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THE CHALLENGE OF EVALUATING VIRTUAL COMMUNITIES OF PRACTICE: A SYSTEMATIC MAPPING STUDY

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ABSTRACT

Aim/Purpose	This paper presents a study of Virtual Communities of Practice (VCoP) evaluation methods that aims to identify their current status and impact on knowledge sharing. The purposes of the study are as follows: (i) to identify trends and research gaps in VCoP evaluation methods; and, (ii) to assist researchers to position new research activities in this domain.
Background	VCoP have become a popular knowledge sharing mechanism for both individuals and organizations. Their evaluation process is complex; however, it is recognized as an essential means to provide evidences of community effectiveness. Moreover, VCoP have introduced additional features to face to face Communities of Practice (CoP) that need to be taken into account in evaluation processes, such as geographical dispersion. The fact that VCoP rely on Information and Communication Technologies (ICT) to execute their practices as well as storing artifacts virtually makes more consistent data analysis possible; thus, the evaluation process can apply automatic data gathering and analysis.
Methodology	A systematic mapping study, based on five research questions, was carried out in order to analyze existing studies about VCoP evaluation methods and frameworks. The mapping included searching five research databases resulting in the selection of 1,417 papers over which a formal analysis process was applied. This process led to the preliminary selection of 39 primary studies

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	for complete reading. After reading them, we select 28 relevant primary studies from which data was extracted and synthesized to answer the proposed research questions.
Contribution	The authors of the primary studies analyzed along this systematic mapping propose a set of methods and strategies for evaluating VCoP, such as frameworks, processes and maturity models. Our main contribution is the identification of some research gaps present in the body of studies, in order to stimulate projects that can improve VCoP evaluation methods and support its important role in social learning.
Findings	The systematic mapping led to the conclusion that most of the approaches for VCoP evaluation do not consider the combination of data structured and unstructured metrics. In addition, there is a lack of guidelines to support community operators' actions based on evaluation metrics.
Keywords	systematic mapping, virtual community of practice, evaluation

INTRODUCTION

Individuals and organizations are increasingly acquiring resources and sharing knowledge through online communities and virtual social networks. Knowledge sharing is the notion of exchanging information between people as members of a community (Hung, Chee, Hedberg, & Thiam Seng, 2005). Academics and professionals are investigating the potential of such communities (Yang & Li, 2016) to facilitate learning, improve people's lifestyle and foster professional development (Hafeez, Alghatas, Foroudi, Nguyen, & Gupta, 2019).

Community of Practice (CoP) were initially (Lave & Wenger, 1991) viewed as social structures that support learners in co-creating knowledge (Veenswijk & Chisalita, 2007; Wenger, McDermott, & Snyder, 2002). Virtual Communities of Practice (VCoP) are CoP supported by Information and Communication Technologies (ICT) (Agrifoglio, 2015). Since holding face to face interactions on a regular basis is costly and time consuming, VCoP supported by ICT are among the few viable alternatives to live conversations and knowledge sharing in communities geographically distributed (Hafeez et al., 2019). There are evidences of the adoption of VCoP in several areas such as: teacher's education and training (Chan et al., 2016; Clarke, 2009; Nistor et al., 2015; Waycott, Thompson, Sheard, & Clerehan, 2017); health professionals (Lai, 2010; Stewart & Abidi, 2017); Law (Wasko & Faraj, 2005); and Gas and Petroleum industry (Frank, Sander, Gastaldi, Madini, & Corso, 2017). In addition, VCoP have also been applied in multinationals of various sectors such as (Ardichvili, Page, & Wentling, 2003): Hewlett Packard (https://www8.hp.com), Ford (https://www.ford.com), Xerox (https://www.xerox.com), IBM (https://www.ibm.com) and Shell (https://www.shell.com).

Initially, both CoP and VCoP were viewed as spontaneous and self-organized structures. However, it has been increasingly recognized that these communities demand management and evaluation (Wenger, McDermott, & Snyder, 2002). Currently, communities' operators need to apply evaluation processes to analyze their status. These processes can support decision making towards the improvement of the community effectiveness, thus increasing the potential of knowledge sharing (Bolisani & Scarso, 2014; Pattinson, Preece, & Dawson, 2016; Wenger et al., 2002).

VCoP are complex structures that can be evaluated from different perspectives (Frank et al., 2017). Wenger, McDermott and Snyder (2002) point out that an evaluation process can be based on several aspects regarding the three fundamental properties of CoP: Domain, Community and Practice. However, little is known about how to evaluate and support knowledge sharing in such communities (Wang, Liu, Wang, Zhang, & Fan, 2015). Hafeez, Alghatas, Foroudi, Nguyen, and Gupta (2019) state that their extant literature review indicates an absence of measures to evaluate knowledge sharing in

VCoP. Although some evaluation processes have been produced, most of them are based on empirical or qualitative analysis. Effort needs to be made to produce more comprehensive evaluation approaches based on quantitative analysis so that we can better understand the communities' performance (Bolisani & Scarso, 2014). In addition, the evaluation of VCoP brought about new challenges because additional properties were introduced, as compared to CoP, such as the intense Web-based interaction and more possibilities of investigating recorded data.

This scenario led us to undertake a systematic mapping study that aims at: (i) identifying trends and research gaps in VCoP evaluation processes; and, (ii) assisting researchers to position new research activities in this domain. Our study was developed according to the protocol defined by Kitchenham and Charters (2007). The results point out at trends and research gaps regarding VCoP evaluation methods, based on defined research questions. The findings can be used to assist researchers and professionals to conceive more rigorous methods, in particular based on quantitative data.

In the rest of this paper, we use the term VCoP referring to virtual communities of practice or similar knowledge-based social structures. The literature might show different definitions related to CoP, mainly depending on their purpose and characteristics, such as knowledge networks, networks of practice or communities of interest (Creech, Laurie, Paas, & Parry, 2012; Hafeez et al., 2019). We have included in our systematic mapping primary studies that adopted these terminologies, because such studies may contain important elements or, according the authors' studies, can be directly applied in VCoP evaluation.

THEORETICAL BACKGROUND

This section gives an overview of the main concepts related to the study presented in this paper namely: CoP and VCoP; evaluation processes; and, data analysis of social networks.

CoP and VCoP

CoP have three fundamental properties: Domain, Community and Practice. Domain is the area of knowledge that brings the community together and pushes a common agenda (Wenger et al., 2002). It encompasses mutual engagement, shared repertoire and joint enterprise. A well-established domain legitimates and gives identity to a community; and therefore, makes CoP different from a friend's club or a network of connected people (Wenger et al., 2002). Community involves social structures that stimulate the learning through interactions and relationships amongst their members (Agrifoglio, 2015). It is characterized by a group of people engaged in a process through which they interact, jointly learn and build relationships. In this process, they develop a sense of belonging and a mutual compromise that creates a community identity (Wenger et al., 2002). Finally, the Practice represents the specific knowledge developed and shared within the community. Wenger, Trayner, and De Laat (2011) emphasize that CoP members are practitioners who produce a repository of shared resources such as: experiences, histories, tools, and problem-solving strategies.

