A Systematic Literature Review on Misconceptions in Software Engineering

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***Abstract*—From a constructivist perspective, learning is an active, cognitive process in which individuals construct their own knowledge by connecting new concepts with previous knowledge, skills, and experience that serve as points of departure. The purpose of this study is to identify and analyse known evidence-based misconceptions in Software Engineering to use these insights for higher education. We used a systematic literature review as a secondary data accumulation, searching 10 databases automatically using predefined search queries and selection criteria. Out of 2,158 publications found, 18 could be identified as appropriate for the selection criteria. These contain over 100 statements which the authors of these publications refer to as misconceptions/beliefs/myths. Yet, only a fraction of these are based on evidence; namely 20 items from 3 papers. Currently, evidence-based research on misconceptions in Software Engineering is limited. We, therefore, deduce that evidence-based primary data acquisition and analysis should be the research desideratum.**

Keywords–Software Engineering, Higher Education, Misconceptions, Systematic Literature Review.

I. INTRODUCTION

From a constructivist point of view, learning is to be understood as an active, individual, situated, social, and cognitive psychological process. Each individual has to build up their own knowledge by combining new concepts based on previous knowledge, existing competencies, previous experience, as well as conceptions and putting it into a network-like relationship. This means, learners form conceptions and models to explain phenomena, processes, and artifacts before they are confronted with them in institutional learning. These possibly alternative – from scientific or expert perspective – conceptions have a twofold significant impact on the learning process. On one hand, they can serve as the basis for learning, on the other, they can also contradict the educational content and thus hinder the learning process.

In order to be able to achieve sustainable learning (in higher education), a purely technical structuring of the learning content is therefore insufficient. Furthermore, didactics should do justice to the learners' "points of departure" [1, p. 6]. The Model of Educational Reconstruction, which is epistemologically based on the constructivist position, calls for precisely this consideration [1][2]. The model comprises the triad of *content clarification*, *learners' conceptions*, and *didactic design*; it considers the scientific concepts and the student conceptions as equivalents.

To be able to use this model in Software Engineering (SE) education, we have to take a step back and clarify which misconceptions undergraduates bring to university. Thus, a Systematic Literature Review (SLR) as a secondary data analysis provides information about known SE misconceptions.

Therefore, the paper is structured as follows: It starts with terminological aspects, as a plurality of terms evolved, and related work in other disciplines. The SLR process is explained in Section II, complemented by the results (Section III). Before the paper closes, a short discussion is given (Section IV).

A. Terminological Aspects

Due to many different ways of looking at the research object '*(mis-)conceptions*' as well as the critical examination of the terminology, an abundance of terms has developed. The different understandings have led to a plurality of terms with multiple connotations. The abundance of technical terms has risen so much in the course of research (especially in natural sciences didactics) that it is now almost impossible to survey. The fact that the terms cannot be clearly distinguished from each other often leads to a more or less synonymous use and thus to an undifferentiated mix. As a result of the dissatisfaction with this situation, researchers have again constructed and defined additional terms, which expands the existing term dilemma.

In addition to [3] [4], also others include entire collections of terms. This list (merely referenced by single publications due to restricted page space) gives an impression of the broad spectrum:

- *Preconceptions* [3]–[6]
- *(Students') conceptions* [3][4]
- *Alternative conceptions* [3]
- *Naïve conceptions* [4]
- *Naïve theories* [3][4]
- *Naïve beliefs* [3]
- *Beliefs* [7]
- *Alternative beliefs* [3]
- *Alternative frameworks* [3][4][6]
- *Intuitive theories/science* [6]
- *Prior knowledge* [6]
- *Misconceptions*, the "standard term" as [3, p. 119] state – despite the negative connotation [4] [6].

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In spite of the heterogeneity of terms, opposed opinions and discussions on the different types of expression, it can be stated consensually that individuals each develop different conceptions of certain concepts, which should and must be used as a starting point in teaching. These conceptions can, but do not have to be in line with modern scientific theories [4] and therefore may act as learning obstacles [8], often referred to as *misconceptions*.

