development firms, and others). The writings appear in a variety of forms. They reflect different purposes, perspectives, and information bases. They address different aspects of the topic and incorporate different research or non-research logics”.

The paper in [13] suggested that, for fields “characterized by an abundance of diverse documents and a scarcity of systematic investigations”, multivocal synthesis by taking GL into account is highly recommended. Researchers also have reported that: “another potential use of multivocal literature reviews is in closing the gap between academic research and professional practice” [14].

The study in [40] uses the term state-of-the-evidence reviews as an alternative to multivocal literature review and they state that “State-of-the-evidence reviews are broader than traditional systematic reviews and may include not only published and unpublished research, but also published and unpublished non-research literature”.

#### 2.2.2 MLRs in other fields

MLRs and the consideration of grey literature has become popular in other fields, e.g., educational research [11, 12] and health sciences [36, 41, 42]. For instance, a 1991 paper [11] in the field of educational research proposed an approach based on exploratory case studies to conduct rigorous MLRs, a 1990 paper [36] investigated the use of GL in health sciences, and a 2007 paper [42] discussed the use of GL for meta analyses also in health sciences.

While the notions of “MLR“ and “multivocal” have been used in the research community, still many papers use the “grey” literature terminology and whether/how to include them in SLRs, e.g., [40, 43, 44]. For example, [40] discussed the advantages and challenges of including GL in state-of-the-evidence reviews, in the context of evidence-based nursing. [43] discussed the challenges and benefits of including for GL in SLRs.

Hopewell et al. [45] conducted a review of five studies, in the field of evidence-based medicine, comparing the effect of the inclusion or exclusion of GL in meta-analyses of randomized medical trials.

Another type of literature reviews are Grey Literature Reviews (GLR). As the name implies, they only consider the GL sources in their pool of reviewed sources. Many GLR studies have also appeared in other disciplines e.g., [46-49]. For example, a GLR of special events for promoting cancer screenings was reported in [46]. To better understand and characterize the relationship of SLR, GLR and MLR studies, we visualize their relationship as a Venn diagram in Figure 1. As Figure 1 clearly shows, an MLR in a given subject field is somewhat a union of the sources that would be studied in a SLR and in a GLR of that field. As a result, an MLR, in principle, is expected to provide a more complete picture of the evidence in a given field.
2.2.3 MLRs in SE

The “multivocal” terminology has only been recently started to appear in SLRs in SE, i.e., since 2013 in [15]. We found only a few SLRs in SE which explicitly used the “multivocal” terminology, e.g., [15-23]. The paper in [15] is a 2013 MLR on technical debt. [16] is a 2015 MLR on iOS applications testing. [17] is a 2016 MLR on when and what to automate in software testing. [18] is a 2016 MLR on software test maturity and test process improvement, with a more comprehensive study reported in [20]. [19] is another 2016 MLR on gamification of software testing. [21] is a 2016 MLR on relationship of DevOps to Agile, lean and continuous deployment. [22] is a 2017 MLR about “threat intelligence” sharing platforms. Entitled “Characterizing DevOps by hearing multiple voices”, [23] is another 2016 MLR in the area of DevOps.

Many other SLRs have also included the GL in their reviews and have not used the “multivocal” terminology, e.g., [50]. A 2012 MSc thesis entitled “On the quality of grey literature and its use in information synthesis during systematic literature reviews” [34] explored the state of including the GL in the SE SLRs. The study found that the ratio of grey evidence in the SE SLRs were only about 9%, and the GL evidence concentrated mostly in the recent past (~48% between years 2007-2012). Finally, our 2016 paper [24] raised the need (awareness) for more MLRs in SE.

More recently, GLR studies are slowly starting to appear in SE. A 2017 GLR paper [74] was published on the subject of choosing the right test automation tools.

2.3 THE NEED FOR UTILIZING GREY LITERATURE AND MLRS IN SE

By summarizing our recent work [24] in this section, we first explore the need for MLRs in SE. Then we reflect on the need for MLRs in SE by looking at the literature of other disciplines and offer a hypothesis for benefits of using GL in SE.

2.3.1 Exploring the need in the SE literature

The paper in [24] explored the need for MLRs in SE. As SE is an application-oriented research field [51], where a large number of software practitioners constantly produces a huge wealth of valuable GL knowledge, utilizing that knowledge in research activities is important.

The key findings of the study reported in [24] are that: (1) GL can give substantial benefits in certain areas of SE, and that (2) the inclusion of GL brings forward certain challenges as evidence in them is often experience and opinion based.

To raise the awareness for more MLRs in SE, the paper in [24] addressed two research questions (RQs): (1) What types of knowledge are missed when an SLR does not include the multivocal literature in an SE area? and (2) What do we, as a community, gain when we include the multivocal literature and conduct MLRs? We briefly summarize the results next.

Regarding RQ1, we found that numerous practitioner sources could be found that had been ignored in several previous SLRs, that we used in [24] as a baseline for comparison. For example, referring to an SM in the area of Graphical User Interface (GUI) testing [52], we found that the practitioner sources including Google, YouTube and StackOverflow returned 74M, 237K and 6,286 hits, respectively. Surprisingly, many of those important information was missing from the SM on GUI testing [52], e.g., a large number of test tools and cutting-edge automation approaches available in the industry, the challenges faced and success storied reported by practitioners in that area. We think that missing such information could have profound impact in steering the research directions for the researchers in this area, i.e., when researchers do not realize the practical real-life challenges of GUI testing, their solutions are not likely going to address real industrial challenges. We believe that this issue is quite generalizable to many SE research areas.

For RQ2 of the study in [24], we used existing MLRs as a baseline and analyzed their GL sources. Table 2 shows the number of literature entries (formal versus grey) and the ratio of the grey literature sources for each MLR.
Table 2- Three MLRs sampled for analysis in [24]

| Ref. | Year | Topic                                                         | Number of sources reviewed |
|------|------|---------------------------------------------------------------|----------------------------|
| [17] | 2016 | MLR on deciding when and what to automate in testing         | 36, 52 (66%)               |
| [18] | 2016 | MLR on test maturity assessment and test process improvement | 130, 51 (28%)              |
| [15] | 2013 | MLR on technical debt                                        | 0, 35 (100%)               |

As an example, we reviewed the MLR in [17] and found that we would have missed a lot of experience and knowledge from test engineers on the topic of when and what to automate in testing, if we had not included the GL. That MLR [17] aimed to synthesizing the factors used for deciding when and what to automate in testing. To assess the shares of knowledge provided by formal vs. GL, Figure 2 shows the number of formal and grey literature sources for each of the 15 different types of factors. Grey literature sources contributed a total of 219 occurrences (instances) of factors while formal literature sources discussed only a total 67 of factor instances.

Furthermore, we can see that, if we were to not include the GL in [17], two categories (namely: test oracle and development process) would not have existed as a factor in what to automate in software testing decision. This all denotes a major source of knowledge and experience. In addition, we extracted a large number of qualitative quotes, related to and in support of the factors presented in Figure 2, which gave credibility and details of real problems of the industry in this active area of testing.

Additionally, grey literature sources of [17] presented viewpoints and ideas that could be scientifically studied as well as explanations why and in what contexts some factors may be considered while others should not. However, in the MLR study [17], we did not find any rigorous empirical evidence from the GL. The stated findings were mostly based on opinions, claims and experience. Also, the source of evidence was difficult to identify as the reporting of GL sources was generally of low quality. Furthermore, the replication of reported results in the GL was generally not possible.

![Figure 2-A major output of the MLR on ManAutoTest](image)

Another recent study, a paper [53] published in 2017, argues for use of blog articles (as a form of GL) as a source of evidence in SE research. For blog articles to be valuable to research, a method for extracting high quality articles from the vast amount of available online articles was presented. To better define the benefits and challenges of using blog articles in SE research, the authors of [53] developed a set of criteria for evaluating blog articles to be used in the method. They conducted a pilot study to explore the challenges of classifying blog articles. They also analyzed the criteria that have been used in previous research to assess credibility of blog articles. Based on their analysis, the authors concluded that blog articles need to be rigorous, relevant, well written and experience-based to be considered credible to researchers.

Having an interesting phrase in its title “Too long; didn’t watch”, a 2016 study [54] argued that, when knowledgeable colleagues are not available, software engineers (usually) resort to offline and various online GL resources for their information needs, e.g., tutorials, mailing lists, Q&A websites, and video tutorials. These, however, need to be found, read, and understood, which takes its toll in terms of time and mental energy. Although, as a form of GL, online video tutorials in recent years have seen a steep increase in popularity, they are an intrinsically noisy data source, and finding the right piece of information might be even more cumbersome than using the previously-mentioned resources (not easy to search by text inside their contents). To address that challenge, the authors of [54] presented CodeTube, an approach which mines video tutorials found on the web, and enables software engineers to query their contents. The results of two studies to assess CodeTube indicated that video tutorials---if appropriately processed---represent a useful, yet still under-utilized source of information in SE practice.
2.3.2 Reflecting the need of MLRs in SE based on other disciplines

Based on our survey of MLRs in other disciplines (see Section 3 for more details), we wanted to characterize the potential benefits of including (reviewing) the GL in review studies in SE. To that end, we pose and formulate in the following five hypotheses. Note that these hypotheses will not be empirically evaluated in this paper, but are underpinned by references and are posed as potential benefits of conducting MLRs in SE. We hope that future efforts of the community will shed light on them.