The literature agrees that when a community predominantly uses ICT it can be called "virtual," but otherwise "face to face" (Dube, Bourhis, & Jacob, 2006; Wenger et al., 2002). Older communities in which members usually carried out their practice in the same organization or city, or at least in places nearby, have expanded to people around the world. ICT have reduced the spatial (physical space) and temporal (time) distances, enabling people from anywhere and at any time to join communities and perform their practices (Agrifoglio, 2015). This led to VCoP which are physically unlimited extended versions of CoP. They break the constraints of a physical space, thus promoting the interaction of a network of people geographically distributed (Hara, Shachaf, & Stoerger, 2009).

Evaluation of CoP and VCoP

The evolution of CoP from spontaneous and self-organizing communities to cultivated and managed structures which aim to achieve their goals efficiently brought about the need of evaluation processes. Evaluation processes were initially developed to CoP based on face to face interactions. Value creation is one of the main concepts measured in their evaluation process. This concept represents a cause and effect relationship between activities of creation and the practical application of knowledge. Value creation is used in several CoP's evaluation frameworks to express the creation and sharing of knowledge in the community (Abigail, 2016; Creech et al., 2012; McDermott, 2002; Wenger, Trayner, & De Laat, 2011). Wenger, Trayner, and De Laat (2011) proposed an evaluation framework that integrates processes and heterogeneous data types in order to provide a panorama of how CoP create values to their members, hosts and sponsors. The framework evaluates value creation by analyzing the link between activities and their outcomes. In addition to the analysis of cause and effect between activities and results, the framework offers a guide on how to proactively foster value creation within five cycles, as shown in Figure 1: immediate; potential; applied; realized and reframing. Examples of identification of value creation in these cycles are:

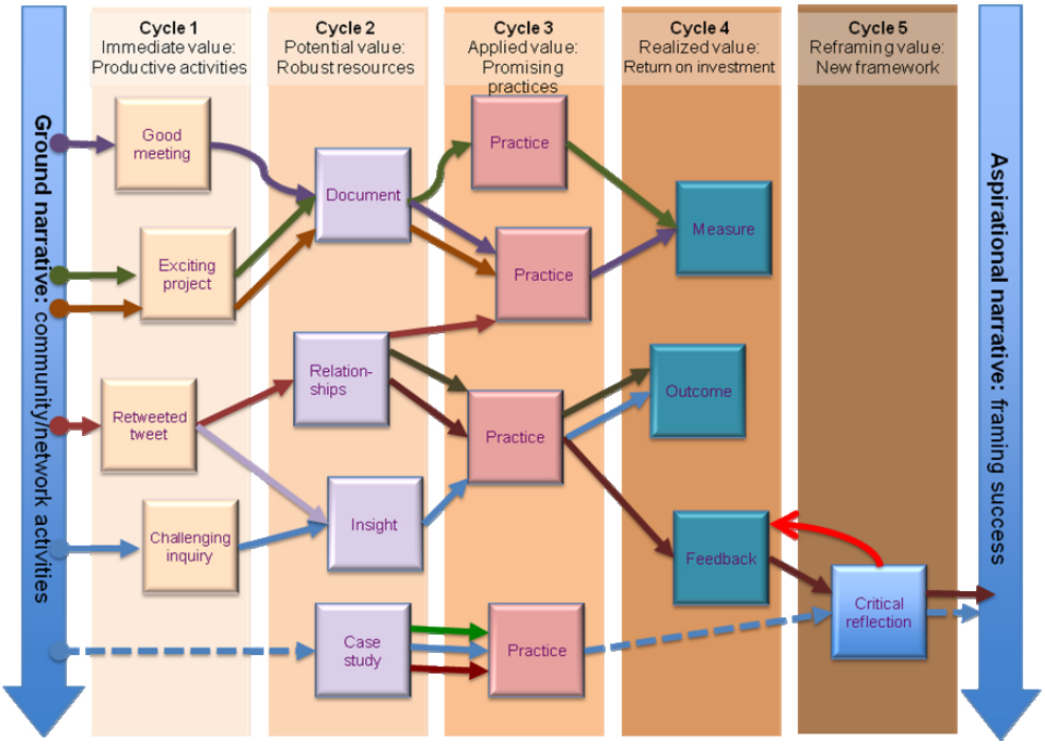


Figure 1: Value-creation matrix (Wenger et al., 2011)

- Cycle 1 - Immediate value: activity and interaction indicators such as participation in meetings, number and characteristics of active participants; number of questions; number and time of responses; discussions intensity; length of discussion threads; self-reports; and, interactions frequency.
- Cycle 2 - Potential value: production of artifacts that register practice, methods and patterns; social network analysis; report of complex problems; recommendations; event and discussion summaries; frequent asked questions; stakeholders feedback; and, references to their own community.

- Cycle 3 - Applied value: promising practices such as new forms of problem solving; new perspectives; new terms and concepts; reuse estimates; collaborative arrangements; use of connections to carry out tasks; new policies; and the use of community processes to learning in different contexts.
- Cycle 4 - Realized value: practices that result in performance improvement, speed and accuracy; clients' feedback and satisfaction; students' success; project evaluation; results' metrics; and, ability to attract projects related to the domain.
- Cycle 5 - Reframing value: new learning agenda; new views about values; new visions; new metrics; need of new evaluation processes; new arguments with stakeholders; new strategic directions that reflects new understanding.

The accumulation of evidences of value creation in a CoP can be represented by a matrix of indicators as shown in Figure 1. The squares represent indicators of each cycle. The colored lines represent histories that connect the indicators of each cycle. Dotted lines represent premises and hypotheses. The red arrow represents the reconsideration of an indicator due to reflection. The figure shows a sequential display; however, there is not any hierarchical relation between the cycles of value as learning is not considered a linear process (Wenger et al., 2011).

CoP's evaluation processes have solid theoretical basis which is supported by measures of community effectiveness and degree of knowledge sharing applying concepts, such as value creation. In contrast, VCoP's evaluation processes are heterogeneous as they make use of diverse aspects of the communities. In addition, these processes are not usually supported by CoP's theoretical background. Therefore, we decided that it was important to identify the characteristics of current evaluation approaches to VCoP and their relationship to CoP by developing a systematic mapping study. The research questions established to this study includes: the identification of the strategies used to analyze the interaction between community members and the knowledge produced by them. These strategies are named Social Network Data Analysis, as discussed in the next Section.

Social Network Data Analysis

Social networks consist of a set of connections between people, either physical or virtual (Wenger at al., 2011). VCoP hold a great amount of data that can be analyzed because community participants carry out their practices on technological platforms which are able to trace and register actions and processes. Such data can be classified as structured or unstructured, as illustrated in Figure 2. They are described as follows (Sapountzi & Psannis, 2018):

- structured – information that be represented as graphs which contain nodes that represent people, organizations, or products, and links that connect the nodes to represent patterns or interactions;
- unstructured (or semantic) – is the content produced or shared in a social network including text, images, documents, videos, preferences (e.g., likes), products and other multimedia data. These data are typically studied in content-based analysis, for instance, to infer behavior and trends.

Social Network Analysis (SNA) (Ehrlich & Carboni, 2005) and related techniques studies structured data in order to explore linkage data that represent interactions between participants of a VCoP. For instance, it is possible to detect sub-communities; deadlocks; and, influent and passive members. On the other hand, unstructured analysis explores content data generated by participants, for example messages' content. Recent studies have been applying Big Data Analytics (Braun, Cuzzocrea, Leung, Pazdor, & Tran, 2016; Khan, Liu, Shakil, & Alam, 2017) to social networks in order to extract con-

clusions through data mining and multimedia data mining (Gandomi & Haider, 2015; Tanwar, Duggal, & Khatri, 2015). Both structured and unstructured data analysis use statistical methods and algorithms of artificial intelligence to infer conclusions (Sapountzi & Psannis, 2018).