B. Related Work on Misconceptions in Didactics

The research and publications about misconceptions in natural sciences in the context of school are immense, as a bibliography by Duit [9] proves. When looking at the catalogue, encompassing over 8,300 publications and summarizing them per decade (Figure 1), it is obvious that since the mid-1970s international researchers have been investigating the field.

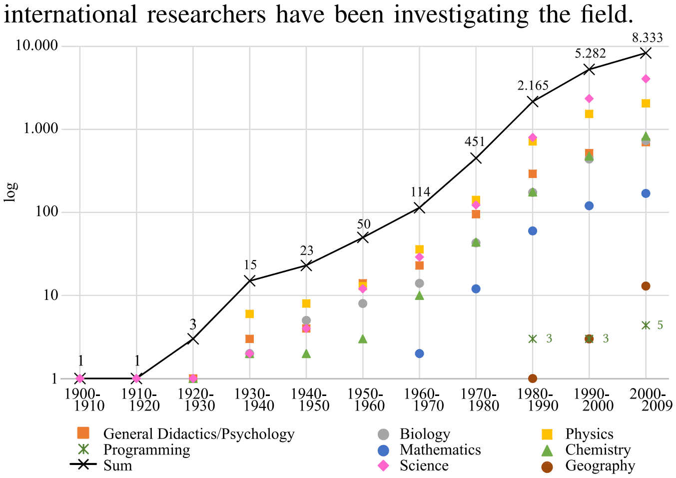

Fig. 1. Diagram of Accumulated Number of Publications per Decade, Sorted by Discipline Listed in [9]; esp. Focused on 'Programming'

Out of these, merely five publications [10]–[14] can be assigned to 'programming' as nearest to SE, but also to science and/or maths; i.e. they are equivocal.

Moreover, in the last few years, several papers on misconception research in computer sciences appeared concerning:

- ... programming [15]–[18] and object-oriented programming in particular [19][20].
- ... artifacts, e.g., computers, smartphones, and so on [21, and others].
- ... the Internet [22].

All publications listed have in common that they do not particularly deal with SE and are contextualised within school education. This results in research needs for SE in university.

II. Method: SLR on Misconceptions in SE

In order to be able to present the state of research on (undergraduate) conceptions in SE, there is a need for a SLR, which summarizes all available information about this phenomenon thoroughly and impartially [23, p. 7]. Conducting a SLR is a quantitative methodology of secondary data collection for the synthesis of research results from primary studies. The guidelines – used here – that Kitchenham and Charters have drawn up for SE are derived from several approaches in medicine and the social sciences [23, p. vi].

The following explanations, which describe the three-phase process of the SLR – carried out as a computer-based, automated search – are divided into the initial planning in Section II-A, the actual practical implementation (Section II-B) and the subsequent presentation and use of the results (Section III), see also [23][24].

A. Phase 1: Initial Planning

The planning of the SLR contains some parameters that require previous definition in order to minimize bias. The SLR is determined as follows:

1) Research Question(s): To what extent does research on misconceptions in SE already exist? Which misconceptions in SE are known/documented?

2) Search Strategy:

a) Language Selection: At this point, the language radius, which is one of the inclusion criteria, should be anticipated. The reason for this is the following definition o f the Search Query (SQ). Since research on conceptions is international, publications in German and English are considered.

b) Queries and Synonyms: Regardless of the various connotations (Section I-A), the search should encompass the previous research on misconceptions in SE as broadly as possible. Therefore, the search query is based on the numerous synonymously used English terms shown in Table I. (Indicating wildcards, i.e. placeholders, by an asterisk (*).)