- **Hypothesis 1: GL can be useful for finding research topics and trends**: A high impact paper [55] (> 1,100 citations) mentions that early years of object-based image analysis were dominated by GL but more recent years (2005-2010) have had a sharp increase in peer-reviewed literature. This puts forward the hypothesis that GL can enable the identification of emerging research topics. For SE, this is nothing new as many research topics stem from industry, but it may be a more general trend in computing. From another highly cited paper [56], we can see that GL searches can go far beyond simple Google searches. The authors searched “44 online resource and database websites, 14 surveillance system websites, nine regional harm reduction websites, three prison literature databases, and 33 country-specific drug control agencies and ministry of health websites”. That paper highlighted the benefits of the GL by pointing out that, 75% to 85% of their results were based on data sourced from the GL. Another example [30] from medical domain suggests that “excluding grey literature from meta-analyses can lead to exaggerated estimates of intervention effectiveness”. For SE, we also have GL sources that contain quantitative data: (1) Industry surveys conducted by industry, e.g., the annual World Quality Report [57] by Capgemini Corp., the annual State of Agile report [58] by VersionOne, and the worldwide software testing practices report by the International Software Testing Qualifications Board (ISTQB); and (2) Social networking and Q/A sites, e.g., the StackOverflow.

- **Hypothesis 2: Qualitative GL reviews should utilize exploratory case-study approach**: A paper [11] titled “Towards rigor in reviews of multivocal literatures: applying the exploratory case study method” in the educational research domain proposed that the exploratory case study approach can be used to add rigor to the process of analyzing multivocal literature sources. They address the problems related to validity, control, bias and error. Their advice is mostly applicable to cases and other sources that rely on qualitative data. Similarly, a case study approach is also used in [59] to study GL of school-based breakfast programs.

- **Hypothesis 3: Both rigor and relevance should be addressed in GL reviews**: A response to their paper [11] is provided by M. Patton [12] who argues that utility rather than rigor should be the most important criterion when judging a literature review. Patton proposes starting the review by focusing on the purpose and audience. Utility means the practical impact of the work and this topic has been discussed in software engineering in papers addressing the relevance of studies, e.g., [60]. We obviously agree that both and rigor and relevance (utility) are important for GL reviews.

- **Hypothesis 4: Reviews in SE and also majority of SE research questions can benefit from the inclusion of GL**: As we know, a very large number of software practitioners constantly produces a huge wealth of GL knowledge, and utilizing that knowledge in research activities is very important. Almost all of our research activates in SE can benefit from the inclusion of GL.

- **Hypothesis 5: Mappings and qualitative synthesis can benefit from GL**: Since the GL usually includes qualitative data rather than quantitative data, data from those sources could benefit SM and qualitative synthesis studies. The GL sources in SE, in general, do not include much quantitative data. Thus, we think that qualitative synthesis studies will not benefit that much from the GL.

2.4 Adopting a Model for Differentiating Types of Sources in the Grey Literature

When conducting MLRs, it is often important to classify different types of sources in the GL. For that purpose, as per our extensive review of the literature, we adopted an existing model for this purpose from the management and organization studies domain [27]. The existing model seemed already applicable to SE too. The adopted model for GL sources in SE is shown in Figure 3. The only minor change that we made to the base model in [27] to make it more applicable to SE was slight revision of the outlets in the right-hand side under the three “tier” categories, e.g., we added the Q/A websites (such as StackOverflow).

The model has two dimensions: Expertise and outlet control. Both dimensions have the two extreme values “unknown” and “known”. Expertise is the extent to which the authority of the producer of content can be determined. Outlet control is the extent to which content is produced, moderated or edited in conformance with explicit and transparent knowledge creation criteria. Rather than having discrete bands, the gradation in both dimensions is on a continuous range between known and unknown, producing the “shades” of GL.
When adopted to SE, the model recognizes that experts generate a range of material based on their expertise and experience in SE that may be of scholarly interest. Similarly, prominent outlets (established blogs) sometimes publish unreviewed material written by people with unknown training and experience. In the middle ground lie online articles, company publications and so on that may be of interest even though source expertise and outlet control cannot be fully determined. In all cases, there are dangers of irrelevance, mistakes and fraudulent claims, as can be the case with the white literature, but, in the opinion of researchers [27], the challenges of assessing quality of grey literature sources require additional strategies.

2.5 EXISTING GUIDELINES FOR SLR AND SM STUDIES IN SE

There are existing guidelines for SLR and SM studies in SE, e.g., [2, 25, 26], which relate to the current guideline. The most cited guidelines are the one by Kitchenham and Charters, entitled “Guidelines for performing systematic literature reviews in software engineering”, the last version of which is 2.3, which was published as a technical report in 2007 [26], and was cited more than 2,400 times as of this writing (March 2017).

Petersen et al. discussed the emergence of SM studies in SE in 2008 and wrote a guidelines paper entitled “Systematic mapping studies in software engineering” [25], which were applied as guidelines by many researchers since then. Petersen et al. published an “updated” version of their guidelines in 2015 [2].

A more recent 2017 pragmatic guidelines [61] for SLR studies were published. This “experience-based” guidelines look at the pragmatic design of literature studies in SE. The authors of [61] argue that: “Although there are several guidelines to conduct literature studies, they do not yet help researchers coping with the specific difficulties encountered in the practical application of these guidelines”. The authors then present an experience-based set of guidelines to aid researchers in designing SLRs with special emphasis on the data collection and selection procedures.

3 METHODOLOGY FOR DEVELOPING THESE GUIDELINES

In this section, we discuss the methodology that we applied to derive the guidelines for including the GL and conducting MLRs in SE. Figure 4 shows an overview of our methodology. Three sources are used as input for synthesis and development of MLR guidelines: (1) Surveying and benefitting from other MLR guidelines and experience papers in other fields; (2) Existing guidelines for SLR and SM studies in SE, notably the popular SLR guidelines by Kitchenham and Charters [26]; and (3) Our own experience in conducting three MLRs [17-19]. Also, for better understanding of guidelines, we choose three MLRs, two from SE and one from another field (medical sciences), as running examples when discussing each guideline. We discuss each of the above issues in the next sub-sections.
3.1 A SURVEY OF MLR GUIDELINES AND EXPERIENCE PAPERS IN OTHER FIELDS

Many guidelines or experience papers about MLR studies have been published in other fields. We wanted to ensure that we would utilize and adopt all the knowledge and best advices provided in those studies in developing our current guidelines. For this purpose, we conducted a mini-SLR of those studies. For brevity, we discuss briefly next the process for this mini-SLR (e.g., search process and inclusion criteria) and then focus on the actual results of the mini-SLR. Throughout the rest of our paper in Sections 4-6, we benefit and adopt those suggestions and guidelines for conducting MLRs in SE.

3.1.1 Survey’s process and pool of studies

Using the guidelines for SLR studies in SE, e.g., [2, 25, 26], we searched in Scopus and Google Scholar. The search keywords were: “Multivocal Literature Review” and “Grey Literature AND Systematic Reviews”. To ensure that as many as possible of the relevant sources are included, we also conducted forward and backward snowballing [62], as recommended by the SLR guidelines, on the set of papers already in the pool. Snowballing, in this context, refers to using the reference list of a paper (backward snowballing) or the citations to the paper to identify additional papers (forward) [62].

We considered the following inclusion criteria: (1) the source should have discussed guidelines or experiences about MLR or GLR studies; and (2) the full-text of the source should be accessible. The sources, which did not satisfy the inclusion criteria (discussed above), were excluded. After finishing the search process and applying the above criteria, our pool contained 24 sources [11, 12, 14, 27, 30-34, 36, 40, 41, 44, 59, 63-72]. The entire pool of the reviewed sources in the mini-SLR and how each of them was classified is presented in the appendix. More details and the actual spreadsheet can be found in an available online source [73].

In terms of research areas, the 24 MLR guideline/experience papers were distributed as follows. Note the summation of numbers below is more than 24 since some studies were categorized in more than one area, e.g., [44] presented guidelines and explicitly mentioned three fields: medicine/health, education and social sciences.

- 15 papers were from medicine / health sciences,
- 6 papers were from educational sciences,
- 3 papers from the social sciences [11, 12, 44],
- 2 papers from [63] and [31] were from library and information research,
- 1 paper [66] was from psychology, and
- 1 paper [34] was from SE. The source from SE was a MSc thesis entitled “On the quality of grey literature and its use in information synthesis during systematic literature reviews” [34].

3.1.2 Survey’s summary of results

We classified the 24 MLR guidelines (see appendix for the classification of all 24 papers) and experience papers based on the type of guidelines in each of them to nine categories (MLR phases): (1) (guidelines on) decision to include GL in review studies, (2) (guidelines on) MLR planning, (3) (guidelines on) search process, (4) source selection (inclusion/exclusion), (5) source quality assessment, (6) data extraction, (7) data synthesis, (8) reporting the review (dissemination), and (9) any other type of guideline. Figure 5 shows the number of papers per category presenting guidelines for the specific category. For instance, five papers [11, 27, 31, 43, 70] provide guidelines for the data extraction phase.
Figure 5-Number of papers presenting guidelines of different types

Our methodology for this article on providing MLR guidelines for SE is to use and adopt the guidelines extracted from the above 24 sources, in each of the above nine categories, to the domain of SE, treating. Guidelines for each MLR phase (as shown in Figure 5) are presented individually in Sections 3.4-6.