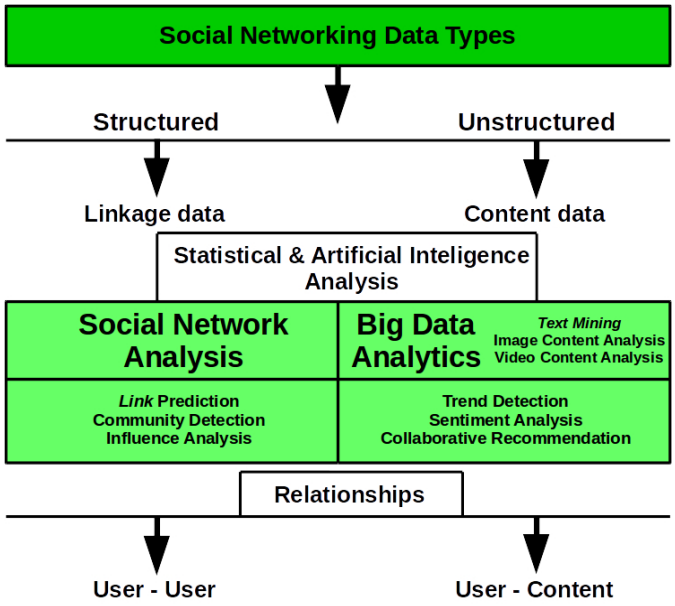


Figure 2: Data types and analysis (Sapountzi & Psannis, 2018)

THE SYSTEMATIC MAPPING STUDY

A systematic mapping is a secondary study that makes it possible to identify, evaluate and interpret data extracted from primary studies related to predefined research questions, thus leading to the elicitation of evidences about important issues and conclusions (Kitchenham, 2004). According to Kitchenham and Charters (2007), a systematic mapping study is composed of three phases: Planning, Conduction and Reporting. Figure 3 shows the activities of each of these phases which are described in the next sections. Our systematic mapping was carried out between October 2018 and July 2019.

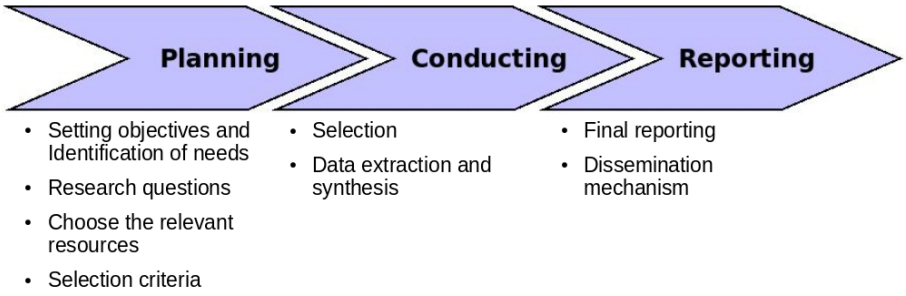


Figure 3: Systematic mapping phases and activities

PLANNING

The planning phase aims to define the objectives and identify the specific needs for the systematic mapping, thus defining the research questions, the search string and the digital databases to be used.

Setting objectives and identifying needs

The main objective of our systematic mapping study is to present an analysis of VCoP evaluation methods and identify their current status and impact in knowledge sharing. Thus, the next activity of

the planning phase is to make sure that there are not similar existing studies by carrying out searches in scientific database. We investigated digital libraries such as Scopus (http://www.scopus.com), ScienceDirect (http://www.sciencedirect.com) and Google Scholar (http://scholar.google.com.br). The most similar studies identified were Bolisani and Scarso (2014); McKellar, Pitzul, Yi, and Cole (2014); and Jan (2019).

Bolisani and Scarso (2014) report the investigation of the importance of CoP for Knowledge Management (KM) bringing about how the concept of CoP is used in theory and practice. The authors analyzed 82 studies developed by researchers and professionals of the KM area in order to identify emergent trends, open research questions and opportunities for further research. They concluded that CoP need to be designed, created and managed. As this process is not trivial, additional studies need to be carried out related to CoP evaluation and management.

The systematic mapping study of McKellar et al. (2014) aims to identify the methods and frameworks that have been used to evaluate CoP (either face to face or virtual) and similar systems, such as knowledge networks. The authors analyzed more than eight thousand works recovered from digital libraries. They have also applied the snowballing technique where references of the papers are also analyzed to detect relevant works. As result 19 works published between 2002 and 2012 were further selected to extract data. The authors focused in the identification of the main objective of the analyzed frameworks. These objectives included the evaluation of the CoP effectiveness and the factors that led to the community success. The authors concluded that there is a need for customizable evaluation frameworks that can be adapted to different contexts as this was reported as a weak point in existing approaches.

Jan (2019) presents a systematic review of research that uses social network analysis (SNA) to investigate virtual communities of practice. The review was driven by the lack of immediate value of time-consuming qualitative analyses typically conducted on VCoP. The review seeks to assess the viability of SNA as a primary technique for structural investigation in such communities. However, it must be taken into account that the study is context specific, as it focuses on the structural aspect of the primary studies analyzed.

Research Questions

Given the main objective of our study, as defined above, three specific objectives were established: *(i)* to identify the aspects used to measure VCoP; *(ii)* to identify the computational strategies and techniques used by VCoP evaluation processes; and, *(iii)* to identify methods for defining guidelines to support VCoP operators based on measured results.

Based on these specific objectives, the following research questions (Kitchenham, 2004) were defined:

- ***RQ1 (Typology and Domain)**: which typology and application domains have been considered in the primary studies?* This research question aims to identify which community structures have been evaluated and if the process is either general or domain specific.
- ***RQ2 (Theoretical bases)**: which theoretical bases have been applied in the primary studies?* The objective of this research question is to trace which is the background applied by the authors to conceive their processes.
- ***RQ3 (Strategies and Techniques to analyze structured and unstructured data)**: which are the strategies used to analyze VCoP structured and unstructured data?* This question aims to identify the strategies adopted in the primary studies to analyze both the interaction between VCoP members and the content produced by them.
- ***RQ4 (Aspects measured)**: which aspects of VCoP have been measured?* This question aims to identify the aspects of VCoP that have been considered in the evaluation processes.

- ***RQ5 (Guidelines Definition)**: which strategies have been used to establish guidelines to support VCoP management based on the evaluation results?* This question aims to elicit which strategies have been used to defining guidelines to support VCoP management based on the results of evaluation approaches.

Choose the relevant resources

The activity of choosing the relevant resources consists of defining the strategy to search for related primary studies. It defines the search string and the selection of publication databases.

In order to define the search string three keywords were initially defined: "community of practice", "virtual" and "evaluation". We have also considered related terms to these keywords; plural; and, verb tenses. Thus, our search string was composed using logical operators as follows: `(CoP OR "communit* of practice" OR "knowledge network*" OR "network* of practice" OR "situated learning" OR "communit* of interest") AND (online OR virtual) AND (evaluat* OR assess* OR diagnosis OR analysis).`

The following criteria were used to select the publication databases (Dieste & Padua, 2007): *(i)* databases which are regularly updated; *(ii)* availability of the complete primary study; *(iii)* accuracy of the published results; and, *(iv)* availability of mechanisms to export results. The selected databases were: ACM Digital Library, Engineering Village, IEEE Xplore, ScienceDirect and Scopus. These databases are amongst the most relevant for computer science, according to Kitchenham and Charters (2007).