TABLE I. Development of the English Search Query Using Synonyms

Synonyms	Substrings	
	Noun	**Adjective**
preconceptions	preconception*	–
students' conceptions	conception*	–
alternative conceptions	conception*	alternative
naïve conceptions	conception*	naïve
naïve theories	–	naïve
naïve beliefs	belief*	naïve
beliefs	belief*	–
alternative beliefs	belief*	alternative
alternative frameworks	–	alternative
intuitive theories	–	intuitive
intuitive science	–	intuitive
prior knowledge	–	prior
misconceptions	misconception*	–

In contrast to *preconception*, *conception*, *belief* and *misconception*, the terms *theory*, *framework* and *science* (plus plurals) are only included in combination with the respective adjectives (Table I), since they are often used as technical terms in SE and unspecific for answering the research question. Same applies to the terms *student*, *knowledge* and *science*, because of the usage of pedagogical databases. These are combined with the disciplinary focus on SE, resulting in Search Query 1; including wildcards (*) and search for exact phrases (quotation marks). (The equivalent German SQ is not attached here.)

c) Database: Electronic literature databases are selected based on Kitchenham et al. [25] in combination with [26]. Kitchenham et al. have already dealt intensively with SLRs in the area of SE and set up a list of important English-language journals and conferences, which they themselves use for their literature research (see Table II).

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(“software engineer*” OR “software development*” OR “software process*”)
AND
(“preconception*” OR “conception*” OR “belief*” OR “misconception*”
OR
“naïve theor*” OR “alternative framework*” OR
“intuitive theor*” OR “intuitive science” OR “prior knowledge”)

Query 1. English Search Query

TABLE II. SELECTION OF ELECTRONIC DATABASES FOR SLR BASED ON [25] [26]

Source	IEEE	ACM	SD	SC	SL	ERIC	WoS	GS	arXiv	dblp
Information and Software Technology			X	X				X		
Journal of Systems and Software			X	X				X		
IEEE Transactions on SE	X							X		
IEEE Software	X							X		
Communications of the ACM		X								
ACM Computer Surveys		X								
ACM Transactions on SE Methodologies		X								
Software Practice and Experience								X		
Empirical SE Journal					X					
IEEE Proc. Software (now: IET Software)	X							X		
Proc. Int. Conference on SE	X	X						X		
Proc. Int. Symp. of Software Metrics	X	X						X		
Proc. Int. Symp. on Empirical SE	X	X						X		

These are used as a basis to identify databases that include these compilations, namely: IEEE-Xplore [28], ACM-Digital Library [29], SpringerLink (SL) [30], Scopus (SC) [31], and Science Direct (SD) [32]. This selection is supplemented by further search engines from the educational context (ERIC [33], Web of Science (WoS) [34]) and the metadata database GoogleScholar (GS) [35]. In addition to the proposed ones, arXiv [36], an open access repository for electronic preprints from numerous areas – including computer science –, and the dblp [37], which is co-founded by the German federal government, are used.

3) Selection Strategy: The selection is controlled on the basis of the following predefined Inclusion (IC) and Exclusion Criteria (EC).

- IC.1 The publication is written in English or German language.
- IC.2 It is explicitly about the discipline SE.
- IC.3 Misconceptions in SE are explicitly mentioned.

- EC.1 The contribution is an abstract, workshop, poster, or similar, as these do not provide in-depth information.

4) Quality Assessment: The gathered publications have to be qualified against predefined Quality Criteria (QC):

- QC.1 *Traceability*: How do the authors know this misconception? It is scientifically important to be able to track where the information comes from.
- QC.2 *Validation*: Has it been confirmed that it is a misconception? How did the authors validate the conception to be “at odds with modern scientific theories” [4, p. 2]? If not done, there is no indication that it is really a *mis*conception.
- QC.3 *Occurence in the population*: Does this misconception exist in the population? Did the authors test the misconception in a specific target group? Otherwise, the existence of the misconception is not empirically proven at all or limited to individual subjects (e.g. through interviews).

B. Phase 2: Conducting the SLR

The process of conducting the SLR is shown in Figure 2 as *Phase 2* of the overall process.

