Unifying Classification Schemes for Software Engineering Meta-Research

Angelika Kaplan, Thomas Kühn, Ralf Reussner
Karlsruhe Institute of Technology
Karlsruhe, Germany

ABSTRACT

Background: Classifications in meta-research enable researchers to cope with an increasing body of scientific knowledge. They provide a framework for, e.g., distinguishing methods, reports, reproducibility, and evaluation in a knowledge field as well as a common terminology. Both eases sharing, understanding and evolution of knowledge. In software engineering (SE), there are several classifications that describe the nature of SE research (e.g., classifications of research methods, replication types, types of SE contributions). Regarding the consolidation of the large body of classified knowledge in SE research, a generally applicable classification scheme is crucial. Moreover, the commonalities and differences among different classification schemes have rarely been studied. Due to the fact that classifications are documented textual, it is hard to catalog, reuse, and compare them. To the best of our knowledge, there is no research work so far that addresses documentation and systematic investigation of classifications in SE meta-research.

Objective: We aim to construct a unified, generally applicable classification scheme for SE meta-research by collecting and documenting existing classification schemes and unifying their classes and categories. To validate the generality (i.e., whether it is both general and specific enough) and appropriateness (i.e., whether it fully and correctly covers all relevant aspects of collected classifications), we apply existing metrics from literature. Likewise, we evaluate the applicability of our scheme in a user study.

Method: Our execution plan is divided into three phases: construction, validation, and evaluation phase. For the construction phase, we perform a systematic literature review to identify, collect, and analyze a set of established SE research classifications. In the validation phase, we analyze individual categories and classes of included papers. We use quantitative metrics from literature to conduct and assess the unification process to build a generally applicable classification scheme for SE research. Lastly, we investigate the applicability of the unified scheme. Therefore, we perform a workshop session followed by user studies w.r.t. investigations about reliability, correctness, and user satisfaction (i.e., ease of use). The findings form the basis for further empirical studies that address the applicability of the unified scheme to real-world systems.

CCS CONCEPTS

• Software and its engineering: • General and reference → Empirical studies:

1 INTRODUCTION

Research is a key pillar for progress in science. In turn, the study of research is the focus of meta-research. Ioannidis et al. [7] categorize this discipline into five main thematic areas: Methods (performing research), Reporting (communication research), Reproducibility (verifying research), Evaluation (evaluating research), and Incentives (rewarding research). Although, meta-research is conducted in the software engineering (SE) community, the term itself has not yet become firmly established in this research field and there is a lack of corresponding investigation. This paper contributes to meta-research, focusing on classifications in SE meta-research. Classifications can structure a body of knowledge in a field of interest and can, thus, enable researchers to cope with the large body of knowledge. They also provide and define a common terminology, which eases knowledge communication and sharing [14]. Compared to other research fields, SE venues present different types of papers. For example, papers with new solution approaches (i.e., constructive science with a problem and solution domain), reports on empirical primary and secondary study results (cf. evidence-based methodology [9]) by adapting research methods from other domains, or industrial experiences [3]. We can find several classifications in literature (e.g., classifications for research methods and research questions) that describe and classify the nature of SE research (e.g., Shaw [12]). However, there is no consistency either in the coverage of concepts or in the terminology used (cf. [13]) as well as no holistic overview of all these fragments. Thus, a generally applicable classification scheme is crucial to structure this large body of SE research knowledge. Consequently, the objective of this paper is to analyze these classifications, provide a unified, generally applicable classification scheme, and evaluate its applicability.

To the best of our knowledge, there is no existing research work that systematically investigate classifications in SE meta-research.

Research Approach and Contributions. We plan to conduct a systematic literature review (SLR) to identify an existing set of SE research classifications and discuss commonalities and differences among them. Further, we derived a unified classification scheme
and validate it by means of generality (i.e., whether it is general and specific enough) and appropriateness (i.e., whether it fully and correctly covers all aspects of existing schemes). Moreover, we investigate the applicability of the scheme in a user study.

The main contributions (C) can be summarized as:

C1: Provision of a catalog of proposed classifications in SE meta-research in a machine-readable and human understandable format. Our GitHub-Repo\(^1\) comprises, among others, this artifact. We plan to maintain it for the SE community.