3.2 OVERVIEW OF THE GUIDELINES

We have developed the current guidelines based on the following approach. As discussed in Section 2.5, since there are already specific guidelines for SM and SLR studies in SE, given the relevance and popularity of the SLR guidelines of Kitchenham and Charters [26], we took it as the baseline and extended/adopted it to conduct MLR studies in SE.

The SLR guidelines [26] summarizes the stages of an SLR into three main phases: (1) planning the review, (2) conducting the review, and (3) reporting the review. There are also sub-steps for each phase as shown in Figure 6.

![Figure 6- Phases of the Kitchenham and Charters’ SLR guidelines (taken from [26])](image)

From the SLR guidelines [26], we adopt the three phases for conducting MLRs, since we have found them to be well classified and also applicable to MLRs as per our experience in three recent MLRs [17-19]. The corresponding phases of the current guidelines are presented in Sections 4-6. To prevent duplication, we do not repeat the SLR guidelines [26] steps that are the same for conducting MLRs (e.g., details of the data extraction phase such as descriptive and quantitative synthesis techniques), but only present the steps that are different (specific) for conducting MLRs.

3.3 CHOOSING THREE MLRS AS RUNNING EXAMPLES

As shown in the overview of our methodology (Figure 4), to best convey the proposed guidelines, we choose three MLRs as running examples, as shown in Table 3. The presented guidelines will be discussed in the context of these three MLRs throughout the rest of this article. To have a balanced view and presentations from within SE and outside SE, we have chosen two MLRs from the field of SE [15, 17] and one from another field (medical sciences) [56]. When we present each
step (aspect) of the guidelines in the next sections, we discuss whether and how that aspect has been conducted in each of these three example MLRs. We will use the short names for these three MLRs in the discussions, i.e., MLR-HIV, MLR-TechDebt and MLR-AutoTest.

Table 3- Three MLRs chosen as running examples in this paper

| Ref. | Year | Topic                                                | Short name       | Area                  |
|------|------|------------------------------------------------------|------------------|-----------------------|
| [56] | 2008 | MLR on HIV among people who inject drugs             | MLR-HIV          | Medical sciences       |
| [15] | 2013 | MLR on exploration of technical debt                 | MLR-TechDebt     | Software engineering  |
| [17] | 2016 | MLR on deciding when and what to automate in testing | MLR-AutoTest     | Software engineering  |

3.4 A TYPICAL PROCESS OF A TYPICAL MLR

To better understand the guidelines, we present a typical process for conducting a typical MLR in Figure 7 (as a UML activity diagram). We have developed this typical process based on our experience in conducting MLRs in the past [17-19]. As we can see, this process is also similar to the SLR process as presented in Kitchenham and Charters’ guidelines [26]. We have essentially visualized the process, for better understandability, and have extended it to make it suitable for MLRs.

Figure 7-An overview of a typical MLR process

Similar to the SLR process [26], this process is divided into three phases: planning the review, conducting the review, and reporting the review results (shown as underlined activities in Figure 7). In Figure 7, we have also added the section numbers for the rest of this paper, to ease traceability between this process and the text.

We want to highlight at this point that, in our opinion, MLR studies, and SLR studies alike, should ensure providing concrete benefits for their target audience (researchers and/or practitioners). Thus, we have developed the MLR process and the current guidelines with a specific focus on target-audiences, as shown in Figure 7. Opinions of target researchers and practitioners who will read and benefit from an MLR shall be considered from as early as the planning phase in raising the need/motivations for the MLR and its review questions (RQs) (detailed further in Section 4.2).

4 PLANNING THE REVIEW

In the planning phase of the MLR, we discuss the following items:

- Establishing the need for an MLR in a given topic
- Ensuring usefulness from the planning phase
- Defining MLR’s goal and raising its review/research questions (RQs)
4.1 Establishing the Need for an MLR in a Given Topic

Similar to the SLR guidelines by Kitchenham and Charters [26], prior to undertaking an SLR or an MLR, researchers should ensure that conducting a systematic review is actually necessary. In particular, researchers should identify and review any existing systematic reviews of the phenomenon of interest.

Researchers may wonder whether they should conduct an SLR or an MLR. After establishing the need for an SLR in a given subject, researchers should assess the rationale whether to include the GL in their review and conduct an MLR or just consider the formal literature and conduct an SLR.

In our survey of MLR guidelines and experience papers in other disciplines (in Section 3.1), we found that eight sources have addressed the decision whether to include the GL and conduct an MLR instead of an SLR. The study in [31] argued that the GL provides “very current” perspectives and complements gaps of the formal literature, thus recommended MLRs to be conducted in areas when there is a need to capture current perspectives. It also mentioned that GL has a relatively short life-cycle of information, as an advantage over formal literature.

Another source [68] argued that publication bias is clearly a threat to the validity of any type of review, but particularly of unsystematic reviews, included in regular papers or theses. It also cautioned that the inclusion of data from unpublished studies can itself introduce bias. The studies that can be located may be an unrepresentative sample of all unpublished studies. It recommended the researchers to consider the above issues when establishing the need for an MLR in a given subject.

Another team of researchers [43] reported that their decision to include GL in an MLR was a result of consultation with stakeholders (practicing ergonomists, and health and safety professionals). If GL were not included, the researchers felt that an important perspective on the topic would have been lost. We observed a similar situation in the MLR-AutoTest [17] since, given its high practical relevance, the area of decision support for when and what to automate in testing seems to be more active among GL and practitioners than the research community. On another related more recent work [74], we conducted a GLR on the issue of choosing the right test automation tool and found that, again, the GL and practitioners are much more active than the formal literature and researchers in that area.

A systematic checklist on whether to include GL in review studies was presented in [40] (as shown in Table 4). The checklist includes six criteria, e.g., does the research question under investigation include complex interventions and outcomes? According to [40], “one or more yes responses suggest inclusion of grey literature”. The source [40] mentioned that if the practical contexts have little effect on the implementation of an intervention, information gained from GL may be not that relevant. However, when contextual information is important (which is also the case in SE [75, 76]), GL may reveal how outcomes are influenced by context factors like the domain or applied technology. All these aspects are clearly applicable to numerous research questions in SE as well. Thus, we think that the six criteria in Table 4 support the need for more MLRs in SE.

| 1 | Complex intervention | Yes/no |
| 2 | Complex outcome | Yes/no |
| 3 | Lack of consensus about measurement of outcome in peer-reviewed literature | Yes/no |
| 4 | Low volume of evidence in peer-reviewed literature | Yes/no |
| 5 | Low quality of evidence in peer-reviewed literature | Yes/no |
| 6 | Context important to implementing intervention | Yes/no |

Note: One or more “yes” responses suggest inclusion of grey literature.

In Table 5, we apply the checklist of Table 4 to the three running MLR examples (MLR-AutoTest, MLR-TechDebt and MLR-HIV). Note that the checklist was not actually applied explicitly in any of the three MLRs. Instead we apply it here as an “a-posteriori” analysis. While some of the six criteria in this list may seem subjective (i.e., how do we know if there is complex intervention or not?), but the team of researchers can assess each aspect in its binary form as a group, or even better, using rubrics (e.g., 5-point Likert scales). Nevertheless, we have found the checklist to be a useful tool in establishing the need for an MLR in a given subject.

In Table 5, we show the number of “yes” answers for each of the three cases. The larger the sum of “yes” answers for a given topic, the higher is the need/importance of conducting an MLR in that topic. For the case of MLR-AutoTest, the number of “yes” answers is six out of six, denoting the high need/importance of conducting an MLR in that area. In that particular area, as our review showed [17], there is a general lack of high-quality empirical evidence in the formal literature. Furthermore, the nature of interventions and outcomes are complex in this particular subject, i.e., what factors (interventions) should be considered when deciding when to automate in testing. Furthermore, similar to many other SE problems, context truly matters in this problem domain [75, 76], i.e., in which context/setting which factors play more
role when deciding when to automate in testing? Furthermore, as discussed in Section 2.3, and as we explicitly assessed in [24], important evidence and knowledge would have been missed if that particular MLR [17] had not included the GL. For the case of MLR-TechDebt, the sum of “yes” answers in Table 5 is four among the six criteria, denoting also the need for the MLR in that area. Authors of MLR-TechDebt in fact raised the need for an MLR in that subject area, by stating that findings from a preliminary study showed that “the challenge of defining technical debt in academic literature lies in the fact that such boundaries have not yet been identified through a rigorous process” and therefore academic literature is lacking a conceptual model of technical debt [77]. They mentioned however that other accessible writings in GL (e.g., internet blogs, white papers, and trade magazine paper) readily propose measures, motivations and ideas surrounding the concept of technical debt.