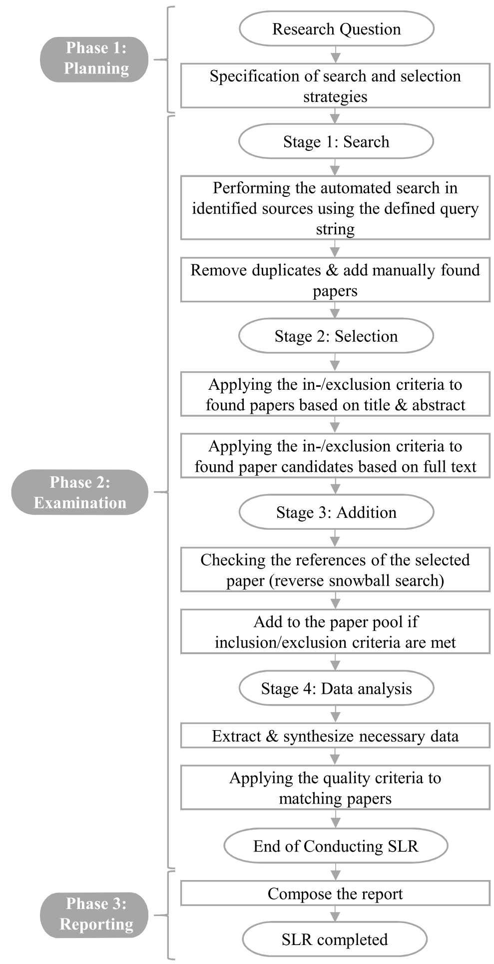

Fig. 2. Flowchart of the SLR process (based on [23][24][27])

1) Stage 1: Conducting the Automated Search: For the search – if possible – use of extended/advanced search functions, wildcards (e.g., “misconception*”), and Boolean operators is made in order to be able to exploit the predefined syntax of the query (see String 1). Nevertheless, the string must be adapted to the options of the search engine. Care is taken to ensure no semantic changes take place.

The SQ is limited to document title and abstract, as recommended by [27, p. 2050] as well as others. (Deviations from this definition, due to the search options of the individual databases, are documented accordingly in the evaluation in Section III). The reason for this is that both metadata are already indicators of the relevance of a publication.

TABLE III. SUMMARY OF SLR RESULTS AFTER APPLYING IN-/EXCLUSION CRITERIA ON TITLE & ABSTRACT

		Search Engines										Sum
		IEEE	ACM	SD	SC	SL	ERIC	WoS	GS	arXiv	dblp	
Results of English SQ		250	410	93	847	0	29	4	87	257	41	2,018
Results of German SQ		16	54	7	46	0	3	0	7	2	5	140
Sum of Search Results		266	464	100	893	0	32	4	94	259	46	**2,158**
No Papers (e.g. Proc.)		2	2	0	53	0	2	0	34	6	0	99
Duplicates		15	85	18	383	0	10	4	16	18	29	578
Balance without Duplicates		249	377	82	457	0	20	0	44	235	17	1,481
IC.1a:	English	249	352	81	442	0	20	0	40	231	10	1,425
IC.1b:	German	0	0	0	5	0	0	0	1	0	0	6
IC.2:	SE Discipline-Specific	223	253	65	381	0	18	0	34	162	7	1,143
IC.3:	Misconceptions	30	60	4	43	0	8	0	6	5	2	158
EC.1:	Contribution Type	0	1	0	0	0	1	0	0	0	0	2
EC:	No Information	0	0	0	1	0	0	0	2	0	0	3
Paper Candidates		**29**	**40**	**4**	**37**	**0**	**6**	**0**	**5**	**5**	**2**	**128**

Note: At this point, IC.3 is not completely applicable, since misconceptions are not specifically mentioned in title & abstract, but it is checked, whether the contribution is explicitly about misconceptions.

2) Stage 2: Applying the In-/Exclusion Criteria: The relevance of a publication is determined in a two-stage process (see Figure 2, *Stage 2*). First of all, the title and abstract are examined and evaluated on the basis of the predefined criteria. These provide enough information to decide whether a publication encompasses insights of interest; in doubt they were included. The papers included are then rechecked regarding the in-/exclusion criteria; this time considering the full text.

