Knowledge Sharing in Software Development: A Tertiary Study

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Abstract. Knowledge is the most important resource in the field of software development, the success of which is based on the exchange of knowledge among the team members of the software development project. The aim of this research is to provide a catalogue of literature reviews available to researchers and software developers. For this tertiary study, a systematic mapping study was conducted to identify and analyze existing secondary studies on knowledge sharing in software development. After the search process, 11 secondary studies were selected, most of them of type SLR and published in journals. In terms of topics, we mainly find changes in behavior in knowledge sharing factors, challenges, and solutions. Regarding to research topics, we found that the category of behavior change was the most reported. Finally, most of the research questions were exploratory, descriptive subtype and classification.

Keywords: knowledge sharing, software development, reviews.

1 Introduction

Knowledge is generated by the interaction of information with people's beliefs, experiences, and commitments within the organization [1]. Some of those experiences are incorporated explicitly, while the others remain in the people's mind [2].

Knowledge management (KM) comprises different processes whose objective is to improve learning and performance in the organization [2]. In that context, in [3], a tertiary study was developed with the aim of providing a complete and updated overview of knowledge management's topic and thus, helping researchers to carry out new studies on KM to close the existing research gaps.

Software industry, in general, performs knowledge-intensive activities because this asset is kept on many people through the different phases or stages which are followed in the software life cycle [4]. Software development comprises collaborative and knowledge-intensive processes that require the mixing and intertwining of diverse knowledge dispersed across expertise domains [5]. Each involved person must make many decisions becoming a group activity in which individual knowledge is required to be shared and used at the project and organization level [6]. Therefore, sharing

knowledge among team members is critical when it is required to get successful results in a project [7].

Various papers have been published on knowledge management in the context of the software industry. In [8], an overview of knowledge management in the context of software engineering is presented, focused on the motivations, approaches and factors that are important when implementing KM strategies in software development companies. In [9], whose objective was to explore how companies that adopt agile methodologies manage to implement KM strategies using practices that promote knowledge processes in different organizational layers.

The secondary studies play an important role both in supporting future research efforts and in providing information to help researchers and practitioners [10].On the other hand, a tertiary study aims to provide more information about published secondary studies on a specific topic by tabulating their information. In the KM literature, there is only one tertiary study [3] that addresses KM in a general way without considering features in the context of software development.

Based on the above, with the purpose of identifying and classifying the reviews of the existing literature about knowledge management in software development, a tertiary study is presented adapting the Petersen's systematic mapping study [11]. The rest of this paper is structured as follows; section 2 describes a relevant tertiary study. Section 3 presents the methodology followed to carry out the systematic mapping. In section 4, the main results of the study are described, while in section 5, a discussion is presented. Finally, in section 6 conclusions are presented.

2. Related Work

In the preliminary review of the literature, a tertiary work by KM de Cerchione et al. [3] was identified. In that study, it was stated that there is no previous tertiary review on KM's topic, so their contribution was the first to focus exclusively on the evolution of published secondary studies in the field of KM. Likewise, in that study, the evolution of the gaps in the literature over time was evaluated.

3. Tertiary Study Design

The general aim of this study is to identify secondary studies about knowledge sharing in software development. A secondary study consolidates data from the primary studies to synthesize and answer a specific research question [12]. This section presents the main aspects of the research protocol according to one of the systematic mapping study guides [11]. Below we present the planning phase of this study.

3.1. Research Question

The research questions established for this tertiary study of the literature on knowledge sharing in the context of software development are:

- RQ1 How have secondary studies evolved?
- RQ2 What research topics were addressed?
- RQ3 What research questions were asked in the secondary studies?

The purpose of RQ1 is to identify secondary studies on the subject to determine its evolution and current validity. Also, we seek to determine when and where the secondary studies were published. Question RQ2 shows the research topics addressed. In RQ2, to identify the issues addressed by the selected secondary studies, we use the classification of dynamic flows in knowledge-intensive organizations proposed by [16]. In this classification, two entities participate as project actors in knowledge-intensive organizations: the person and the project team. Four dynamic flows between these two entities are identified: team building, knowledge flow, behavioral change, and learning [16]. Question RQ3 explores the main research questions and the key constructs studied and classified using scheme proposed by [13] (shown in Table 1).