For the case of MLR-HIV, although we are not experts in its subject area (medicine), but we determined the number of “yes” answers to be three out of six, by reviewing MLR-HIV and understanding the subject to our best ability.
Table 5-Application of checklist in [40] to the three running MLR examples

| Criteria                                      | MLR-AutoTest | MLR-TechDebt | MLR- HIV |
|----------------------------------------------|--------------|--------------|---------|
| Complex intervention                        | Yes          | Yes          | Yes     |
| Complex outcome                             | Yes          | Yes          | Yes     |
| Lack of consensus about measurement of outcome in peer-reviewed literature | Yes          | No           | No      |
| Low volume of evidence in peer-reviewed literature | Yes          | No           | Yes     |
| Low quality of evidence in peer-reviewed literature | Yes          | Yes          | No      |
| Context important to implementing intervention | Yes          | Yes          | No      |
| **Number of “yes” answers:**                | 6            | 4            | 3       |

Another guidelines paper for using GL in systematic reviews for management and organizational studies [27], which was based on reviewing 140 SLRs published in academic and practitioner outlets, presented a decision aid for deciding whether or not to incorporate the GL in reviews. The guidelines suggested to include GL in reviews when relevant knowledge is not reported adequately in academic articles, and for validating scientific outcomes with practical experience, and also for challenging assumptions in practice using academic research. Regarding the notion of different GL “tiers” in Table 6, refer to Figure 3 as discussed in Section 2.4.

Table 6- A decision aid for deciding whether or not to incorporate the GL in systematic reviews (adopted from [27])

| Guidelines on including GL | Consider all tiers of GL to define and contextualize phenomena of research interest when potentially relevant knowledge is not reported adequately in academic articles, clearly stating the rationale for including sources written by practitioners in the review. Consider all tiers of GL when attempting to (a) validate/corroborate scientific outcomes with practical experience, or (b) challenge assumptions/falsify results from practice using academic research. |
| Guidelines on excluding GL | Exclude GL from reviews supporting relatively mature and/or bounded academic conversations with the possible exception of some Tier 1 literatures that are relatively easy to defend on the basis of widely acknowledged decision rules about quality. |

4.2 BEGINNING WITH THE END IN MIND: ENSURING USEFULNESS FROM THE PLANNING PHASE

We think that conductors of MLR or SLR should pay a close attention to ensure usefulness of an MLR for its intended audience (researchers and/or practitioners) as early as its planning phase (in defining its scope, goal and review questions). Some of the existing guidelines have also raised the importance of this issue, e.g., Petersen et al.’s “updated” SM guidelines [2]. Those guidelines [2] encouraged the researchers to “consult with target audience to define questions” and presented a rubric for assessing the quality of motivation of review studies (as shown in Table 7). The motivation score of a given review study is assessed on a three-point Likert scale: (0) No description of the need for review, (1) Partial evaluation, and (2) Full evaluation of the need for review.

Table 7- Rubrics for motivation and need for a review study (adopted from [2])

| Evaluation      | Description                                | Score |
|-----------------|--------------------------------------------|-------|
| No description  | The study is not motivated and the goal is not stated | 0     |
| Partial evaluation | Motivations and questions are provided       | 1     |
| Full evaluation | Motivations and questions are provided, and have been defined in correspondence with target audience | 2     |

In an assessment of 52 review studies in SE, Petersen et al. [2] found that all of them were only assessed in the “Partial evaluation” point in terms of the need for review. Since MLR studies are written by synthesizing both formal and GL, they usually target both researchers and practitioners. Thus, our guidelines encourage conductors of MLRs to directly consult with both those target audience to define the goal and questions of the study. For example, in our MLR-AutoTest, we discussed the idea of the MLR with several industrial partners and researchers before raising the study’s RQs. Furthermore, the entire motivation of conducting that MLR was itself rooted in the need of several of our industrial partners (e.g., [78-80]) in being able to systematically decide when and what to automate in testing, and to find out the factors which has been
considered in the community when answering the when/what questions (the list of factors was raised as one of the MLR’s RQs). Thus, we ensured to explicitly scope the motivation of the MLR and also to raise the RQs (discussed in Section 4.3) in direct correspondence with its target audience.

All the above considerations would ensure conducting a given MLR in such a way to ensure the usefulness of its results and findings, at the end, for the targeted audience. This issue will be revisited again in Section 6 in the reporting phase.

### 4.3 Defining the goal of the MLR and raising its review/research questions (RQs)

Similar to SLRs, the researchers should clearly state the MLR’s goal during the planning phase. It has also become standard for SLRs in SE to also raise review/research questions (RQs) to ensure making their contributions and research targets explicit. To make the connection among the review’s goal, RQs and the metrics to collect more structured and traceable, the authors have often used the Goal-Question-Metric (GQM) methodology [81] in their previous SM, SLR and MLR studies [52, 82-88].

The SLR guidelines of Kitchenham and Charters [26] state that specifying the RQs is the most important part of any systematic review. This is also the case for MLRs. In fact, the RQs drive the entire review by impacting the following aspects directly:

- The search process must identify primary studies that address the RQs
- The data extraction process must extract the data items needed to answer the RQs
- The data analysis (synthesis) phase must synthesize the data in such a way that the RQs are properly answered

As examples, Table 8 shows the RQs raised in the three example MLRs. MLR-AutoTest raised four RQs and several sub-RQs under some of the top-level RQs. This style was also applied in many other SM and SLR studies to group the RQs in categories. MLR-TechDebt raised three RQs. MLR-HIV did not raise any RQs as it seems explicit RQs are not that common in the medical sciences community.

| MLR study       | RQs                                                                 |
|-----------------|----------------------------------------------------------------------|
| MLR-AutoTest    | • RQ 1-mapping of sources by contribution and research facets:       |
|                 |   o RQ 1.1-mapping by contribution facet: How many studies present  |
|                 |     methods, techniques, tools, models, metrics, or processes for   |
|                 |     the when/what to automate questions?                             |
|                 |   o RQ 1.2-mapping by research facet: What type of research methods |
|                 |     have been used in the studies in this area?                     |
|                 | • RQ 2-factors considered for deciding when/what to automate (the   |
|                 |     core contribution of this study): What factors are considered   |
|                 |     in the when/what questions?                                     |
|                 | • RQ 3-tools: What tools have been proposed to support the when/what |
|                 |     questions?                                                      |
|                 | • RQ 4-software systems under test or projects under study: What    |
|                 |     attributes of those systems and projects?                       |
|                 |   o RQ 4.1-software systems or projects under analysis: How many    |
|                 |     software systems or projects under analysis have been used in   |
|                 |     each source?                                                    |
|                 |   o RQ 4.2-domains and types of the software systems or projects     |
|                 |     under analysis: What are the domains of the software systems or  |
|                 |     projects under analysis that have been studied in the sources   |
|                 |     (e.g., embedded, safety-critical, and control software)? Also,  |
|                 |     what types of software systems have been studies in the sources |
|                 |     (i.e., open-source, commercial, or academic experimental systems) |
|                 |   o RQ 4.3-types of measurements: What types of measurements, in    |
|                 |     the context of the software systems under analysis, to support  |
|                 |     the when/what questions have been provided?                     |
| MLR-TechDebt    | • RQ1 – What are the dimensions of technical debt?                   |
|                 | • RQ2 – How does technical debt arise?                              |
|                 | • RQ3 – What are the benefits and drawbacks of allowing technical    |
|                 |     debt to accrue?                                                  |
| MLR-HIV        | No RQs                                                               |

### 5 Conducting the review

Once an MLR is planned, it shall actually be conducted. This section is structured according the five phases of conducting an MLR:

- Search process (Section 5.1)
- Source selection (Section 5.2)
• Study quality assessment (Section 5.3)
• Data extraction (Section 5.4)
• Data synthesis (Section 5.5)

5.1 SEARCH PROCESS

Searching either formal or GL is typically done via means of using defined search strings. Defining the search strings is an iterative search process where the initial exploratory searches reveal more relevant search strings. Literature can also be searched via technique called “snowballing” [62] where one follows citations either backward or forward from a set of seed papers. Here we highlight the differences between searching in formal literature versus GL.

5.1.1 Where to search

Formally-published literature is searched via either broad-coverage abstract databases, e.g., Scopus, Web of Science, Google Scholar or from full-text databases with more limited coverage, e.g., IEEE Xplore, ACM digital library, or ScienceDirect. The search strategy for GL is obviously different since academic databases do not index GL. Our mini-SLR (Section 3.1) identified several strategies, as discussed next:

• General web search engine: For example, conventional web search engines such as Google were used in many GL review studies in management sciences [70] but also in other disciplines, e.g., health [69]. This advice is valid and easily applicable in the SE context as well.