Selection Criteria

The selection criteria to inclusion or exclusion of studies in the systematic mapping results are used to evaluate each primary study obtained from the databases. The criteria for inclusion (IC) are:

- **IC1**: the primary study presents an evaluation approach for VCoP or related knowledge-based social structures;
- **IC2**: the evaluation is focused on internal aspects of the community such as participation, identity and knowledge creation and sharing.

The criteria for Exclusion (EC) are:

- **EC1**: the evaluation is focused on external aspects of the community such as: cultural, social and organizational;
- **EC2**: the primary study does not provide evaluation data of some aspect of the community;
- **EC3**: the primary study is not written in English;
- **EC4**: the full version of the primary study is not available;
- **EC5**: the primary study is a short paper (less than 3 pages);
- **EC6**: the primary study has more than 10 years (before 2008).

CONDUCTING

This section describes how the primary studies were selected, the data extraction and the study synthesis. The conducting activities and the amount of recovered primary studies are represented in Figure 4.

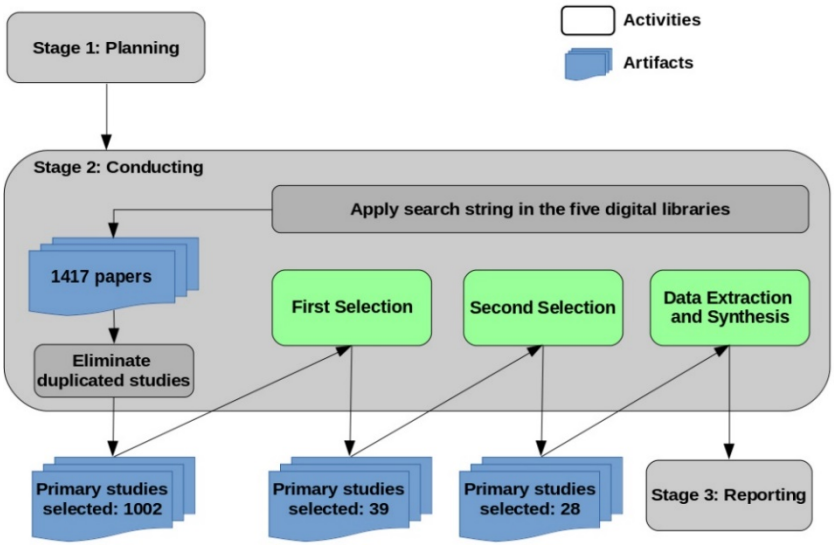


Figure 4: Process of the Conducting phase

The application of the adapted search string to each of selected publication database (see Section Choose the relevant resources) led to 1,417 primary studies. Table 1 shows the number of studies from each database. The activity of eliminating duplicated studies has excluded 415 studies, thus leading to 1002 studies. The First Selection activity involved reading the title, abstract and keywords of each primary study and applying the criteria of exclusion and inclusion. There were cases in which introduction and conclusions were also read. This activity considered that 39 primary studies were relevant to proceed for complete reading, as listed in the Appendix, Table A1. After reading the complete text of these studies, in the Second Selection, the exclusion and inclusion criteria were again applied. This led to 28 relevant primary studies which were analyzed to answer to the established research questions. The eleven excluded studies were marked with ** in the Appendix.

Table 1: Amount of primary studies recovered from digital libraries

Digital Library	URL	Quantity
ACM Digital Library	http://dl.acm.org	61
Engineering Village	http://www.engineeringvillage.com	321
IEEE Xplore	http://ieeexplore.ieee.org	78
ScienceDirect	http://www.sciencedirect.com	42
Scopus	http://www.scopus.com	915
Total	-	**1,417**

As Kitchenham and Charters (2007) do not provide details on how to develop the Data Extraction and Synthesis activity, we developed a strategy (available in the link: http://bit.do/eQ4Vr) to support the data extraction from the 28 selected primary studies based on the established research questions. This strategy included primary study metadata such as year of publication, type of publication (Journal or Conference) and authors' origin country. Further the data obtained were analyzed and grouped to support the conclusions. Finally, the Reporting activity consists of presenting and publishing the systematic mapping study, as described in the next section.

RESULTS AND DISCUSSION

This section presents results, discussion and research gaps of the analysis of the main characteristics of the selected primary studies. They are discussed based on the research questions and information obtained from the data extraction and synthesis phase.

TYPOLOGY, DOMAIN AND THEORETICAL BACKGROUND (RQ1 AND RQ2)

The selected primary studies (28) refer to nine different typologies used to classify the evaluated structures, as shown in Figure 5, from which the most common are: Online CoP, Virtual CoP and Online/Virtual Community. These typologies appear in 67.8% of the studies. Online/Virtual CoP differs from Online/Virtual Community in that the former formally refers to Wenger's framework (Wenger, 1998). Primary studies that refer to other typologies such as the conventional concept of CoP (S06, S14 e S18), more specific systems such as Virtual Enterprises (S09, S25) and Virtual Community of Interest – VCoI (S08) were also included in our systematic mapping study because they contain important elements related to VCoP evaluation. Figure 6 shows a summary of the application domains recovered from the selected primary studies. Twenty of primary studies were domain-specific whereas eight involves general context. Education was the most frequent domain.