C2: Provision of a unified and generally applicable classification scheme to classify existing SE meta-research classifications that is both general (i.e., degree of granularity) and appropriate (i.e., degree of coverage).

C3: Evaluation and assessment of the unified classification scheme by means of existing quantitative and qualitative measures w.r.t. applicability in a user study.

Organization. The remainder is structured as follows:

In the following section, we introduce properties of interest for our unified scheme and corresponding metrics. In Sect. 3, we present our research questions and describe the respective intention and motivation behind. Next, we report our execution plan in more detail that consists of three phases: construction, validation, and evaluation phase. Finally, we conclude the report in Sect. 5.

2 PRELIMINARIES

According to Usman et al. [14], there is an increasing interest in classifications that are, however, rarely evaluated. Thus, it is important to consider adequate evaluation criteria according to the research goals or metrics for data analysis. Following, we describe properties and corresponding metrics and, thus, introduce relevant terms for our research questions and execution plan (cf. Sect. 4).

2.1 Structure of a Classification Scheme

First, the classification’s structure should be validated. As baseline, we check whether our unified classification scheme is suitable to classify objects under study, i.e., we validate its generality and appropriateness regarding SE research knowledge assigned to the five meta-research areas (cf. [7]). To quantify the generality and appropriateness of our unified scheme w.r.t. existing classification schemes, we use the four metrics — laconicity, lucidity, completeness, and soundness — proposed by Ananieva et al. [1] to validate their unified conceptual model. These metrics are based on Guizzardi et al. [6]’s framework for the evaluation and (re)design of modeling languages. We argue that they are also applicable to validate the generality and appropriateness of a unified scheme when compared with existing SE research classifications based on considerations in [8]. Fig. 1 visualizes the concept of the metrics and an illustrative mapping between classes of different classification schemes.

**Generality.** The generality of a classification should be adequate by means of being both general and specific enough. This property is an indicator for a classification’s granularity level and mapping concepts w.r.t. the classified subject matter. It determines whether a classification is too coarse-grained or too fine-grained for the intended purpose. The metrics laconicity and lucidity measure the generality of a classification, i.e., whether it is both general and specific enough. This, thus, assesses the granularity of categories and classes in a classification scheme.

**Definition 1 (Metrics for Generality).** Let \( C \) be a unified classification with classes and categories \( c \in C, T \) a finite set of previous classifications \( T \in T \) with classes and categories \( d \in D, m^C_T \subseteq C \times T \) a relation between classes/categories \( c \in C \) and corresponding class/category \( d \in D \). Then a previous class/category \( d \in D \) is laconic w.r.t. a classification \( C \), if there is at most one \( c \) with \( (c, d) \in m^C_T \), i.e., whether it fully and correctly covers all relevant classifications. The corresponding function \( \text{laconic}(C, T, d) \) yields \( 1 \) if \( d \) is laconic and \( 0 \) otherwise. The lucidity metric is defined as:

\[
\text{lucidity}(C, T) = \frac{\sum_{T \in T} \sum_{d \in D} \text{laconic}(C, T, d)}{|T|} \in [0, 1]
\]

A class/category \( c \in C \) is lucid, if there is at most one \( d \in D \) with \( (c, d) \in m^C_T \). Conversely, the function \( \text{lucid}(C, T, c) \) yields \( 1 \) if \( c \) is lucid and \( 0 \) otherwise. The lucidity metric is defined as:

\[
\text{lucidity}(C, T) = \frac{\sum_{c \in C} (\min_{T \in T} \text{lucid}(C, T, d))}{|C|} \in [0, 1]
\]

Laconicity determines the fraction of laconic classes and categories among all previous classifications, whereas a higher value is better. If there are not laconic classes in previous classifications, the unified classification might be too fine-grained, i.e., there are redundant classes in the unified classification that should be merged. Similarly, lucidity determines the fraction of lucid unified classes and categories, which, in turn, should approach \( 1 \). If a unified classification encompasses not lucid classes, the unified classification might be too coarse-grained, meaning that there are unspecific classes in the unified classification that should be split up.