• Specialized databases: Many papers mentioned specialized databases and websites that would be different for each discipline. For example, in medical sciences, clinical trial registries are relevant (e.g., the International Standard Randomized Controlled Trials Number, www.isrctn.com). As another example, in management sciences, investment sites have been used (e.g., www.socialfunds.com). GL database such as www.opengrey.eu provide broader coverage but search for “software engineering” provided only 4,115 hits as of this writing (March 21, 2017). For comparison, Scopus provides 120,056 hits for the same search. Relevant databases for SE would be non-peer reviewed electronic archives (e.g., www.arxiv.org), social question-answer websites (e.g., www.stackoverflow.com). In essence, the choice of websites that the review authors should focus on, would depend on the particular search goals. For example, if one is interested in agile software development, a suitable website could be AgileAllience (www.agilealliance.org). A focused source for software testing would be the website of the International Software Testing Qualifications Board (ISTQB, www.istqb.org). Also, many annual often world-wide surveys in SE exists which can provide inputs to MLRs, e.g., the World Quality Report [57] by Capgemini Corp., the annual state of Agile report [58] by VersionOne, worldwide software developer and ICT-skilled worker estimates by the International Data Corporation (IDC (www.idc.com), National-level surveys such as the survey of software companies in Finland (Ohjelmistoyrityskartoitus) [89], or the Turkish Software Quality report [90] by the Turkish Testing Board. However, figuring out suitable specialized databases is not trivial which brings us to our next method (contacting individuals).

• Contacting individuals directly or via social media: Individuals can be contacted for multiple purposes for example to provide their unpublished studies or to find out specialized databases where relevant information could be sought. [70] mentions contacting individuals via multiple methods: direct requests, general requests to organizations, request to professional societies via mailing list, and open requests for information in social media (Twitter or Facebook).

• Reference lists: Studying references lists, aka snowballing [62], is done in the white (formal) literature reviews as well in GL reviews. However, in GL and in particularly GL in web-sites, formal citations are almost always not present. Yet, features such as backlinks can be navigated either forward or backward. Backlinks can be extracted using various online back-link checking tools (such as www.majestic.com).

In MLR-TechDebt, the Google search engine was used. The authors also used iterative search strategy as they started out with three search terms and then used any new terms found to update the search string and performed additional iterations. In MLR-AutoTest, authors also used the Google search to search for GL and Google Scholar to search for academic literature. The authors used four separate search strings. In MLR-HIV, multiple sources were used. Formally-published literature was searched from several medical databases, e.g., PubMed. GL was searched from broad range of sources: “we searched the grey literature and online databases, including 44 online resource and database websites, 14 surveillance system websites, nine regional harm reduction websites, three prison literature databases, and 33 country-specific drug control agencies and ministry of health websites”. Additionally, the authors of MLR-HIV contacted individuals via email through their collaborators that included high-profile organizations such as World Health Organization (WHO) and UN Office on Drugs and Crime (UNODC).

5.1.2 When to stop the search

In the formal literature, one first develops the search string and then uses this search string to collect all the relevant literature from an abstract or full text database. This brings a clear stopping condition for the search process and allows
moving to study’s next phases. We refer to such as a condition as data exhaustion stopping criteria. However, the issue of when to stop the GL search is not that simple. Through our own experiences in MLR studies [17-19], we have observed that different stopping criteria for GL searches are needed.

First, the stopping rules are intervened with the goals and types of evidence of including GL. If evidence is mostly qualitative, one can reach theoretical saturation, i.e., a point where adding new sources do not increase the number of findings, even if one decides to stop the search before finding all the relevant sources.

Second, the stopping rules can be influenced by the large volumes of data. For example, in MLR-AutoTest, we received 1,330,000 hits from Google. Obviously, in such cases, one needs to rely on the search engine page rank algorithm [91] and choose to investigate only a suitable number of hits. In MLR-AutoTest for example, we checked the first 10 Google result pages and continued further if needed, e.g., when the results in a given page still looked relevant. In MLR-AutoTest, we referred to this phenomenon as the search “saturation” effect. Such an approach has also been used in other fields [59].

Third, are different stopping rules due to the varying quality and availability of evidence (see the model for differentiating the GL in Figure 3). For instance, in our review of gamification of software testing [19], the quality of evidence quickly declined when moving down in the search results provided by Google search engine. More and higher qualities for evidence were available for our MLR-AutoTest. Thus, the availability of not only resources but also the availability of evidence can determine whether data exhaustion stopping rule is appropriate.

To summarize, we offer three possible stopping rules for GL searches:

1. Theoretical saturation, i.e., when no new concepts emerge from the search results anymore
2. Effort bounded, i.e., only include the top N search engine hits
3. Evidence exhaustion, i.e., extract all the evidence

In MLR-TechDebt, authors limited their searched to the top 50 Google search engine hits. This matches the “effort bounded” stopping rule. In MLR-TechDebt, the authors also used theoretical saturation but only with respect to interviews they conducted. It would have been possible to use it also for the GL review. In MLR-AutoTest, authors limited their searches to the first 100 search hits and continued the searches further if the hits in the last page still provided relevant search results. This partially matches the “effort bounded” stopping rules augmented with subjective criteria. In MLR-HIV, authors used multiple sources and although they are not specific about the stopping rules, it appears they primarily used the “data exhaustion” stopping rule.

5.2 SOURCE SELECTION

Once the potentially relevant primary sources have been obtained, they need to be assessed for their actual relevance. The source selection process normally includes determining the selection criteria and performing the selection process. As GL is more diverse and less controlled than formal literature, source selection can be particularly time-consuming and difficult. Therefore, the selection criteria should be more fine-grained and take criteria considering the source type and level of control into account. The source selection process itself is not specific for GL, but typically more time-consuming as the selection criteria are more diverse and can be quite vague. Note that source selection often overlaps with study quality assessment (presented in Section 5.3), if the quality of one or several the study reported in the source is taken into account as a selection criterion already in the source selection phase.

5.2.1 Source selection criteria

Source selection criteria are intended to identify those sources that provide direct evidence about the MLR’s research (review) question. In order to reduce the likelihood of bias, selection criteria should be decided during the protocol definition in the MLR’s planning phase. The criteria are expressed as inclusion as well as exclusion criteria. Some selection criteria are generic such as: publication language (usually, only source in English are considered), publication date, or results reported in more than one paper. Other criteria are more technical and usually challenging to interpret, for instance criteria regarding details of the papers that are included in the review or the rationale for excluding marginal papers.

In MLR-TechDebt, data sources were excluded according to the following criteria: (a) a duplicate record, (b) did not relate to the process of software development, and (c) sources which did not discuss the concept of technical debt. In MLR-AutoTest, sources were included if they are (a) in the area of automated testing ROI calculations since they could be used as decision support mechanisms for balancing and deciding manual versus automated software testing, or (b) sources which provide decision support for the two questions “what to automate” and “when to automate”. Sources which did not meet the above criteria were excluded. In addition, the authors of MLR-AutoTest provided concrete examples for excluded sources. Finally, in MLR-HIV, only those sources that had abstracts available in English were included, and sources reporting estimates with unknown methodology or where there were no details on how those estimates had been derived were excluded. Furthermore, if national data was available, city-specific data was excluded in MLR-HIV.
An important aspect and selection criterion of GL is the source type which impacts a given source’s level of credibility and outlet control. Related to this issue, the model in Figure 3 proposes 1st tier GL such as books or white papers, 2nd tier GL such as videos or presentations, and 3rd tier GL such as blogs or tweets. Besides the type of the GL itself, additional criteria – which have not been considered in one the three running MLR examples – can be applied to filter various GL sources. In [34], 12 criteria for categorizing and selecting different types of GL sources were proposed (as shown in Table 9).

| Criterion | Explanation |
|-----------|-------------|
| 1 Num. of hits | Number of hits of a source provides an idea of its popularity |
| 2 Num. of citations | Number of citations of a source in other sources |
| 3 Type of source | Annual reports, theses/dissertations, blogs, etc. |
| 4 Methodology | Type of research method, e.g., survey, case study or experiment, applied in a specific source |
| 5 Social sharing | Number of likes or shares on social platforms like Twitter or YouTube |
| 6 Date/year | Date/year when the sources were written |
| 7 Organization | Organization, e.g., governmental institution, company, research center or university, publishing a source |
| 8 Author(s) | Reputation of an author, e.g., measured in terms of number of publications or h-index, of a source |
| 9 Country | Country of the source |
| 10 Online comments | Number of comments posted for a specific online entries like a blog post or a video |
| 11 File format | Format in which the source is provided, e.g., PDF, HTML, DOC or PPT |

Each of these criteria has strengths and weaknesses (presented in [34]) and is suitable only for specific types of GL sources. For instance, online comments can only be counted for source types open for comments like blog posts, news articles or videos. A highly-commented blog post may show its popularity, but on the other hand, spam comments may bias the number of comments, thus invalidating the high popularity. The provided criteria for source selection overlap with study quality assessment, especially if the methodology is used as a classification criterion and related to the validity of the reported study. However, the more sources can be excluded with certainty based on suitable selection criteria, the less effort is needed for study quality assessment, which requires a probably time-consuming content analysis of a source. Therefore, suitable selection criteria are of high importance for GL. An important criterion already mentioned before (and also presented in [34]) is the publication date of a source or the date of its last update.

Another framework proposing criteria for GL source selection and quality assessment is titled AACODS (Authority, Accuracy, Coverage, Objectivity, Date, and Significance) [63]. The AACODS checklist was designed to enable evaluation and critical appraisal of GL based on the following criteria: authority, accuracy, coverage, objectivity, date, and significance. A critical appraisal is the process of carefully and systematically examining research to judge its trustworthiness, and its value and relevance in a particular context. The fulfillment of each criterion is assessed by answering specific questions which provide the basis to decide whether a specific criterion is fulfilled or not. To decide on authority of the source, the following questions may be answered [63]:

- “Is the publishing organization reputable? (e.g., the Software Engineering Institute)”
- “Is an individual author associated with a reputable organization?”
- “Has the author published other work in the field?”