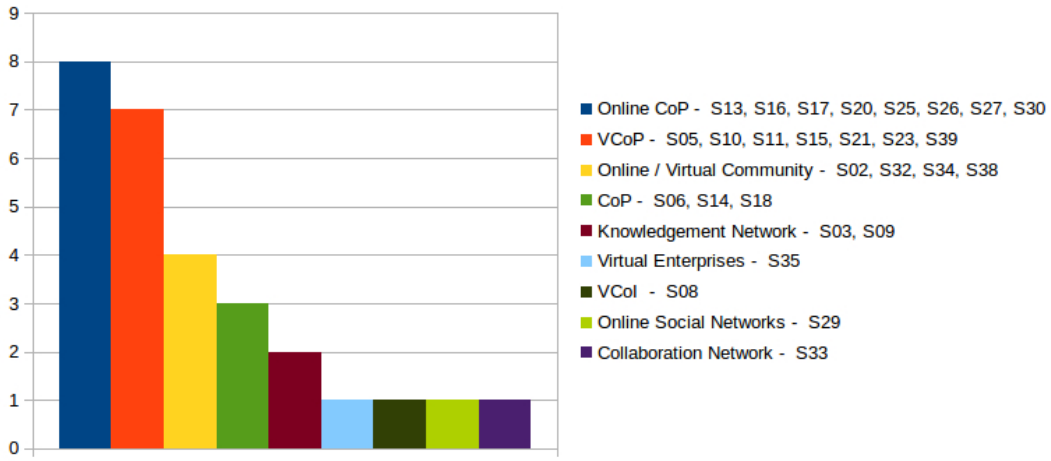


Figure 5: Typologies referred in the primary studies

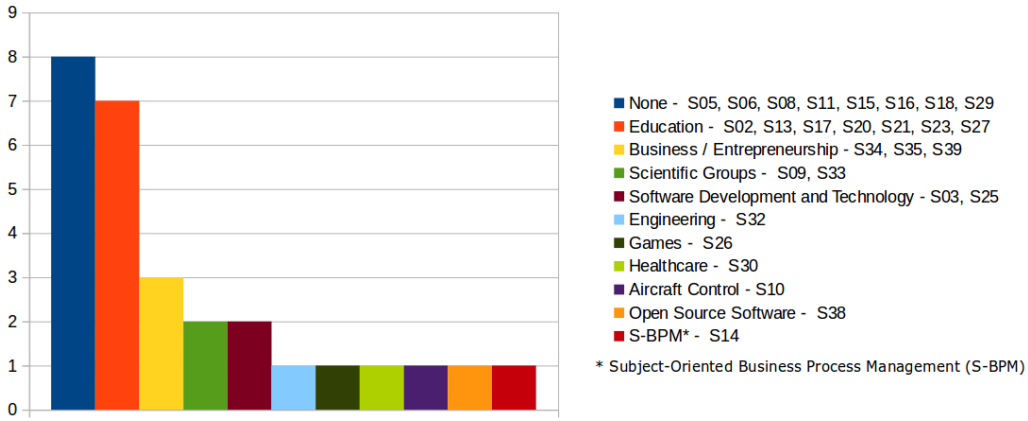


Figure 6: Domain referred in the primary studies

The design of an approach to community evaluation requires the definition of the typology of target community. This definition is not trivial due to the variety of existing terminology. Although some

authors argue that small differences do not impact the community performance evaluation process (Creech et al., 2012), we could see that there is a relation between the theoretical background that supports the approach and the community typology, such as knowledge management and CoP evaluation frameworks. The majority of the selected primary studies clearly establish the typology of the evaluated system in the title or abstract. Some examples of the relationship between typology and theoretical background are shown in Table 2.

Table 2: Relation between typology and theoretical background

Study	Typology	Theoretical Background	Theoretical Background References
S03	Knowledge Networks	Social Network Structural Analysis	Cross and Parker (2004); Dorogovtsev and Mendes (2003)
S15	CoP / VCoP	Knowledge Management	Lee (2001); O'Dell and Jackson (1998)
		CoP Diagnosis	McDermott (2002); Wenger (2004); Wenger and Snyder (2000)
S20	Online CoP	Knowledge Management in CoP	Wenger et al. (2002)
S23	VCoP	Discourse in Virtual Communities	Lave and Wenger (1991); Wenger (1998)
S27	Online CoP	CoP Evaluation (Value Creation Framework)	Wenger et al. (2011)
S32	Online Community	Knowledge Creation in Online Communities	Paavola and Hakkarainen (2005); Scardamalia and Bereiter (2006)
S35	Enterprise Social Network	Knowledge sharing in internal social networks	Al-Oufi and Kim (2012); Reagans and Zuckerman (2008); Smith et al. (2014)

There is an extensive literature regarding evaluation of conventional CoP, in which interaction between members of a community are predominantly face to face, as described in the section Evaluation of CoP and VCoP. However, this literature has not been considered in most of the primary studies that presents evaluation of VCoP and knowledge networks. Our systematic mapping shows that only two (S06 e S27) of the selected primary studies make explicit application of CoP evaluation background to design their approach for evaluating Online/Virtual CoP, as illustrated in Figure 7.

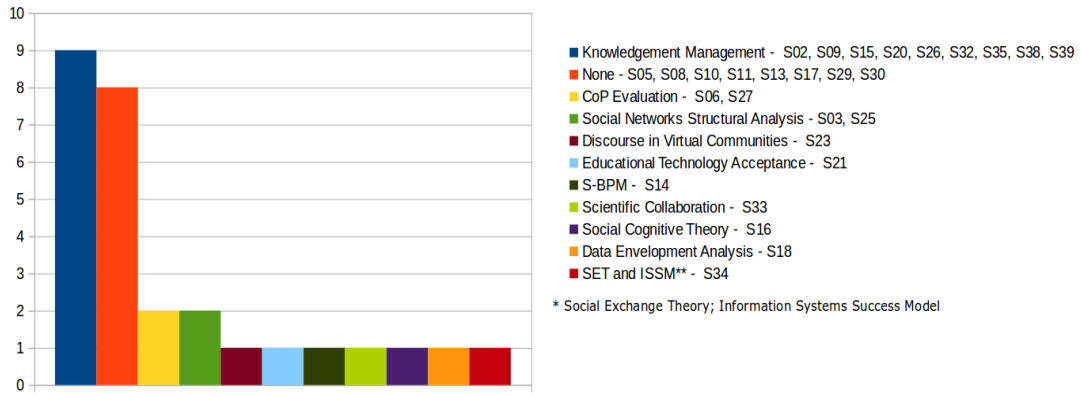


Figure 7: Theoretical background referred in the primary studies

Other studies use the following background:

1. Theories related to CoP cultivation, such as: knowledge management (S02, S09, S15, S20, S26, S32, S35, S38 and S39); and discourse in virtual communities (S23);

2. Specific concepts of the domain of application (S14, S16, S18, S21, S33 and S34);
3. Theories related to Social Network Analysis (S03 and S25); or
4. Do not include theoretical background related to CoP, knowledge sharing or specific concepts of the domain of application (S05, S08, S10, S11, S13, S17, S29 and S30).

Strategies and Techniques to analyze structured and unstructured data (RQ3)

The techniques used to analyze structured and unstructured data, and the respective numbers of primary studies which apply them are presented in Figure 8. Details of the techniques used the studies are reported in Table 3.

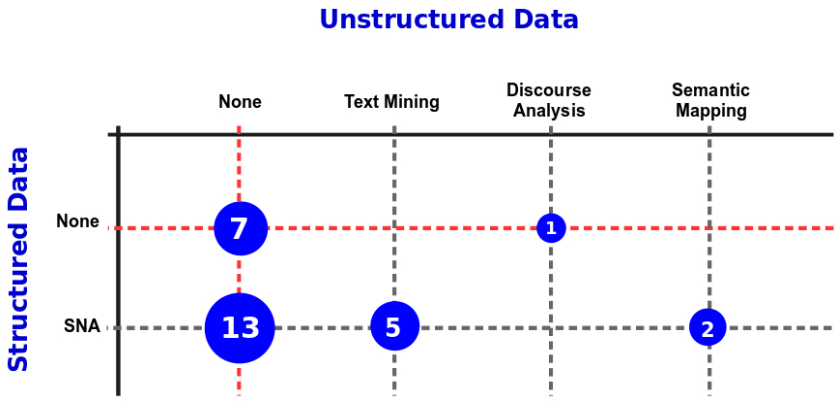


Figure 8: Structured and unstructured data analysis techniques referred in the studies

Seven primary studies (S02, S06, S10, S16, S18, S26 e S34) used observations, interviews and questionnaires to analyze social interaction and content of messages between participants of virtual communities. These approaches are more onerous and inefficient regarding cost and time (Kim, Hong, & Suh, 2012). In contrast, Social Network Data Analysis is frequently referred to as an efficient computational technique, both for structured and unstructured data, to analyze virtual communities and networks (Sapountzi & Psannis, 2018). Kim et al. (2012) state that approaches to evaluate VCoP based on computational techniques demands less effort and time to collect and treat data because they undertake automated analysis of information generated from technological platforms in which the communities were implemented.