In conclusion, a unified classification has a suitable granularity, if it yields a sufficiently high laconicity and suitably high lucidity.

**Appropriateness.** The coverage of a classification should be appropriate by means of fully and correctly covering all relevant categories and classes of existing schemes. The metrics completeness and soundness measure and quantitatively assess the classification’s appropriateness, i.e., whether it fully and correctly covers all relevant categories/classes of previous classifications.

**Definition 2 (Metrics for Appropriateness).** Under the preconditions of Def. 1, a previous class/category \( d \in D \) is complete, if there is at least one \( c \in C \) with \( (c, d) \in m^C_T \). The corresponding function \( \text{complete}(C, T, d) \) yields \( 1 \) if \( d \) is complete and \( 0 \) otherwise.

\[
\text{complete}(C, T, d) = \begin{cases} 1 & \text{if } (c, d) \in m^C_T \\ 0 & \text{otherwise} \end{cases}
\]

\[
\text{complete}(C, T) = \frac{\sum_{T \in T} \text{complete}(C, T, d)}{|T|} \in [0, 1]
\]

\[
\text{soundness}(C, T) = \frac{\sum_{c \in C} \text{complete}(C, T, c)}{|C|} \in [0, 1]
\]

\[
\text{completeness}(C, T) = \frac{\sum_{c \in C} | \{ d \in D | (c, d) \in m^C_T \} |}{|D|} \in [0, 1]
\]

A classification is sound, if all classes and categories \( d \in D \) are complete, which means that they are sufficiently covered by some class in \( C \). A classification is complete, if it is both sound and laconic.

![Figure 1: Illustration of generality and appropriateness](image-url)
The completeness metric is defined as:

$$\text{completeness}(C, T) = \frac{\sum_{T \in T} \sum_{d \in \text{complete}(C, T, d)} |T|}{\sum_{T \in T} |T|} \in [0, 1]$$

Likewise, a class/category \( c \in C \) is sound, if there is at least one \( d \in T \) with \((c, D) \in m^C_T \). The function \( \text{sound}(C, T, c) \) yields 1 if \( c \) is sound and otherwise 0. The soundness metric is defined as:

$$\text{soundness}(C, T) = \frac{\max_{T \in T} \text{sound}(C, T, c)}{|C|} \in [0, 1]$$

Completeness denotes the fraction of complete classes and categories over all previous classifications. If there are not complete classes in previous classifications, the unified classification would be missing classes to cover those previous classes.

Soundness represents the fraction of sound classes in the unified classification. If the unified classification contains not sound classes, the classification would include unnecessary classes.

In conclusion, a unified classification is appropriate, if it has both sufficiently high completeness and soundness.

### 2.2 Applicability of a Classification Scheme

Based on insights of a classification’s structure, it is important to evaluate its applicability (i.e., investigate how a classification is applied by users). We consider the evaluating properties [8]:

**Reliability.** To evaluate the reliability, researchers needs to show that different users come to at least very similar results. Thus, a user study needs to be conducted. In this study, users apply the classification in the problem domain. The results can then be compared between users. For this comparison, there are different metrics to show the inter-annotator agreement.

**Correctness.** Although users might produce reliable results, they can still differ from the intended results. This can happen if class definitions are not clear enough and can be misinterpreted. Therefore, comparing classifications from user studies with a gold standard is necessary. Metrics like precision, recall, F_1-score and accuracy can help to show how correct users applied the classification.

**Ease of use.** When performing a user study to assess reliability and correctness, the ease of use can also be evaluated. The main goal is to find out if users are able to understand and apply the classification easily. Researchers can ask users via surveys etc. or observe users during the study for investigation purpose.

### 3 RESEARCH QUESTIONS

Based on our aims and contributions, we derive the following research questions to form the rationale for this research work:

**RQ 1: What kind of classifications in software engineering meta-research exist?**

We subdivide RQ 1 further into:

- RQ 1.1: How can classifications be extracted and documented?
- RQ 1.2: What are commonalities and differences between existing classifications in each meta-research area?