Table 1. A classification scheme for RQs as proposed by [13]

RQ category	Sub-category	RQ model
Exploratory	Existence (E)	Does X exist?
	Description and classification (DCL)	How do the components relate to one another? / What are all the types of X?
	Descriptive-Comparative (DCO)	How does X differ from Y?
Base-rate	Frequency distribution (FD)	How often does X occur?
	Descriptive-process (DP)	What is the process by which X happens? / How does X achieve its purpose?
Relationship	Relationship	Are X and Y related?
Causality	Causality (C)	What are all the factors that cause Y? / What effect does X have on Y?
	Causality-comparative (CC)	Does X cause more Y than does Z?
	Causality-comparative interaction (CCI)	Does X or Z cause more Y under one condition but not others?
Design	Design (D)	What's an effective way to achieve X? / What strategies help to achieve X?

3.2. Search String

To achieve this, a search string was built using the concepts of Population and Intervention [11] suggested by Petersen. In our case, the Population is the "knowledge sharing" and "software development". The intervention is "secondary studies". The list of synonyms for knowledge exchange was based on [14], as were the terms relevant to software development and the list of alternative terms for review studies were taken from [15]. The search string (see Table 2) remained as: *P AND I = ("Knowledge sharing" AND "Software development") AND ("Secondary studies")*, was set up to run on the Scopus, Web of Science, Science Direct, IEEE Xplore and ACM Digital Library databases

Table 2. Terms used in the search string.

Main term	Alternative terms
Knowledge sharing	"Knowledge sharing" OR "Knowledge transfer" OR "transfer of knowledge" OR "knowledge exchange" OR "Exchange of knowledge" OR "share of knowledge"
Software development	"Software development" OR "system development" OR "software engineering" OR "information system development"
Secondary studies	"Review of studies" OR "structured review" OR "systematic review" OR "literature review" OR "literature analysis" OR "in-depth survey" OR "literature survey" OR "meta-analysis" OR "past studies" OR "subject matter expert" OR "analysis of research" OR "empirical body of knowledge" OR "evidence-based software engineering" OR "overview of existing research" OR "body of published research" OR "study aggregation" OR "study synthesis" OR "critical review" OR "mapping study" OR "mapping literature"

The list of synonyms for knowledge exchange was based on [14], as were the terms relevant to software development and the list of alternative terms for review studies were taken from [15]. The search string remained as: *P AND I = ("Knowledge sharing" AND "Software development") AND ("Secondary studies")*, was set up to run on the Scopus, Web of Science, Science Direct, IEEE Xplore and ACM Digital Library databases.

3.3. Selection Process

For the tertiary study of the literature, a set of inclusion criteria (IC) and exclusion criteria (EC) were established. The list of IC and EC is showed in Appendix A. For the selection process, the following stages were established: (i) a stage of obtaining the metadata of the selected databases; (ii) review of titles, where they apply: IC2, EC2 and EC3; (iii) review of the abstracts, where they apply: IC1, IC2 EC1, EC2; and (iv) quick review of the content, where they apply: IC1, IC3 and EC1. For this study, it was established to use quality criteria (QC) on the results, with the purpose of determining the reliability of the conclusions provided in each secondary study selected. The list of QC is showed in Appendix A.

Data extraction was based on a structure that includes: reference, year of publication, type of publication (journal/conference), type of secondary study reported by the authors, author affiliation, study objective, research questions, term of search used, databases searched, number of primary studies, years covered and research topic according to the Lytras' classifier [16].

4. Results

In this section, we will present the main findings of this tertiary study. The results are depicted following the same order of the research questions.

The selection process for secondary studies was carried out in accordance with what was established. Running the search string (February 2023) returned the following

numbers of records: Scopus (112), IEEE (33), Science Direct (99), Web of Science/Clarivate (41), and ACM (171). The quality of each study was assessed according to the DARE method [12], [17] and presented in Appendix A. Finally, in the selection process, 11 articles were obtained as selected secondary studies (see Table 3).

Table 3. Selected secondaries studies.