3) Stage 3: Backward Snowballing: Once *Stage 2* is completed, "the references of the selected papers [are] reviewed and any missing candidate papers [are] assessed against the inclusion/exclusion criteria" [27, p. 2052] as well; this is referred to as 'backward snowballing'.

4) Stage 4: Data Analysis: To assess the quality of the methods and results in the gathered publications, quality criteria have to be predefined against which to assess the data extracted and synthesized.

III. PHASE 3: RESULTS

The results of the coarse search based on the selection criteria (Section II-A3) applied to titles and abstracts (Section III-A) and the detailed search using full texts (Section III-B) are presented. Additionally, the results of the analysis of the misconceptions found in the selected publications is shown in Section III-C, which is based on the QCs (Section II-A4).

A. Results: Coarse Search

The automated search has been completed between April, 30^{th} and May, 1^{st} 2020. Since the search was not limited to a date range, the review process timewise included every research found, covering papers as of 1970. Table III illustrates the number of matches ($n = 2,158$) initially received through the SQs. Excluding data sets that contained entire proceedings/compilations instead of contributions as well as duplicates, results in $n = 1,481$. Finally, after applying the inclusion and exclusion criteria to title and abstract, $n = 128$ papers/articles can be identified as potentially relevant to our interest. Therefore, only these are considered in the next step, in which the full text of these publications is considered.

Duplicates could be localized both internally – within the results of the same SQ, within the same database, or overlaps between English and German SQs – and externally – between the results of different search engines. The number of duplicates can be seen in Table IV including multiple mentioning, as papers might be found in multiple databases. (Therefore, the sums are not equivalent with the numbers of duplicates in Table III.)

TABLE IV. NUMBER OF DUPLICATES

	IEEE	ACM	SD	SC	SL	ERIC	WoS	GS	arXiv	dblp
IEEE	15	32		222		1	2	15	5	12
ACM		54		111				9	4	7
SD			18	60				4		2
SC				53		7	4	31	10	21
SL					0					
ERIC						3		3		
WoS							0	3		4
GS								17		19
arXiv									8	2
dblp										4

B. Results: Full Text Search

Proceeding further, the predefined inclusion and exclusion criteria are then applied to the paper candidates based on the full text of the contributions. This results in $n = 15$ papers that match the criteria (see Table V, on the next page). Papers are excluded that cover the topic 'misconception', but did not explicitly mention at least one statement the respective authors refer to as misconception concerning the topic SE (cf. IC.3). The subsequent backward snowball search – based on the adequate papers found – reveals some additional publications that have been checked against the inclusion/exclusion criteria listed as well. Summing up, a total of $n = 18$ papers are found (see Table V) that are of interest to the research question of this SLR.

Through the selection process in *Stage 2* and Backward Snowballing in *Stage 3* as a whole, we double-checked the contributions by assessing each paper. As Kitchenham et al. suggest, publications are included if we cannot make a consensual decision [27, p. 2052].

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TABLE V. SUMMARY OF SLR RESULTS AFTER APPLYING IN-/EXCLUSION CRITERIA ON FULL TEXTS

	Search Engines										Sum
	IEEE	ACM	SD	SC	SL	ERIC	WoS	GS	arXiv	dblp	
Paper Candidates (see Table III)	29	40	4	37	0	6	0	5	5	2	128
IC.1a: English	29	40	4	37	0	6	0	5	5	2	128
IC.1b: German	0	0	0	0	0	0	0	0	0	0	0
IC.2: SE Discipline	29	40	4	37	0	6	0	4	5	2	127
IC.3: Mention Misconceptions	5	3	1	2	0	0	0	1	3	0	15
Papers Found	**5**	**3**	**1**	**2**	**0**	**0**	**0**	**1**	**3**	**0**	**15**
Backward Snowballing	27	5	0	2	0	0	0	1	4	0	39
Already Included in SLR	2	1	0	1	0	0	0	0	2	0	6
After Applying Selection Criteria	0	0	0	1	0	0	0	0	2	0	3
Result	**5**	**3**	**1**	**3**	**0**	**0**	**0**	**1**	**5**	**0**	**18**