Table 3: Techniques used in each study to analyze structured and unstructured data

Structured Data	Unstructured Data	Studies	Quantity
None	None	S02, S06, S10, S16, S18, S26, S34	7
None	Discourse Analysis	S23	1
SNA	None	S03, S09, S13, S14, S15, S17, S20, S25, S27, S33, S35, S38, S39	13
SNA	Text Mining	S05, S08, S11, S21, S29	5
SNA	Semantic Mapping	S30, S32	2

SNA is predominantly applied to analyze structured data; it was used in 20 primary studies. Two of them proposed specializations of SNA in order to deal with specific aspects of the application domain. S13 uses Social Learning Network Analysis (SLNA) and Social Learning Context Analysis (SLCA) to map a greater amount of activities developed in online communities of educators; and,

S14 applies, in addition to SNA, Organizational Network Analysis (ONA) and Value Network Analysis (VNA) to generate metrics that indicate possible information deficiency of the community, information flow deadlocks and communication patterns that could be improved.

SNA is frequently referred to as an efficient technique to analyze the behavior and the interaction between members of VCoP (Ríos, Aguilera, Nuñez-Gonzalez, & Graña, 2017). However, it is not sufficient to provide a complete overview of the community performance regarding its evolution and knowledge sharing. Alvarez, Ríos, Aguilera, Merlo, and Guerrero (2010) propose the combination of SNA with text mining to obtain results closer to the scenario of knowledge sharing. One of the concerns of domain specific VCoP operators is to keep the discussions of the members within the domain context. The analysis of unstructured data might help in dealing with this issue (Alvarez et al., 2010).

Techniques of SNA are combined with analysis of unstructured data in seven of the selected primary studies in order to obtain a more accurate diagnosis about the content of the discussions of virtual communities; five of them applied text mining related strategies as follows:

a. S05, S08, S11 and S29 applied the Topic Modeling method to undertake a semantic analysis of the main terms used by members of virtual communities. This method used techniques such as Latent Dirichlet Allocation (LDA) and Latent Semantic Analysis (LSA), for instance to identify influent members of the community;

b. S21 applies LDA and LSA in a Unified Theory of Acceptance and Use of Technology – UTAUT to analyze the quality of interactions between participants in a VCoP of an American university.

S30 and S32 undertake a semantic mapping in order to relate the lexical terms correspondent to the investigated domains to topics discussed by the community members. This was made to analyze the creation of knowledge within the community. S30 used a tool called Metamap (Aronson & Lang, 2010) to relate terms of medical dictionaries with the topics discussed by the community members whereas S32 used dictionaries of electrical and electronic engineering of IEEE to analyze variables that could suggest creation of knowledge in online communities of engineers. In addition, S23 used a strategy of discourse analysis to deal with unstructured data to investigate the quality of dialogs in a VCoP of an American university, instead of using SNA.

VCoP Aspects measured (RQ4)

The aspects measured by most of the studies are related to knowledge management: creation, flow or knowledge sharing; CoP maturity stage; and, value creation, as shown in Table 4. Only one primary study (S27) measured the aspect value creation. This aspect is used in several face to face CoP evaluation frameworks to express the creation and sharing of knowledge in a community (McDermott, 2002; Wenger et al., 2011; Creech et al., 2012). Both S06 and S27 primary studies used theoretical background specific for CoP evaluation.

Our systematic mapping shows that some primary studies analyze a very specific aspect of VCoP, like key-members, influencers or experts (S05, S08, S26, S29); interest topics (S17); or relation posts/members (S13). VCoP are complex and multifaceted structures which can be observed from different viewpoints, thus models that focus on specific aspects provide insufficient contribution to research and practice (Bolisani & Scarso, 2014).

On the other hand, approaches that focus on broader aspects related to knowledge management were found in 15 of the selected primary studies (see Table 4). These approaches confirm the arguments of Bolisani and Scarso (2014) that describe CoP as a powerful tool for knowledge management. It should be emphasized that S06 and S27 evaluated maturity and value creation in their com-

munities applying theoretical background specific for CoP evaluation. However, both studies collected evaluation data using questionnaires which is not considered a proper technique for VCoP, as described in Section Strategies and Techniques to analyze structured and unstructured data (RQ3).

Table 4: Aspects measured in the primary studies

Measured Aspect		Primary Studies	Quantity
Knowledge Management	Creation, Flow or Knowledge Sharing	S02, S09, S14, S15, S16, S18, S20, S25, S30, S32, S35, S38, S39	13
	CoP/VCoP Maturity Stage	S06	1
	Value Creation	S27	1
Key-members, influencers or experts		S05, S08, S26, S29	4
Collaboration Intensity/Frequency		S33, S34	2
Community characterization		S11	1
Competencies of the Community		S10	1
Interest topics		S17	1
Network Structure		S03	1
Quality of the collaborative dialogue		S23	1
Relation post/members		S13	1
Technology Acceptance		S21	1

GUIDELINES DEFINITION (RQ5)

Lee, Suh, and Hong (2010) argue that several existing approaches to evaluate VCoP do not provide guidelines to overcome the community weak points after the evaluation. They emphasize the need to provide guidelines that can support community operators to improve the community performance. Only 17.8% (S06, S09, S15, S16 and S34) of the selected primary studies included this kind of guidelines, thus there is a research gap that needs to be explored in order to improve the application and management of VCoP. Table 5 reports a summary of the five primary studies and their guidelines.

Table 5: Summary of the Studies and their Guidelines

Study	Summary of the Studies and their Guidelines
S06	The authors describe a systematic framework with maturity stages for navigating CoP. They provide a road map for moving from immature activities to mature approaches aligned to strategic business imperatives.
S09	The approach uses SNA to analyze a scientific knowledge network. From the perspective of improved network management, strategies are suggested to improve knowledge sharing ability in the scientific collaborative network.
S15	The purpose of the study is to develop a diagnosis framework for identifying knowledge sharing activities in CoP using SNA and to suggest strategies for individual CoP based on the proposed diagnosis framework.
S16	The authors examine why members continue to share knowledge in VCoP. They suggest that VCoP administrators adopt systematic procedures to promote knowledge sharing.
S34	The authors propose several guidelines that assist business-to-business VCoP providers in building and maintaining successful communities.

RESEARCH GAPS

In order to highlight the research gaps obtained from our systematic mapping study, we formulated three questions based on research questions RQ3, RQ4 and RQ5: *(i)* the primary study combines strategies or techniques to analyze VCoP structured and unstructured data? *(ii)* The primary study measure aspects related to knowledge management: creation, flow or knowledge sharing? and *(iii)* The primary study establishes guidelines to support VCoP management based on the evaluation results? The Figure 9 shows the studies that answer these questions positively (inside the circle) and negatively (outside the circle). The majority of studies measure aspects related to knowledge management, however only S06 measure the aspect value creation. It should be emphasized that no study met all the three questions. This shows a research gap, because we did not find studies to VCoP evaluation that combine strategies or techniques to analyze structured and unstructured data, measure aspects related to knowledge management and establish guidelines to support VCoP management based on the evaluation results.