With these research questions, we want to address our documentation process regarding data extraction of included SE meta-research classifications. The choice of a machine-readable and human understandable format and its applicability is discussed and presented by this questions. In addition, we present the review results in terms of identified SE research classifications. We point out commonalities and differences between these existing classifications.

**RQ 2: Which categories and classes belong to a unified classification scheme?**

We subdivide RQ 2 further into:

- RQ 2.1: To what extent is the unified classification scheme of adequate generality?
- RQ 2.2: To what extent is the unified classification scheme of appropriate coverage?

The results from our SLR serve as a reusable data set for constructing unified classification scheme to structure the body of knowledge SE research. We define a methodology comprising a construction method and a validation method by using metrics to assess generality and appropriateness of our unified classification scheme.

**RQ 3: How applicable is the unified classification scheme?**

We subdivide RQ 3 further into:

- RQ 3.1: How reliable and correct is the unified classification scheme when employed by users?
- RQ 3.2: How satisfied are users with the applied unified classification scheme?

With these research questions, we aim to understand the applicability and understandability of our approach as well as our participants’ satisfaction levels with the applied classification task.

### 4 EXECUTION PLAN

The execution plan comprises three phases (i.e., construction, validation, and evaluation phase). In the construction phase, we intend to conduct a systematic literature review to identify, report, and document existing classifications in SE meta-research by addressing RQ 1. The validation phase includes the unification process of existing schemes. Its results comprise a unified classification scheme for SE research and quantitative measures for generality and appropriateness (i.e., answering RQ 2 and its subquestions). This phase is conducted in several iterations to further extend or refine the unified classification scheme. Besides, it is also possible to extend the construction and validation method with additional qualitative and quantitative analysis to gain further results and insights in future work. The evaluation phase addresses investigations of the unified scheme about the applicability in terms of reliability, correctness, and ease of use when applied by users (i.e., answering RQ 3). Fig. 2 visualizes our execution plan including the three phases and corresponding activities. In the following, we describe the phases in more detail.

#### 4.1 Construction Phase

To answer RQ 1 and its sub-questions, we plan to conduct a systematic literature review (SLR) based on the guidelines of Kitchenham and Charters [9] comprising planning by performing a pilot study, conducting, and reporting the review. After determining the need of the review (i.e., identifying existing classifications in SE research), we conducted a pilot study to define the final review protocol.

**4.1.1 Pilot Study.** A pilot study, an iterative approach was used to identify a suitable search strategy, to refine inclusion and exclusion criteria for the study selection process, and to formulate the data extraction form for the final review protocol. For generating a search strategy, we investigated the database search strategy first
as recommended in [9]. For this, we used Google Scholar (GS) that supports full-text searches and a list of result hits up to 1000 papers per search query for inspection. Derived from RQ 1 (i.e., core elements from this question), the following search string with three search terms (concatenated with AND operator) were defined: (i) synonyms for classifications, (ii) research domain (i.e., software engineering), and (iii) research topic (i.e., meta-research). Since meta-research is not yet an established term in SE, the database search leads to low precision/recall in terms of relevant hits and to an unmanageable number of publications for further investigation. However, we observed that several SE research classification were proposed, applied or extended (updated) in secondary studies (i.e., research approach to conduct research on research). Consequently, we inspect secondary studies (i.e., following the evidence-based methodology) in SE per year including referenced classifications in these studies by backward reference search. Furthermore, we select a random set of papers to finalize selection criteria and data extraction form.

4.1.2 Final Review Protocol. Based on the definition of the need of the SLR (formulated as RQ 1) and the findings of the pilot study, we determine the final review protocol.

**Literature Search Process.** Based on insights from the pilot study, we observed that several SE research classifications were proposed, applied, or extended (updated) in secondary studies. Thus, we formulate the following search strings per year starting with 2004 (introduction of the evidence-based research methodology in SE by [9]) to keep the number of resulting hits under 1000 for further inspection:

GS search string 1: "systematic literature review" AND "software engineering" AND "meta analysis"
GS search string 2: "mapping study" AND "software engineering" AND "meta analysis"

In the first iteration, we initially filtered the results. In the second iteration, we merged each query of each year and removed duplicates. Finally, we obtain 1255 publications in total for further data selection by inspecting the full-text and by applying our selection criteria (cf. Study Selection Process). We will consider further databases if needed. The selection of publications gives us a set of proposed classifications, extended classifications of prior work, or used and applied classifications in secondary studies to literature data. Used classifications are included by backward reference technique. Table 1 summarizes our data collection process for the final database strategy. This SLR procedure is documented in our open-access repository comprising our artifacts for reproducibility, further reuse, and maintenance.