The matching papers found ($n = 18$, shown as the result in Table V) are listed below:

- IEEE: [38]–[42]
- ACM: [43]–[45]
- Science Direct: [46]
- SCOPUS: [47] (cites and covers the myths of the primary source [48] and 7 new statements) [48][49]
- Google Scholar: [50]
- arXiv: [51][52] (is included in [53] and thus not considered further) [53][54] (is the basis for [53]); and thus considered together, covering 21 misconceptions in total) [55]

C. Results: Misconceptions Found

Within the publications named, a total of 167 individual statements (see Table VI; without cross-references) are declared as misconceptions by the respective authors. The misconceptions gathered should be evaluated by assessing the quality of the publications in order to determine the capacity of the findings, using the quality criteria from Section II-A4.

The coding of the subcategories of the quality criteria was not determined in advance, but developed during the analysis based on and close to the available data; i.e. the publications themselves. The following subcategories are considered as high-quality (see grey marking in Table VI):

QC.1 *Traceability*: A primary *study* as well as the *reference* to quotable publication(s), in which the misconception(s) were found is defined as satisfying scientific claims. In contrast, no indication is insufficient.

QC.2 *Validation*: The conception has to be *empirically confirmed* as “at odds with modern scientific theories” [4, p. 2] to be a *mis*conception. Whereas, a rejection, an explanation by the author(s) or reference(s) that the statement given is supposed to be a misconception is no sufficient evidence for validation. This is also due to the fact that misconceptions exist in all ages, from primary level to university and even experts and professors can hold them themselves [56, p. 9, 11].

QC.3 *Occurrence in the population*: Practitioners misconceptions are included, as it is very likely that students have them as well, if they can be encountered in professionally experienced. However, no indication of occurrence in the population can initially only be interpreted as a presumption.

The intersection of the QCs results in $n = 20$ misconceptions (Table VI). Yet, the papers [53] and [54] only deal with the topic ’defect prediction’, the authors of [45] look at SE covering the software life cycle more holistically; see thematic structuring in Table VII (on the next page).

Note: [45] would actually not be included in the intersection, as it is not explained where the misconceptions come from (QC.1). But the authors validated them (QC.2) and tested their occurrence concerning students (QC.3). Thus, the misconceptions listed are hypotheses, that have been empirically confirmed; thus, nevertheless, they are included in the intersection.

TABLE VI. SUMMARY OF MISCONCEPTIONS FOUND IN THE FULL TEXTS USING THE QUALITY CRITERIA

		Papers Found																	Sum
		[38]	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[47]	[48]	[49]	[50]	[51]	[53]	[54]	[55]	17
Misconceptions explicitly named		16	12	12	7	6	4	5	12	4	7	7	10	36	4	10	21	4	167
QC.1:	- Study						4							36		21 (in [54])			51
Traceability	- Reference(s)	15	6			6													37
	- No Indication	1	6	12	7			5	12	4	7	7	10		4			4	79
QC.2:	- Empirically Confirmed								12							8 (in [53])			20
Validation	- Empirically Rejected															2 (in [53])			2
	- Reference(s)	6	6		5														17
	- Only based on Explanation						4			4	7	7	10		4				36
	- No Indication	10	6	12	2	6		5						36		11		4	92
QC.3:	- Practitioners	16				6	4									21 (in [54])			37
Occurrence	- Undergraduates		12	12					12										36
	- No Indication				7			5		4	7	7	10	36	4	10/21 (in [53])		4	94
Intersection (of rows marked)									12							8			20