Id	Author	Title
S01	Anwar, R., 2019 [18]	Systematic Literature Review of Knowledge Sharing Barriers and Facilitators in Global Software Development Organizations Using Concept Maps
S02	Ghobadi S., 2015 [14]	What Drives Knowledge Sharing in Software Development Teams: A Literature Review and Classification Framework
S03	Habeh, O., 2021 [19]	Knowledge Sharing Challenges and Solutions Within Software Development Team: A Systematic Review
S04	Kroll, J., 2016 [20]	Challenges and Practices for Effective Knowledge Transfer in Globally Distributed Teams: A Systematic Literature Review
S05	Ouriques, R., 2019 [9]	Knowledge management strategies and processes in agile software development: a systematic literature review
S06	Sarka, P., 2017 [21]	Knowledge sharing via social media in software development: a systematic literature review
S07	Zahedi [22], M., 2016	A systematic review of knowledge sharing challenges and practices in global software development
S08	Fatima, N., 2012 [23]	Knowledge Sharing Factors for Modern Code Review to Minimize Software Engineering Waste
S09	Soroka-Potrzebna, H. 2022 [24]	Barriers of knowledge management in virtual project teams: a TISM model
S10	Bjornson, F., 2008 [8]	Knowledge Management in Software Engineering: A Systematic Review of Studied Concepts, Findings and Research Methods Used
S11	Navimipour, N. 2016 [25]	Knowledge sharing mechanisms and techniques in project teams: Literature review, classification, and current trends

4.1. RQ1 How have secondary studies evolved?

Figure 1a shows that a study was published in 2008, followed by 6 unpublished years. Since 2015 to date the frequency of publication has been one article per year approximately. Section 1b shows that more secondary articles were written on the European continent. Similarly, in parts c and d of Figure 1 it is shown that the largest number of secondary studies is of type SLR published in Journals.

4.2. RQ2 What research topics were addressed?

Table 4 shows the dynamic flows identified in each of the secondary studies. In this regard, the flow of behavioral change is mostly identified in 7 studies (S01, S02, S03, S04, S07, S08, S09), followed by 2 studies both in knowledge flow (S06, S11) and in learning (S05, S10).

In addition, two general themes were identified in the category of behavior change. The first, related to the factors which involve identification of barriers, drivers, and facilitators in the exchange of knowledge in the software development teams (S01, S02, S08 and S09). The second, related to the identification of challenges and solutions in software development knowledge sharing (S03, S04 and S07).

On the other hand, in the subject corresponding to the flow of knowledge, the means, techniques and practices used for the exchange of knowledge in software development

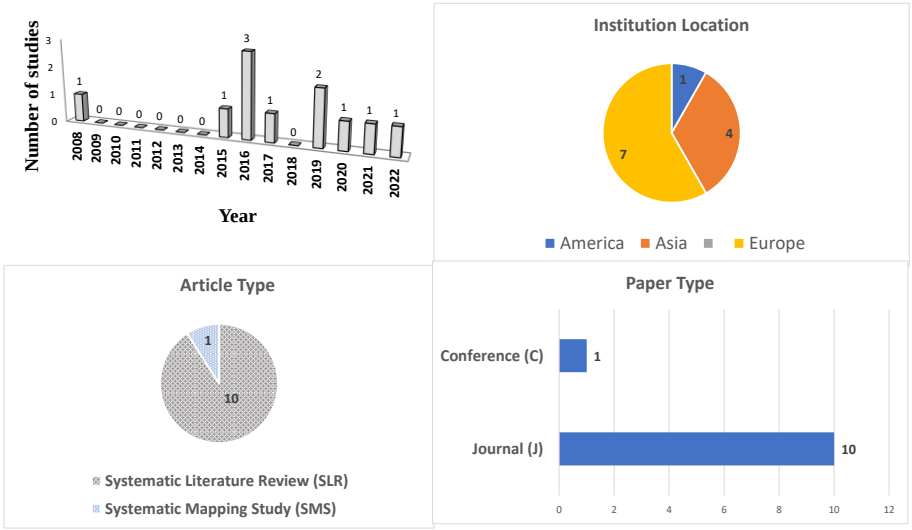

Fig. 1. Evolution of Secondary studies (a) by year, (b) by institution location, (c) by article type and (d) by paper type

were investigated (S06 and S11). Finally, learning is also considered as a subject in two studies through the investigation of concepts, strategies, findings in knowledge management in software engineering (S05 and S10). It is shown in Table 4.

4.3. RQ3 What research questions were asked in the secondary studies?

In relation to the research questions, the RQs are classified using scheme as shown in Table 1. Five categories are shown on which the RQ of secondary studies will be classified. Only one category is considered for each RQ.