**Study Selection Process.** In the following, the inclusion and exclusion criteria for further data selection are defined.

**Inclusion Criteria (IC):**
IC1: Publication that proposes new SE research classification approach, extends or uses a referenced classification (in a secondary study) w.r.t. the five main meta-research areas according to Ioannidis et al. [7] (i.e., Methods, Reporting, Reproducibility, Evaluation, and Incentives), whose structure is explicitly denoted as classification, taxonomy, (classification scheme, classes, types, or listing).

IC2: The SE research classification is defined for general SE use and is not dedicated to a specific sub-domain of SE.

**Exclusion Criteria (EC):**
EC1: Classification standards like the Software Engineering Body of Knowledge (SWEBOK)² or ACM Computing Classification System (ACM CCS)³ are excluded.
EC2: Publication where the full-text is not freely accessible and available online as open manuscript at one of the four publisher IEEE, ACM, Springer, and Elsevier.
EC3: Publication that is not written in English.
EC4: Publication that is not reported in a peer-reviewed workshop, conference, or journal (i.e., not published by IEEE, ACM, Springer, and Elsevier). Books, keynotes, posters, PhD theses, and other gray literature are excluded.
EC5: Duplicates are eliminated. If the same publication content is published in several venues, we consider the most recent and more complete version.

**Data Extraction Form.** A data extraction form is designed to collect all relevant information needed to address our research aim (i.e., the objective of this fragment is to design data extraction form to accurately record the information we obtain from the included studies) and to mitigate bias in our review process. Therefore, we define data items to extract of the included publications and the corresponding descriptions. To address our research objective, we regard (i) meta-data, (ii) type of collection via database search, and (iii) content data of each included publication. Data extraction is conducted via tool-support for documentation purpose. The derived data set is machine readable and human understandable. It can

---

²https://www.computer.org/education/bodies-of-knowledge/software-engineering
³https://dl.acm.org/ccs
In this section, we explain the refinement and validation of our unified classification (cf. Validation Phase in Fig. 2). The validation comprises a quantitative analysis using well-defined metrics [1, 8] introduced in Sect. 2. We use the Goal-Question-Metric (GQM) approach [2, 4] to structure the validation and to answer RQ 2 and its sub-questions that we derive from the following research goal.

4.2.1 Research Goal. The goal of the classification scheme is to cover and unify aspects of existing classifications included in our SLR. This allows us to holistically structure an increasing body of SE research knowledge and provide a common terminology to ease knowledge sharing and comparison. Therefore, we consider the following two validation properties: generality and appropriateness (cf. Sect. 2).

4.2.2 Unification Process and Validation Metrics. Based on the results from our SLR (cf. Sect. 4.1), we obtain classifications to categorize software engineering research that are assigned to the five main meta-research areas according Ioannidis et al. [7] (i.e., Methods, Reporting, Reproducibility, Evaluation, and Incentives). First, we initially analyze the most applied classifications identified in our SLR in each of the five areas and construct our initial unified scheme based on the identified classes. Next, we successively start the refinement of our scheme by unifying concepts and analyzing further included classifications of the five meta-research areas and inspecting concepts of corresponding classes and categories. Thus, we then conduct a mapping between classes and categories between the unified scheme and the included classifications from the SLR (cf. Validation Phase in Fig. 2). We investigate the generality (i.e., degree of granularity) and appropriateness (i.e., degree of concept coverage) of our unified classification scheme w.r.t. existing classification schemes in a quantitative analysis.