To decide on accuracy, the following questions may be answered [63]:

- “Does the source have a clearly stated aim?”
- “Does the source have a stated methodology?”
- “Is the source supported by authoritative, documented references?”

To decide on coverage, the following questions may be answered [63]:

- “Are any limits clearly stated?”
- “Does the work cover a specific question?”
- “Does the work refer to a particular population?”

To decide on objectivity, the following questions may be answered [63]:

- “Does the work seem to be balanced in presentation?”
- “Is the statement a subjective opinion?”
- “Are the conclusions biased?”

To decide on date, the following questions may be answered [63]:

- “Check the bibliography: have key contemporary material been included?”
- “If no date is given, but can be closely ascertained, is there a valid reason for its absence?”
- “Does the item have a clearly stated date related to content?”
Finally, to decide on significance, the following questions may be answered [63]:

- “Does it enrich or add something unique to the research?”
- “Does it strengthen or refute a current position?”
- “Does it have impact?”

The decision whether to include a source or not can beyond a bare binary decision (“yes” or “no” informally decided on guiding question), and can be based on a richer scoring scheme. For instance, da Silva et al. [92] used a 3-point Likert scale (yes=1, partly=0.5, and no=0) to assign scores to assessment questions. Based on these scoring results, agreement between different persons can be measured and a threshold for inclusion of sources can be defined.

It seems that the AACODS criteria has some overlap with the selection criteria presented in Table 9. For instance, asking for the applied methodology is a question related to accuracy in AACODS and also a selection criterion (which can actually also be applied as a study quality assessment criterion) in Table 9. For practical application, the available criteria can be combined from different guidelines and adapted depending on the context and the types of GL.

### 5.2.2 Source selection process

The source selection process itself does not differ from classical systematic reviews and therefore available guidelines for systematic reviews are applicable. According to the guidelines for performing SLRs in Software Engineering by Kitchenham and Charters [26], source selection is a multi-stage process: Initially, selection criteria (see the previous section) should be interpreted liberally, so that unless sources identified by the electronic searchers can be clearly excluded based on titles and abstracts, full copies should be obtained. Source selection can overlap with the searching process when searching involves snowballing or contacting authors of relevant papers. When two or more researchers assess each paper, agreement between researchers can be measured using the Cohen Kappa statistic [93]. Disagreements must be discussed and resolved. Finally, according to Kitchenham and Charters [26], uncertainty about the inclusion/exclusion of some studies should be investigated by sensitivity analysis.

In MLR-TechDebt, the selection process comprised of applying the inclusion and exclusion criteria (see Section 5.2.1) as well as by quality criteria (see Section 5.3). In MLR-AutoTest, only inclusion criteria were provided (see Section 5.2.1) and sources not meeting them were excluded. In addition, forward and backward snowballing [62] was applied to include as many relevant sources as possible. MLR-HIV presented an integrated search and selection process. From 11,022 documents collected from peer reviewed and GL, 22,767 documents were selected after review of title and abstract. Furthermore, 783 documents contained relevant metrics, and 168 of those were used for quantitative synthesis.

### 5.3 Study quality assessment

In addition to defining inclusion and exclusion criteria to select relevant sources, it is also important to assess the quality of the studies. Study quality assessment is about determining the extent to which a source is valid and free of bias. For quantitative systematic reviews aiming for meta-analysis in particular, it is essential to assess the quality of the primary studies included in the review because if their results are invalid, then this should be taken into account during the synthesis. Quality assessment can be of less importance when undertaking a mapping study since the focus for these is usually on classifying information or knowledge about a topic. However, differing from formal literature, which normally follows a well-defined and controlled review and publication process, respective processes for GL are more diverse and less controlled. As a consequence, the quality of GL is more diverse and often difficult to assess. Therefore, quality assessment of GL requires typically more effort than for formal literature.

In MLR-TechDebt, the study quality of the included sources was assessed in terms of the position and certainty of the source, clarity, detail, consistency, plausibility, and alignment with the research focus as determined by the research questions. Studies were classified into three categories, i.e., above the quality threshold, uncertain, or below the quality threshold. The assessment was performed iteratively until no results remained in the uncertain category. In MLR-AutoTest, the quality criteria was whether a given study in a source provides decision support for the two questions “what to automate” in testing and “when to automate” testing. Finally, in MLR-HIV, sources reporting estimates with unknown methodology or where there were no details on how those estimates had been derived were excluded.

As already highlighted in Section 5.2.1, in practice, study quality assessment overlaps and is sometimes even integrated with source selection. Therefore, selection criteria already discussed in Section 5.2.1 may also be used as quality assessment criteria. For instance, when using the “research method” as the selection criterion in a specific source, e.g., survey, case study or experiment, it also addresses the study quality. To investigate the quality of specific study types in detail, checklists tailored to specific study types are available. For GL especially, case studies are an important study type (see Hypothesis 2: “Qualitative GL reviews should utilize exploratory case-study approach” in Section 2.3.2). For case studies, Runeson et al. [94]
presented a quality checklist for readers of case studies, which can also be utilized for case studies reported in GL. It comprises the following 11 questions:

1. Are the case and its units of analysis adequately presented?
2. Are the objective, the research questions and corresponding answers reported?
3. Are related theory and hypotheses clearly reported?
4. Are the data collection procedures presented, with relevant motivation?
5. Is sufficient raw data presented (e.g., real life examples, quotations)?
6. Are the analysis procedures clearly reported?
7. Are threats to validity analyses reported along with countermeasures taken to reduce threats?
8. Are ethical issues reported openly (personal intentions, integrity issues, confidentiality)
9. Does the report contain conclusions, implications for practice and future research?
10. Does the report give a realistic and credible impression?
11. Is the report suitable for its audience, easy to read and well structured?

For systematic reviews and meta-analyses, there is the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses available at [www.prisma-statement.org](http://www.prisma-statement.org)) which aims to help authors (originally within the clinical medicine field) improve the reporting of systematic reviews and meta-analyses. It has been suggested that PRISMA can be useful for the critical appraisal of SLRs in SE [95] and thus also for GLR and MLRs in SE. Another quality checklist that can be used across multiple study types in SE was provided in [96]. That checklist includes the following items: (1) level of evidence reported (from individual opinions to randomized, controlled trials), (2) aim of the research, (3) context, (4) research design, (5) data collection, (6) data analysis, (7) clear statement of findings, as well as (8) study value for research and practice.

5.4 DATA EXTRACTION

For the data extraction phase, we discuss the following aspects:

- Design of data extraction forms
- Data extraction procedures and logistics
- Possibility of automated data extraction and synthesis

5.4.1 Design of data extraction forms

Most of design aspects of data extraction forms for MLRs are similar to those aspects in the SLR guidelines of Kitchenham and Charters [26]. We discuss next a few important additional considerations in the context of MLRs based on our experience in conducting MLRs.

Since many SLR and MLR studies have, as a part of them, an SM step first, it is important to ensure the rigor in data extraction forms. Also, a recent paper [97] presented a set of experience-based guidelines for effective and efficient data extraction which can apply to all four types systematic reviews in SE (SM, SLR, MLR and GLRs).

Based on the suggestions in [97], to facilitate design of data extraction forms, we have developed spreadsheets with direct traceability to MLR’s RQs in mind. For example, Table 10 shows the systematic map that we used developed and used in the MLR-AutoTest. In this table, column 1 is the list of RQs, column 2 is the corresponding attribute/aspect. Column 3 is the set of all possible values for the attribute. Finally, column 4 indicates for an attribute whether multiple selections can be applied. For example, in RQ 1 (research type), the corresponding value in the last column is ‘S’ (Single). It indicates that one source can be classified under only one research type. In contrast, for RQ 1 (contribution type), the corresponding value in the last column is ‘M’ (Multiple). It indicates that one study can contribute more than one type of options (e.g., method, tool, etc.).

Table 10: Systematic map developed and used in MLR-AutoTest

| RQ | Attribute/Aspect       | Categories                                                                 | (M)ultiple/ (S)ingle |
|----|------------------------|-----------------------------------------------------------------------------|----------------------|
| 1  | Contribution type      | Heuristics/guideline, method (technique), tool, metric, model, process, empirical results only, other | M                    |
|    | Research type          | Solution proposal, validation research (weak empirical study), evaluation research (strong empirical study), experience studies, philosophical studies, opinion studies, other | S                    |
Factors considered for deciding when/what to automate

A list of pre-defined categories (Maturity of SUT, Stability of test cases, 'Cost, benefit, ROI, and Need for regression testing) and an ‘other’ category whose values were later qualitatively coded (by applying 'axial' ‘open' coding)

Decision-support tools

Name and features

Attributes of the software systems under test (SUT)

Number of software systems: integer
SUT names: array of strings
Domain, e.g., embedded systems
Type of system(s): Academic experimental or simple code examples, real open-source, commercial
Test automation cost/benefit measurements: numerical values

5.4.2 Data extraction procedures and logistics

Many authors are reporting logistical and operational challenges in conducting SLRs, e.g., [61]. We suggest next a summary of best practices based on our survey of MLR guidelines and experience papers (as reported in Section 3) and then report our own experiences.