Within the exploratory category, both in the existence subcategory and in the descriptive-comparative subcategory, no RQ was found, however in the description and classification subcategory the most common RQs were found, in number of 10 corresponding to 7 secondary studies (S03, S04, S05, S06, S07, S09 and S10). The RQs of this subcategory are shown in the RQs column of Table 5 crossing with the marks of the "DCL" column.

In the causality category, subcategory C (causality) we found the second most frequent RQs, in number of 6 RQs in 5 studies. In this case RQs were associated with the type of question "what effect does X have on Y?" because the factors that influenced

the knowledge sharing in software development were identified (S01, S02, S07, S08 and S09). They are shown in the RQs column of Table 5 crossing with the marks of the "C" column.

In this same category, there is the comparative-causality subcategory in which we found the third most frequent, in number of 4 RQs in 3 studies (S09, S10 and S11). In this case, it was necessary to compare the causal relationships to identify the most important factors. The RQs of this category are shown in the RQs column of Table 5 crossing with the marks of the "CC" column. In the subcategory Causality-comparative interaction (CCI) we did not locate any RQ.

Table 4. A classification scheme as proposed by [16] about Dynamic flows

Id	Dynamic flows	General topic
S01	behavioral change	KS factors
S02	behavioral change	KS factors
S03	behavioral change	KS challenges and solutions
S04	behavioral change	KS challenges and solutions
S05	learning	KM concepts
S06	knowledge flow	KS flow
S07	behavioral change	KS challenges and solutions
S08	behavioral change	KS factors
S09	behavioral change	KS factors
S10	learning	KM concepts
S11	knowledge flow	KS flow

The next category is design, in which we found 3 RQs in 3 studies (S04, S05 and S07). The objective of these RQs is to identify practices and strategies in knowledge management in software engineering. The RQs are shown in the RQs column of Table 5 crossing with the marks of the "D" column.

Finally, the least frequent, with a frequency of 1, corresponds to the base rate category, both in the frequency distribution subcategory (S05) and in the descriptive process subcategory (S04). The RQs of these categories are shown in the RQs columns of Table 5 crossing with the marks of the "FD" and “DP” columns respectively.

Table 5. A classification scheme for RQs as proposed by [13]

Id	Research question	E	DCL	DCO	FD	DP	R	C	CC	CCI	D
S01	What are the KS barriers in GSDOs?							X			
S01	What are the KS facilitators in GSDOs?							X			
S02	What drives knowledge sharing in software development teams?							X			
S03	What are the studies that exhibit main challenges or barriers of sharing knowledge ...?		X								
S03	What are the studies that provide solutions for knowledge sharing challenges...?		X								
S03	What are the research methods used for addressing challenges and provide...?		X								
S04	What builds up the "noise" in the KT?		X								
S04	What are the recommended practices for effective KT in GSD projects?										X
S04	How the KT is processed in GDT?					X					
S05	How have knowledge management practices been distributed in companies...?		X								
S05	How do knowledge management strategies promote knowledge processes in ASD?										X
S05	To what degree have knowledge management strategies been validated in industrial...?				X						
S06	How are social media reported to be used for knowledge sharing...?		X								
S06	How is knowledge sharing via social media being researched?		X								
S07	In What contextual settings are challenges and practices reported?		X								
S07	What are the knowledge sharing challenges in GSD?							X			
S07	What are the knowledge sharing practices in GSD?										X
S08	What factors influence the knowledge sharing in MCR to minimize ...?							X			
S09	Which barriers are considered to be at strategic level?		X								
S09	How the barriers affect each other?							X			
S09	What are the most important barriers of knowledge management in virtual project ...?								X		
S10	What research methods have been used within the area so far?		X								
S10	What are the major knowledge management concepts that have been investigated ...?								X		
S10	What are the major findings on knowledge management in software engineering?								X		
S11	What are the most important knowledge sharing mechanisms in the project teams?								X		
	Total	0	10	0	1	1	0	6	4	0	3

4.4. Threats to Validity

To mitigate validity threats, this tertiary study relied on sound procedures [11]. Also, to mitigate the impact of selection bias, a protocol was built in the early stages of this research. In this document, key search terms have been identified and alternative terms have been included.