4.2.3 Quantitative Analysis. We intend to perform a quantitative analysis based on the aforementioned metrics — laconicity, lucidity, completeness, and soundness — introduced in Sect. 2 to assess the generality and appropriateness of the unified classification scheme w.r.t. the included SE research classifications from the SLR. This analysis method allows us to answer research questions RQ 2.1 and RQ 2.2 that we derive from our research goal and corresponding validation properties (cf. Sect. 2). Ultimately, we aim to achieve metric results for laconicity, lucidity, soundness, and completeness that are close to 100 %. Here, we prefer completeness to be at least 95% to cover the most important aspects in our unified scheme w.r.t. existing classifications. We tolerate soundness to be lower, if we introduce or propose new classes as research outcome in the five main meta-research areas according to Ioannidis et al. [7] that are not covered by existing classifications. Of course, these new concepts have to be evaluated in user studies to investigate the applicability (cf. Sect. 4.3). The metrics laconicity and lucidity...
balance each other as they indicate to obtain a unified scheme that is either too fine-grained or (i.e., redundant classes in our unified scheme) or too coarse-grained (i.e., too general).

4.3 Evaluation Phase

In this section, we explain the evaluation of our unified classification (cf. Evaluation Phase in Fig. 2) to address RQ 3. In this phase, we evaluate the applicability of the unified scheme in a user study.

4.3.1 Selection of Participants. We plan to select several researchers as participants with different SE backgrounds and experiences (i.e., early stage researcher to senior researchers) to groups. Before the study starts, they have to complete a self-assessment.

4.3.2 Study Design. In a workshop session, the facilitating researcher starts with an introduction to the problem domain and explain the unified classification scheme in more detail providing an illustrative example for the participants. The goal is to ensure that the participants are aware of how to apply the unified classification scheme and the objectives of the study. The introduction is followed by a learning phase where participants could apply the scheme to their own research (papers) and ask questions for clarification. Each participant perform the results of the classification task to the audience at the end of the session. In addition, we plan to provide a one-page summary of our unified classification scheme and the illustrative example to the participants. Finally, the participants receive a set of papers, which they should classify according to the unified scheme and comment on in a given time period. Each paper is assigned to at least two researchers. We will ensure that participants perform the classification task independently of each other. In the post-task surveys, we aim to ask a list of Likert-scale questions to the users and asked them to answer on a scale from "strongly disagree" to "strongly agree" based on the System Usability Scale (SUS) [11]. Additionally, we plan to ask about the experience when using the scheme.

4.3.3 Data Collection and Evaluation Metrics. We aim to collect the classification results of each participant. Then, we intend to calculate reliability (i.e., investigating whether participants have consistent results) and correctness (i.e., comparing the classification results to a predefined gold standard). After gathering all results, we calculate Krippendorff’s α [10] to measure the inter-annotator agreement (IAA). We aim to select this metric as it is very flexible and can deal with different issues such as incomplete data, varying sample sizes, and various categories. Then, we calculate precision (i.e., positive predictive value (PPV)), recall (i.e., sensitivity and true positive rate (TPR)), and F-measure (combines precision and recall) to determine the evaluation property correctness. In a post-task survey (cf. subsection 4.3.2), we plan to quantitatively and qualitatively evaluate the ease of use of our unified scheme.

4.3.4 Threats to Validity. According to Feldt and Magazinius [5], we regard and will discuss several threats to internal, external (i.e., generalizability), construct, and conclusion validity for the user study in the evaluation phase.

5 CONCLUSION

In this research work, we aim to provide and evaluate a generally applicable classification scheme to characterize the nature of software engineering (SE) research. Our execution plan encompasses three phases. In the first phase (i.e., construction phase), we systematically collect existing classifications in SE meta-research. They build a basis for the validation w.r.t. our developed unified classification scheme. We use quantitative metrics from literature to perform the unification process and the refinement of the classification scheme in the second phase (i.e., validation phase). In the last phase (i.e., evaluation phase), we investigate the applicability of the unified scheme in a user study and assess the approach’s ease of use. These results form the basis for further empirical studies that address the applicability of the unified scheme to real-world systems, e.g., a knowledge management system for SE papers.