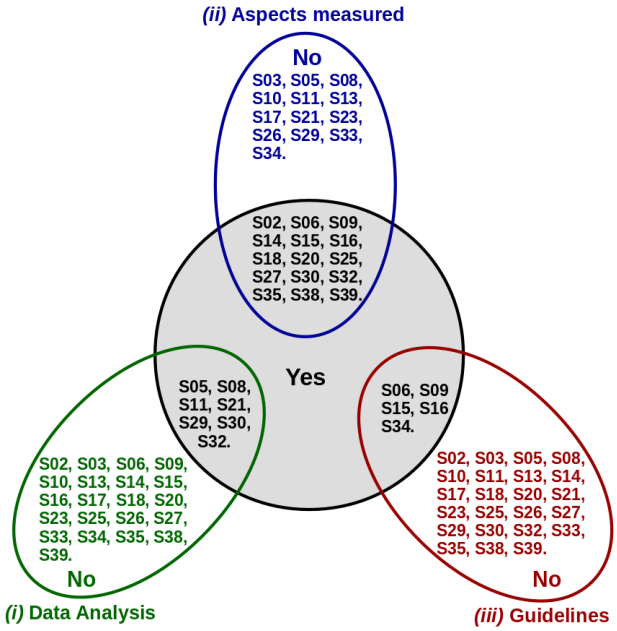


Figure 9: Primary studies and three research questions

THREATS OF VALIDITY

Our study has some threats to the validity inherent to the process of systematic mapping. During the analysis of the abstracts, some papers may have been excluded even if they matched the inclusion criteria in their content, for example: the authors did not mention clearly, in the abstract, the objective of evaluating some knowledge-based social structure, the community's typology or the aspect to be measured in the evaluation method. Furthermore, the decision to exclude a paper based on its contents could be biased by the researcher's interpretation of some of the criteria (both inclusion and exclusion). Both cases were mitigated by the following: before excluding a primary study, the reviewers performed a quick reading on the whole study to certify that it really does not present any method, process or framework to evaluate VCoP or knowledge-based social structure.

During the data extraction, the studies were classified based on our own judgment. This means that some studies could have been classified incorrectly. In order to mitigate this threat, the classification process was revised; in cases of conflict a specialist was consulted. Another threat concerning data extraction refers to the fact that there is not only one classification for theoretical background and aspects to be measured in VCoP. The primary studies do not always explicitly refer to these issues,

when they did it, they sometimes use terms that are different from ours. When a primary study referred to several theoretical backgrounds, we selected the most outstanding ones. Over again, we mitigated this threat asking a specialist in cases of conflict.

Our study tried to gather all available primary studies. Studies were retrieved by an automated search and the use of different databases. However, it is important to consider the absence of some important studies. First, even with simple filters, it is possible that some study has been incorrectly removed. Secondly, even using five databases some relevant studies could be not indexed within our choices. We tried to mitigate these problems with a review of the protocol and validating carefully the search string.

Lastly, a large quantity of duplicate primary studies was found. Databases as Scopus and Engineering Village do the indexing by gathering other databases which generate this problem. We use the Parsifal1 to manage the selection of primary studies and to automate the elimination of duplicate studies avoiding manual errors.

CONCLUSION AND RESEARCH OPPORTUNITIES

This paper presents a systematic mapping study which identifies the main features of VCoP evaluation processes. It involved 39 primary studies, recovered from 5 digital libraries based to predefined research questions, which were further analyzed and resulted in 28 selected studies to be deeper explored. VCoP, similar to CoP, are complex structures that can be analyzed according to several aspects, thus their evaluation process is not trivial. The systematic mapping study mainly focused on predefined research questions and the identification of research gaps that need to be further explored. These gaps are classified into: *(i)* aspects measured; *(ii)* strategies applied to analyze structured and unstructured data; and, *(iii)* guidelines proposed to improve community management.

The systematic mapping pointed out that the aspects measured to evaluate VCoP have not been considering the existing theoretical background for CoP evaluation; evidences of this were found even in studies that used the typology online or virtual CoP. When comparing VCoP to CoP, it is important to emphasize that VCoP have intrinsic features due to the fact that they operate on ICT platforms and interactions are predominantly made over the Internet; however, they still have close relation to traditional CoP as initially defined by Wenger (1998). Thus, a raised research gap is the possibility of applying existing concepts of CoP evaluation such as value creation in the design of VCoP evaluation approaches.

The strategies used to analyze structured and unstructured data in evaluation approaches are considered complementary because they can provide metrics of different aspects of the communities, such as: data about how VCoP members interact and about themes debated and the intensity of the discussions on these themes. Most of the selected studies used several computational techniques for social network data analysis. On the other hand, only, 25% (seven studies) combined both structured and unstructured techniques in order to analyze interaction between members and the content discussed by them.

The evaluation process needs to be based on a set of metrics that expresses significant aspects of a VCoP. These metrics should be enough to provide guidelines to support community operators to improve the community performance according to the interest of its stakeholders. For instance, the facilitators are responsible for stimulating interactions and steering the community, thus they are interested in the activities that provide results. Techniques of analysis of structured data such as SNA can be used to provide metrics and guidelines to support these stakeholders. On the other hand, community members and managers are interested in challenges associated to the practices which are more concerned with unstructured data. Thus, the techniques associated with unstructured data can provide data about the discussion carried out by the community and therefore support the definition of guidelines to support community managers to improve the performance of aspects related to

knowledge sharing and domain evolution. Lastly, only 17.8% of the selected primary studies considered the use of guidelines based on the results of the evaluation, thus there is a need to improve the VCoP evaluation models in order to connect metrics with guidelines to improve their performance.

REFERENCES

Abigail, L. K. M. (2016). Do communities of practice enhance faculty development? *Health Professions Education*, *2*(2), 61–74. https://doi.org/10.1016/j.hpe.2016.08.004

Agrawal, V., & Snekkenes, E. A. (2017). An investigation of knowledge sharing behaviors of students on an online community of practice. *Proceedings of the 5th International Conference on Information and Education Technology (ICIET17)* (pp. 106–111). ACM. https://doi.org/10.1145/3029387.3029412

Agrifoglio, R. (2015). Communities of practice abstract. In R. Agrifoglio, *Knowledge preservation through community of practice: Theoretical issues and empirical evidence*. Springer, Cham. https://doi.org/10.1007/978-3-319-22234-9

Al-Oufi, S., & Kim, H. N. (2012). A group trust metric for identifying people of trust in online social networks. *Expert Systems with Applications*, *39*(18), 13173–13181. https://doi.org/10.1016/j.eswa.2012.05.084

Alshammari, A. O., & Jung, H. (2017). Designing community of practice systems: A value sensitive approach. *2017 International Conference on Informatics, Health and Technology (ICIHT)* (pp. 1-7). Riyadh, Saudi Arabia: IEEE. https://doi.org/10.1109/ICIHT.2017.7899005

Alvarez, H., Ríos, S. A., Aguilera, F., Merlo, E., & Guerrero, L. (2010). Enhancing social network analysis with a concept-based text mining approach to discover key members on a virtual community of practice. In R. Setchi, I. Jordanov, R. J. Howlett, & L. C. Jain (Eds.), *Knowledge-based and intelligent information and engineering systems (KES 2010): Lecture Notes in Computer Science, Volume 6277*, (pp. 591–600). Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-15390-7_61

Ardichvili, A., Page, V., & Wentling, T. (2003), Motivation and barriers to participation in virtual knowledge-sharing communities of practice. *Journal of Knowledge Management*, 7(1), 64-77. https://doi.org/10.1108/13673270310463626.