TABLE VII. LIST OF MISCONCEPTIONS MATCHING THE QUALITY CRITERIA

Topic(s): Project	Process Models	Team Skills	Reuqirements	Implementation	Defects	Documentation	Misconception	Reference(s)
	X						A defined software process is only important when you are working with people who are less skilled.	[45, (1)]
		X					A good software developer will often choose to work alone on a project in order to get it done faster.	[45, (2)]
	X	X					When you have a team of good programmers who work well together, a software process will usually get in the way.	[45, (3)]
				X			My code should take advantage of the implementation details in other code.	[45, (4)]
			X				It is expected that clients will describe their requirements accurately before a team begins programming.	[45, (5)]
				X			As a software developer, most of my time will be spent designing and implementing new algorithms and data structures.	[45, (6)]
X							Most of the time when I start a new programming task in industry, I will be working on a new project.	[45, (7)]
				X			Developers do not need to know the high-level context of the system; this allows them to concentrate on their task.	[45, (8)]
					X		A software project is successful only if it ships with very few known defects.	[45, (9)]
						X	Software engineering is about producing lots of documentation on the requirements and implementation of the project.	[45, (10)]
	X	X	X				Process, requirements, and team-management are important to business majors, not software developers.	[45, (11)]
				X			The majority of the cost of a successful software project will be the initial implementation effort.	[45, (12)]
					X		A file with a complex code change process tends to be buggy.	[53, (B1)], [54, (S2)]
					X		A file that is changed by more developers is more bug-prone.	[53, (B2)], [54, (S14)]
					X		A file with more added lines is more bug-prone.	[53, (B3)], [54, (S4)]
					X		Recently changed files tend to be buggy.	[53, (B4)], [54, (S7)]
					X		Recently bug-fixed files tend to be buggy.	[53, (B6)], [54, (S10)]
					X		A file with more fixed bugs tends to be more bug-prone.	[53, (B7)], [54, (S11)]
					X		A file with more commits is more bug-prone.	[53, (B8)], [54, (S12)]
					X		A file with more removed lines is more bug-prone.	[53, (B9)], [54, (S13)]

IV. DISCUSSION

A. Methodology: Threats to Validity

Several aspects regarding the SLR should be remarked upon.

First, one significant limitation is the broad number of synonyms for 'misconception'; it is almost impossible – despite all efforts – to ensure that all relevant papers are found.

Second, we used the four-eyes principle to proceed and discussed to achieve consensus, but enclosed papers causing persistent disagreement. However, this is not an ideal process, affecting reliability of assessment and evidence of results.

Third, a limitation is that own publications could turn out to be matches in the SLR, which must be handled objectively. This can result in a systematic error. It is therefore noted that authors of this paper also authored the publication [50].

B. Discussion of Results

Regarding the results of the SLR, it is noted that the cut of 2,158 publications to merely 3 [45] [53] [54] of interest identified is immense. As a result, it could be assumed that the search (engines/query) or the selection (in-/exclusion/quality criteria) are inadequate. However, this contradicts that ...

- ... SE didactics are still developing.
- ... the consideration of another database (Section I-B, [9]) also indicates that little research is available to date.
- ... other authors report the same for the adjacent field of computer sciences: "At present, hardly any empirical data concerning the issue of expectations and prior knowledge [...] in informatics [...] are available" [57, p. 143].

V. CONCLUSION

The paper's purpose, to identify and analyse known misconceptions in SE to use these insights in higher education, has been pursued using a systematic literature review. Predefined search queries have been applied to search 10 databases before the publications have been filtered using the selection strategy described. Out of 2,158 publications, 18 could be identified as appropriate for the selection criteria. These contain 167 statements, which the authors of these papers refer to as misconceptions. 20 of them met the quality criteria specified; i.e. only 3 publications cover valuable data.

To conclude, the results show that currently evidence-based research on misconceptions in SE is limited; this secondary study demonstrates, there is not enough research on evidence-based misconceptions in SE to use these insights for higher education. So, in addition a primary study to identify misconception in SE is indispensable before addressing them.

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