REFERENCES

[1] Sofia Ananieva, Sandra Greiner, Thomas Kühn, Jacob Krüger, Lukas Linsbauer, Sten Grüner, Timo Kohler, Heiko Klute, Anne Kozailek, Henrik Linn, Sebastian Krieter, Christoph Seidl, S. Ramesh, Ralf Reussner, and Bernhard Westfechtel. 2020. A Conceptual Model for Unifying Variability in Space and Time. In 24th ACM Conference on Systems and Software Product Line: Volume A (Montreal, Quebec, Canada) (SP'20). Association for Computing Machinery, New York, NY, USA, Article 15, 12 pages. https://doi.org/10.1145/3382025.3414955

[2] Victor R. Basili and David M. Weiss. 1984. A Methodology for Collecting Valid Software Engineering Data. IEEE Transactions on Software Engineering 10, 6 (1984), 728–738. https://doi.org/10.1109/TSE.1984.5010361

[3] Antonia Bertolino, Antonello Calabrò, Francesca Lonetti, Eda Marchetti, and Breno Miranda. 2018. A categorization scheme for software engineering conference papers and its application. Journal of Systems and Software 137 (2018), 114–129. https://doi.org/10.1016/j.jss.2017.11.048

[4] Victor R. Basili Gianluigi Caldiera and H. Dieter Rombach. 1994. The goal question metric approach. Encyclopedia of Software Engineering (1994), 528–552.

[5] Robert Feldt and Ana Magazinius. 2010. Validity Threats in Empirical Software Engineering Research - An Initial Survey. In Proceedings of the 22nd International Conference on Software Engineering & Knowledge Engineering (SEKE’2010). Redwood City, San Francisco Bay, CA, USA, July 1 - July 3, 2010. Knowledge Systems Institute Graduate School, 374–379.

[6] Giancarlo Guizzardi, Luis Ferreira Fires, and Marten van Sinderen. 2005. An Ontology-Based Approach for Evaluating the Domain Appropriateness and Comprehensibility Appropriateness of Modeling Languages. In International Conference on Model Driven Engineering Languages and Systems (MODELS). Springer. https://doi.org/10.1007/11557432_51

[7] John PA Ioannidis, Daniele Fanelli, Debbie Drake Dunne, and Steven N Goodman. 2015. Meta-research: evaluation and improvement of research methods and practices. PLoS Biol 13, 10 (2015), e1002264. https://doi.org/10.1371/journal.pbio.1002264

[8] Angelika Kaplan, Thomas Kühn, Sebastian Hahner, Niko Benkler, Jan Keim, Dominik Fuchs, Sophia Corallo, and Robert Hennrich. 2022. Introducing an Evaluation Method for Taxonomies. In The International Conference on Evaluation and Assessment in Software Engineering 2022 (Gothenburg, Sweden) (EASE 2022). Association for Computing Machinery, New York, NY, USA, 311–316. https://doi.org/10.1145/3536019.3535805

[9] Barbara Kitchenham and Stuart Charters. 2007. Guidelines for performing Systematic Literature Reviews in Software Engineering. Technical Report EBSE 2007-001. Keele University and Durham University Joint Report.

[10] Klaus Krippendorff. 2018. Content Analysis: An Introduction to its Methodological Traditions and Recent Developments. Sage Publishing.

[11] James R. Lewis. 2018. The System Usability Scale: Past, Present, and Future. International Journal of Human–Computer Interaction 34, 7 (2018), 577–590. https://doi.org/10.1080/10447318.2014.1553307

[12] Mary Shaw. 2003. Writing Good Software Engineering Research Papers. In Proceedings of the 25th International Conference on Software Engineering, May 3–10, 2003, Portland, Oregon, USA, Lori A. Clarke, Laurie Dillon, and Walter F. Tichy (Eds.). IEEE Computer Society, 726–737. https://doi.org/10.1109/ICSE.2003.1201262

[13] Klaus-Jan Stol and Brian Fitzgerald. 2018. The ABC of Software Engineering Research. ACM Transactions on Software Engineering and Methodology 27, 3 (2018), 11:1–11:51. https://doi.org/10.1145/3241743

[14] Muhammad Usman, Ricardo Britto, Jurgen Börsler, and Emilia Mendes. 2017. Taxonomies in software engineering: A systematic mapping study and a revised taxonomy development method. Inf. Softw. Technol. 85 (2017), 43–59.