Out of the 24 MLR guideline/experience papers (as reported in Section 3), 4 reported experience-based guidelines for data extraction, as summarized next. [31] offered a worksheet sample to extract data from the GL sources including fields such as: database, organization, website, pathfinder, guide to topic/subject, date searched, # of hits, and observations.

Entitled “Searching and synthesizing grey literature and grey information in public health”, the paper [70] argued that, when possible, the authors emailed and even called individuals to gather more detailed GL data. They reported that, for the case of GL, often no original data is available and also much information is in peoples’ heads and not written down somewhere. Furthermore, the authors of [70] reported that some information is much more likely to be documented than others (similar to publications bias), which makes data extraction more challenging and even biased.

The authors of [43] tried to find both the grey and peer-reviewed documents that described the same study. In those cases, the team decided the primary document would be the peer-reviewed with GL documents as supplemental.

Another paper [11] suggested that, to meet standards for rigor in reviews of GL, steps should be taken to prevent ambiguity in data collection. The study suggested maintaining “chains of evidence (records of sources consulted and inferences drawn)”. In another part of [11], the authors mention that: “To meet these (rigor) requirements, researchers can maintain an audit trail”. This is similar to what we call “traceability” links in SE and in our experience and guidelines report for data extraction [97]. For example, Figure 8 shows a snapshot of the online repository (spreadsheet hosted on Google Docs) for MLR-AutoTest in which the contribution facets are shown and a classification of ‘Model’ for the contribution facet of [Source 2] is shown, along with the summary text from the source acting as the corresponding ‘traceability’ link.

The guidelines in [11] also argue that, because documents in the GL are often written for non-academic purposes and audiences and because documents often address different aspects of a phenomenon with different degrees of thoroughness, it is essential that researchers record the purpose, specify the coverage, and assess the quality of each GL document. Authors of [11] also wanted to record the extent to which the implicit assumptions or causal connections were supported by evidence in the GL documents. For that purpose, they developed matrices that enabled them to systematically track and see what every document in every category of the dataset said about causal connection in every theory of action.

Our own experiences from our past SLRs and MLRs have been as follows. To extract data, the studies in our pool were reviewed with the focus of each specific research question. During the analysis, each of the researchers extracted and analyzed data from the share of sources assigned to her/him, then peer reviewed the results of each other’s analyses. In the case of disagreements, discussions were conducted. We utilized this process to ensure quality and validity of our results.
5.4.3 Possibility of automated data extraction and synthesis

While we and most researchers have extracted data for SLR and MLR studies manually, it should be mentioned that the idea of automated data extraction and synthesis for review studies is starting to appear in the community, e.g., [98-103]. We encourage the application of those approaches and tools, and then reporting their effectiveness and efficiency in follow-up papers. Furthermore, if the review pool includes sources of type video, automated data extraction from online videos may also be possible, using approaches such as [104].

5.5 DATA SYNTHESIS

There are various data synthesis techniques, as reported in Kitchenham and Charters’ guidelines for SLRs [26] and also elsewhere, e.g., a guidelines paper for synthesizing evidence in SE research [105]: descriptive (narrative) synthesis, quantitative synthesis, qualitative synthesis, thematic analysis, and meta-analysis.

Based on the type of RQs and the type of data (primary studies), the right data synthesis techniques should be selected and used. We have observed that practitioners provide in their reports mainly three types of data:

- First, qualitative and experience-based evidence is very common in the GL as practitioners share their reflections on topics like when to automate testing (MLR-AutoTest) or views on technical debt and its management (MLR-TechDebt). This requires qualitative data analysis techniques. Their reflection may occasionally include quantitative data, e.g., in some presented quantitative data on ROI when automating software testing, as well. However, we see that typically the quality and accuracy of the reporting does usually not allow quantitative meta-analysis to take place from practitioner reports.

- Second, quantitative evidence in the form of questionnaires is relatively common in GL, e.g., international surveys such as the state-of the Agile report by VersionOne, and the World Quality Survey by HP & Sogetti. More surveys can be found on national/regional levels such as the survey of software companies in Finland [89], or the Turkish Software Quality report [90] by the Turkish Testing Board. If the same question is repeated in multiple or sequential surveys, this may allow meta-analysis. However, often the GL surveys fail to report standard deviation, which makes statistical meta-analysis impossible. Furthermore, we have seen virtually no controlled experiments nor rigorously conducted quasi experiments in GL, thus, we see limited possibilities in using meta-analytic procedures to combine experiment results from GL in SE.

- Third, using data from particular GL databases such as question/answer sites (such as the StackOverflow website) may allow both the use of quantitative and qualitative research methods. For example, a quantitative comparison of technology usage can be done from the StackOverflow website by extracting the number of questions and view counts
that can give an indication of popularity of testing tools for example [106]. Qualitative analysis can also be conducted and it can analyze the types of problems software engineers are facing with the testing tools for example.

In MLR-TechDebt, authors used qualitative data coding, identified emergent constructs, and developed a theoretical framework using qualitative data analysis strategies. In MLR-AutoTest, using grounded theory, authors started coding with a small set of pre-existing codes. During the coding process, they realized that more factors emerged from the data, thus, they switched to open and axial coding. In MLR-HIV, authors used a customized decision rule-set for data synthesis. For example, if two or more estimates existed, they chose the one collected with the higher research method quality and if several same quality sources existed, the lowest-lower boundary and the highest-high boundary were selected.

6 REPORTING THE REVIEW

As shown in the MLR process (Figure 7), the last phase is reporting the review. Typical issues of the reporting phase of an MLR (specifying the dissemination strategy, and formatting the report/paper) are similar to the SLR guidelines of Kitchenham and Charters [26]. In our experience from our past SLR and MLRs, we have seen two important additional issues that we discuss next: (1) reporting style for different audience types, and (2) ensuring usefulness for the targeted audience.

6.1 REPORTING STYLE FOR DIFFERENT AUDIENCE TYPES

Outputs of MLRs are supposed to provide (concrete) usefulness and benefits for both researchers and practitioners since they provide summaries of both the state-of-the-art and practice in a given area. Readers of MLR papers (both practitioners and researchers) are expected to benefit from the provided evidence-based overview and “index” to the body of knowledge in the given subject area [107].

Furthermore, conveying and publishing results of MLR and SLR studies to practitioners will “enhance the practical relevance of research” [108]. To enhance the practical relevance of research, the paper in [108] suggested among other recommendations, to “convey relevant insights to practitioners”, “present to practitioners” and “write for practitioners”. We have followed that advice, and have reported the shortened (practitioner-oriented) versions of three of our MLR and SLR studies [8, 107, 109] in the IEEE Software magazine. When the reporting style of SLR or an MLR is “fit” for practitioners, they usually find such papers useful. For example, we had asked a few of our industry partners to provide feedback on the SLR paper on testing embedded software that was recently published in IEEE Software [8]. Here is what one of the asked practitioners explicitly stated: “Our company conducts embedded system testing for software-intensive systems in the military domain. After reviewing this survey paper, I wonder why we do not have any model of these SUTs. If we can create models of these SUTs (e.g., model-in-the loop, MIL), in the future we would not need to borrow the real systems from our customers and models may be sufficient for our test-case design and other test activities. There are a lot of studies in the pool of this review study, which would benefit us.”

Furthermore, writing (reporting) style for scientific journals and practitioners’ magazines are quite different [108, 110]. While papers in scientific journals should provide all the details of the MLR (the planning and search process), papers in practitioner-oriented outlets (such as IEEE Software) should be in general shorter, succinct and “to the point”. We have been aware of this issue and have followed slightly different reporting styles in the set of our recent MLRs/SLRs. For example, we wrote [107, 109] and published them in the IEEE Software magazine targeting practitioners, while we wrote their extended scientific versions afterwards and published in the Information and Software Technology journal [4, 20]. Table 11 shows our publication strategy for three sets of recent MLR/SLR studies, on three testing-related topics: test maturity and test process improvement, testing embedded software, and software test-code engineering. Other readers can review them and adopt similar reporting styles for their MLR/SLR papers.

| MLR/SLR topic                  | Paper title                                                      | Ref. | Journal/magazine                        | Main audience |
|--------------------------------|------------------------------------------------------------------|------|-----------------------------------------|---------------|
| Test maturity and test process  | What we know about software test maturity and test process improvement | [107] | IEEE Software                           | x             |
| process improvement            | Software test maturity assessment and test process improvement: a multivocal literature review | [20] | Information and Software Technology     |               |
| Testing embedded software      | What we know about testing embedded software                      | [8]  | IEEE Software                           | x             |
|                                | Testing embedded software: a systematic literature review         |      | Submitted to a journal                  |               |
Another issue is choosing suitable and attractive titles for review papers, especially those targeting practitioners [111]. In two of our review papers published in the IEEE Software [8, 107], we entitled them starting with “What we know about …”. This title pattern seems to be attractive to practitioners, and has also been used by other authors, e.g., [112-116]. Another IEEE Software paper [117] showed, by textual analysis, that practitioners usually use simpler phrases for titles of their talks in conferences or reports in GL, compared to more complex titles used in the formal literature.