Regarding publication bias, it was mitigated by considering five relevant databases such as: Scopus, Web of Science/Clarivate, ACM, Science Direct and IEEE databases. However, there is always the risk that there are some secondary studies that were not included in our final group due to their lack of availability in the searched digital databases or because the relevant keywords may not have been used in their metadata.

5. Conclusions

This study has completed a tertiary literature review using a systematic mapping study as a procedure [11]. After the process, 11 secondary studies were selected to answer the research questions.

The selected studies, according to RQ1, are mainly of the SLR type and are published in journals (91%). The main problem with quality assessment is the lack of information on the quality of the empirical studies included in each secondary study. In addition, from 2000 to 2022, it was found that most of the identified studies were published between 2015 and 2022. In addition, the results of this study suggest that the current production of SRL articles is strongly supported by European researchers.

In relation to research topics in secondary studies, in RQ2, we found that the category of behavior change is the most common reported according to the classification of Lytras et al. [16]. In addition, the studies show a clear orientation towards identifying factors in knowledge sharing in software development.

Finally, regarding the type of question, RQ3, we found that most of the questions posed in the identified secondary studies are of the "description and classification" type. This subtype corresponds to the exploratory type that is very common as a starting point in bibliographic reviews.

We believe that the findings of this systematic mapping study would be useful to both software development knowledge sharing researchers and practitioners, as it provides an effective starting point for this topic investigated thus far.

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Appendix A: Tertiary study selected process URL

Note to reviewers. The appendix below has only been included for peer-review process. The appendix will be available by URL in a camera ready and published version.

Appendix A: Tertiary study selected process URL

Criteria and Selection Process

- IC1. Articles about literature reviews that report formally a method to carry it out, for example: systematic mapping study or systematic literature review.
- IC2. Articles about sharing knowledge in software development.
- IC3. Articles that include the research questions, the research process, data extraction, classification, summary, or synthesis of the results.
- EC1. Ad hoc literature reviews that lack defined research questions, selection process, or extraction process.
- EC2. Duplicate extended or complementary articles, where the same study is reported. In this case, the most complete version is selected, or they are taken as one.
- EC3. Articles written in languages other than English.

Quality Criteria

- QC1. Are the inclusion and exclusion criteria for the review described and appropriate?
- QC2. Is it likely that the literature search has covered all relevant studies?
- QC3. Did the reviewers assess the quality/validity of the included studies?
- QC4. Were the basic data/studies adequately described?

Each criterion was rated with the values 1, 0.5 and 0.

- (1) For QC1, 1 is assigned when the inclusion and exclusion criteria are explicitly described in the review. The value 0.5 is assigned when a single selection criterion is described or is implicit. The value 0 is used when the selection criteria are not defined.
- (2) For QC2, the value 1 is assigned when at least 5 digital libraries were searched, and an additional search strategy was used. The value 0.5 is assigned when the search is reported in only 3 to 4 digital libraries. The value 0 is assigned when the article reports up to 2 digital libraries or a small set of journals.
- (3) For QC3, the value 1 corresponds to the article that explicitly defines the evaluation of the quality of the empirical evidence provided in each primary study. The value 0.5 is assigned when the evaluation focuses on answering the research question posed in the main paper. The value 0 is assigned when there is no explicit assessment of the quality of the primary works.
- (4) For QC4, the value 1 corresponds to articles that present data on each primary study. The value 0.5 is assigned when the data from the primary studies are presented in summary form. The value 0 is assigned when data from individual primary studies are not specified.

Quality score

The quality of each study was assessed according to the DARE method [12], [17] is presented in Appendix A.

Likewise, Table A.1 shows the quality score of the studies using the DARE criteria. The results of the quality analysis show that all studies scored 1 or more on the DARE scale and only one study scored 1.5. Despite the qualification obtained, it was decided to keep it in the analysis since it identifies the barriers in the virtual project teams. Consequently, no study was ruled out.

Table A.1. Quality assessment

Id	QA1	QA2	QA3	QA4	Total score
S01	1	1	0	0.5	2.5
S02	1	0	0	1	2
S03	1	1	1	0.5	3.5
S04	1	1	0	1	3
S05	1	0.5	1	0.5	3
S06	1	1	0	0.5	2.5
S07	1	0	0	1	2
S08	1	1	0	0	2
S09	1	0.5	0	0	1.5
S10	1	0.5	1	1	3.5
S11	1	1	0	0.5	2.5