Another useful resource that the authors of some MLR/SLR studies (including the authors of the current paper) usually publish online as the “companion” of the published papers are the online repository of the review studies which many researchers and practitioners find useful, in addition to the MLR/SLR papers themselves. Let us recall Figure 8 from Section 5.4, which shows an example of an online paper repository implemented as a Google Docs spreadsheet, i.e., the list of included sources of MLR-AutoTest. Such repositories provide various benefits, e.g., transparency on the full dataset, replication and repeatability of the review, support when updating the study in a future by the same or a different team of researchers, and easy access to the full “index” of sources.

One of the earliest online repositories, serving as companion to its corresponding survey papers [118, 119] and showing the usefulness of such online repositories, is the one on the subject of Search-based software Engineering (SBSE) [120], which was first published in 2009 and has been actively “maintained” up to this writing.

### 6.2 Ensuring Usefulness for the Targeted Audience

As discussed in Section 4, as early as in the planning phase of an MLR, authors should ensure usefulness for its intended target audience (researchers and practitioners). As important as it is that relevant RQs are raised in the MLRs, the reporting style and the presented materials shall actually benefit the target audience, and a given review paper should not just mention that goal in a “cliché” manner.

We recommend including in review papers a section about implications of the results, as we reported in [17, 20], and if possible, even also a section on benefits of the review. For example, in our SLR on testing embedded software [8], we included a section on “Benefits of this review” in which we reported as follows: “The authors have already started to benefit from the results of this review. In our ongoing collaborations with several industry partners in Turkey and Austria in the area of testing embedded software, our colleagues and we were quite uncertain of whether certain techniques already exist or we shall develop new testing techniques ourselves to solve the existing challenges/gaps. In this context, thanks to our review study, we are currently assessing several existing model-based techniques selected from the literature based on the review at hand for possible adoption/extension in our ongoing industry-industry collaborative projects”.

To further assess the benefits of our review study in [8], we asked several active test engineers in the Turkish embedded software industry to review the review paper and the online spreadsheet of papers, and let us know what they think about the potential benefits of that review paper. Their general opinion was that a review paper like that paper [8] is a valuable resource and can actually serve as an “index” to the body of knowledge in this area. Here is what one of the practitioners explicitly mentioned: “Our company conducts embedded system testing for software-intensive systems in the military domain. In such a context, one of our major problems is to borrow the actual Systems Under Test (SUIT) from our customers because of security concerns. After reviewing this study, I wonder about “why we do not have any model of these SUITs”. If we can create models of these SUITs (e.g., model-in-the-loop, MIL), in the future we would not need to borrow the real systems from our customers and models may be sufficient for our test-case design and other test activities. There are a lot of studies in the pool of this review study, which would benefit us. I think this idea is a major benefit for companies like ours. And I hope we may realize this idea [in near future]. And as you have said in the paper, I believe that many companies are exactly reinventing wheel.”

### 7 Conclusions and Future Works

As existing guidelines for performing systematic literature studies in SE are only partially useful for conducting multivocal literature reviews studies that take GL into account, this article filled this gap by developing and presenting a set of experience-based guidelines for planning, conducting and presenting MLR studies in software engineering. Planning the review comprises establishing a need for an MLR on a given topic, measures to ensure usefulness, as well as defining the MLR’s goal and related research/review questions. Conducting the review comprises defining the search process, selecting the sources, assessing the study quality as well as extracting and synthesizing data.

To develop the MLR guidelines, we benefited from three inputs: (1) existing SLR and SM guidelines in SE, (2), a survey of MLR guidelines and experience papers in other fields, and (3) our own experiences in conducting several MLRs in SE. We
took the popular SLR guidelines of Kitchenham and Charters as the baseline and extended/adopted it to conduct MLR studies. The guidelines were discussed in three context of three examples MLRs as running examples (two from SE and one MLR from the medical sciences). The presented guidelines covered all phases of conducting and reporting MLRs in SE from the planning phase, to conducting the review, and to reporting the review. In particular, we believe that incorporating and adopting a vast set of experience-based recommendations from MLR guidelines and experience papers in other fields enabled us to propose a set of guidelines with solid foundations.

The authors recommend the researchers to apply the guidelines in conducting MLR studies, and then share their lessons learned and experiences with the community. Guidelines like this one have to be assessed and improved in several iterations and we plan to do so.

We suggest future works in the following directions: (1) based on guidelines such as [121] in the educational sciences field, we suggest specific guidelines and considerations for different types of reviews: systematic review, best-evidence synthesis, narrative review and also for different objectives: integrative research review, theoretical review, methodological review, thematic review, state-of-the-art review, historical review, comparison of two perspectives review and review complements; (2) improving the guidelines based on our and other researchers experiences in applying them; (3) refined guidelines for specific types of grey literature sources like blog articles or specific SE areas.

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### Table 12- Pool of the reviewed MLR guidelines and experience papers in other fields, and their classification w.r.t. MLR phases

| Paper/source title                                                                 | Ref. | Year | Field                              | Presented guidelines/heuristics on... |
|-----------------------------------------------------------------------------------|------|------|------------------------------------|---------------------------------------|
|                                                                                   |      |      | Medicining/health                   | Planning                              |
|                                                                                   |      |      | Education                           | Search process                        |
|                                                                                   |      |      | Social sciences                     | Source selection                      |
|                                                                                   |      |      | Other                               | Quality assessment                    |
|                                                                                   |      |      |                                     | Data extraction                       |
|                                                                                   |      |      |                                     | Data synthesis                        |
|                                                                                   |      |      |                                     | Reporting the review                  |
| Number of sources 'checked' under each category→                                   |      |      |                                     | 15                                    |
|                                                                                   |      |      |                                     | 6                                     |
|                                                                                   |      |      |                                     | 3                                     |
|                                                                                   |      |      |                                     | 4                                     |
|                                                                                   |      |      |                                     | 7                                     |
|                                                                                   |      |      |                                     | 14                                    |
|                                                                                   |      |      |                                     | 10                                    |
|                                                                                   |      |      |                                     | 11                                    |
|                                                                                   |      |      |                                     | 5                                     |
|                                                                                   |      |      |                                     | 8                                     |
|                                                                                   |      |      |                                     | 5                                     |
| AACODS checklist [63]                                                             | [63] | 2010 | X                                  | X                                     |
| A response to commentaries on 'towards rigor in reviews of multivocal literatures...?' [64] | [64] | 1991 | X                                  | X                                     |
| Advancing rigorous methodologies-a review of 'towards rigor...' [65]               | [65] | 1991 | X                                  | X                                     |
| Applying systematic review search methods to the grey literature: a case study examining guidelines for school-based breakfast programs in Canada [59] | [59] | 2015 | X                                  | X                                     |
| Between black and white: examining grey literature in meta-analyses of psychological research [66] | [66] | 2014 | Psychology                         | X                                     |
| Blog posts and tweets: the next frontier for grey literature [67]               | [67] | 2009 | X                                  | X                                     |
| Comment on 'towards rigor in reviews of multivocal literatures' [14]              | [14] | 1991 | X                                  | X                                     |
| Does the inclusion of grey literature influence estimates of intervention effectiveness reported in meta-analyses? [30] | [30] | 2000 | X                                  | X                                     |
| Finding the hard to finds: searching for grey (gray) literature [31]              | [31] | 2012 | X                                  | Library & information research         |
| Grey literature and systematic reviews [44]                                       | [44] | 2005 | X                                  | X                                     |
| Grey literature in meta-analyses [32]                                             | [32] | 2003 | X                                  | X                                     |
| Grey literature in the health sciences: evaluating it [33]                        | [33] | 2016 | X                                  | X                                     |
| Grey literature searching for health sciences systematic reviews: a prospective study of time spent and resources utilized [41] | [41] | 2014 | X                                  | X                                     |
| Title                                                                 | Year | Authors | Journal/Book Title                                                                 |
|----------------------------------------------------------------------|------|---------|-----------------------------------------------------------------------------------|
| Including unpublished studies in systematic reviews                  | 2011 |         |                                                                                   |
| On the quality of grey literature and its use in information synthesis during systematic literature reviews | 2012 |         |                                                                                   |
| Review of grey literature on drug prevention among young people       | 2006 |         |                                                                                   |
| Searching and synthesizing ‘grey literature’ and ‘grey information’ in public health critical reflections on three case studies | 2016 |         |                                                                                   |
| Searching for grey literature for systematic reviews: challenges and benefits | 2012 |         |                                                                                   |
| Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies | 2016 |         |                                                                                   |
| State-of-the-evidence reviews-advantages and challenges of including grey literature | 2006 |         |                                                                                   |
| The use of grey literature in health sciences-a preliminary survey   | 1990 |         |                                                                                   |
| Towards rigor in reviews of multivocal literatures- applying the exploratory case study method | 1991 |         |                                                                                   |
| Towards utility in reviews of multivocal literatures                 | 1991 |         |                                                                                   |
| Where is the evidence: realizing the value of grey literature for public policy and practice | 2014 |         |                                                                                   |