Aronson, A. R., & Lang, F. (2010). An overview of MetaMap: Historical perspective and recent advances. *Journal of the American Medical Informatics Association*, *17*(3), 229–236. https://doi.org/10.1136/jamia.2009.002733

Behfar, S. K., Turkina, E., & Burger-Helmchen, T. (2018). Knowledge management in OSS communities: Relationship between dense and sparse network structures. *International Journal of Information Management*, *38*(1), 167–174. https://doi.org/10.1016/j.ijinfomgt.2017.09.004

Bolisani, E., & Scarso, E. (2014). The place of communities of practice in knowledge management studies: A critical review. *Journal of Knowledge Management*, *18*(2), 366–381. https://doi.org/10.1108/JKM-07-2013-0277

Braun, P., Cuzzocrea, A., Leung, C. K., Pazdor, A. G. M., & Tran, K. (2016). Knowledge discovery from social graph data. *Procedia Computer Science*, *96*, 682–691. https://doi.org/10.1016/j.procs.2016.08.250

Cambridge, D., & Perez-Lopez, K. (2012). First steps towards a social learning analytics for online communities of practice for educators. *LAK '12: Proceedings of the Second International Conference on Learning Analytics and Knowledge* (pp. 69–72). https://doi.org/10.1145/2330601.2330622

Chan, R. Y., Ho, K. M., Jia, S., Wang, Y., Yan, X., & Yu, X. (2016). Facebook and information security education: What can we know from social network analyses on Hong Kong engineering students? *2016 International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 303-307). Bangkok, Thailand: IEEE. https://doi.org/10.1109/TALE.2016.7851811

Chang, C. K., Chen, G. D., & Li, L. Y. (2008). Constructing a community of practice to improve coursework activity. *Computers and Education*, *50*(1), 235–247. https://doi.org/10.1016/j.compedu.2006.05.003

Cheung, C. M. K., Lee, M. K. O., & Lee, Z. W. Y. (2013). Understanding the continuance intention of knowledge sharing in online communities of practice through the post-knowledge-sharing evaluation processes. *Journal of the American Society for Information Science and Technology*, *64*(7), 1357–1374. https://doi.org/10.1002/asi.22854

Chou, S. W., & Hsu, C. S. (2018). An empirical investigation on knowledge use in virtual communities – A relationship development perspective. *International Journal of Information Management*, *38*(1), 243–255. https://doi.org/10.1016/j.ijinfomgt.2017.10.003

Clarke, L. (2009). The POD Model: Using communities of practice theory to conceptualize student teachers' professional learning online. *Computers & Education*, *52*(3), 521–529. https://doi.org/10.1016/j.compedu.2008.10.006

Creech, H., Laurie, M., Paas, L., & Parry, J. (2012). Performance improvement and assessment of collaboration: Starting points for networks and communities of practice. *International Institute of Sustainable Development Report*. Winnipeg, Manitoba: Canada. Retrieved from https://www.iisd.org/pdf/2012/performance_improvement_networks.pdf

Cross, R. L., & Parker, A. (2004). *The hidden power of social networks: Understanding how work really gets done in organizations*. Boston, MA: Harvard Business School Press.

Cuadra, L., Ríos, S. A., & L'Huillier, G. (2011). Enhancing community discovery and characterization in VCoP using topic models. *Proceedings of the 2011 IEEE/WIC/ACM International Joint Conferences on Web Intelligence and Intelligent Agent Technology – Workshops, WI-IAT 2011*, *Volume 3*, (pp. 326–329). Lyon, France: IEEE. https://doi.org/10.1109/WI-IAT.2011.97

Del Rosso, C. (2009). Comprehend and analyze knowledge networks to improve software evolution. *Journal of Software Maintenance and Evolution: Research and Practice*, *21*(3), 189-215. https://doi.org/10.1002/smr.408

Dieste, O., & Padua, O. A. G. (2007). Developing search strategies for detecting relevant experiments for systematic reviews. In *1st International Symposium on Empirical Software Engineering and Measurement (ESEM)* (pp. 215–224). Madrid, Spain: IEEE. https://doi.org/10.1109/ESEM.2007.19

Dorogovtsev, S. N., & Mendes, J. F. (2003). *Evolution of networks: From biological nets to the Internet and WWW*. Oxford, UK: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198515906.001.0001

Dube, L., Bourhis, A, Jacob, R. (2006). Towards a typology of virtual communities of practice. *Interdisciplinary Journal of Information, Knowledge and Management*, *1*, 69-93. https://doi.org/10.28945/115

Ehrlich, K., & Carboni, I. (2005). *Inside social network analysis*. Retrieved from https://www.researchgate.net/profile/Inga_Carboni/publication/228397102_Inside_social_network_analysis/links/0deec51f8f0b480f57000000/Inside-social-network-analysis.pdf

Fang, Y. H., & Chiu, C. M. (2010). In justice we trust: Exploring knowledge-sharing continuance intentions in virtual communities of practice. *Computers in Human Behavior*, *26*(2), 235–246. https://doi.org/10.1016/j.chb.2009.09.005

Frank, A. G., Sander, N., Gastaldi, L., Madini, E., & Corso, M. (2017). An assessment model for virtual communities of practice: A study in the oil and gas industry. *Knowledge Management Research & Practice*, *15*(4), 507-522. https://doi.org/10.1057/s41275-017-0074-6

Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management*, *35*(2), 137–144. https://doi.org/10.1016/j.ijinfomgt.2014.10.007

Gharib, R. K., Philpott, E., & Duan, Y. (2017). Factors affecting active participation in B2B online communities: An empirical investigation. *Information and Management*, *54*(4), 516–530. https://doi.org/10.1016/j.im.2016.11.004

Gouardères, E., & Gouardères, G. (2011). Enhancing group cohesion in virtual communities of practice. *2011 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology* (pp. 318–321). https://doi.org/10.1109/WI-IAT.2011.186

Hafeez, K., Alghatas, F. M., Foroudi, P., Nguyen, B., & Gupta, S. (2019). Knowledge sharing by entrepreneurs in a virtual community of practice (VCoP). *Information Technology and People*, *32*(2), 405–429. https://doi.org/10.1108/ITP-09-2016-0202

Hara, N., Shachaf, P., & Stoerger, S. (2009). Online communities of practice typology revisited. *Journal of Information Science*, *35*(6), 740–757. https://doi.org/10.1177/0165551509342361

Hung, D., Chee, T. S., Hedberg, J. G., & Thiam Seng, K. (2005). A framework for fostering a community of practice: Scaffolding learners through an evolving continuum. *British Journal of Educational Technology*, *36*(2), 159–176. https://doi.org/10.1111/j.1467-8535.2005.00450.x

Jan, S. K. (2019). Investigating virtual communities of practice with social network analysis: Guidelines from a systematic review of research. *International Journal of Web Based Communities*, *15*(1), 25-43. https://doi.org/10.1504/IJWBC.2019.098697

Jeon, S. H., Kim, Y. G., & Koh, J. (2011). Individual, social, and organizational contexts for active knowledge sharing in communities of practice. *Expert Systems with Applications*, *38*(10), 12423–12431. https://doi.org/10.1016/j.eswa.2011.04.023

Jiménez-Zarco, A. I., González-González, I., Saigí-Rubió, F., & Torrent-Sellens, J. (2015). The co-learning process in healthcare professionals: Assessing user satisfaction in virtual communities of practice. *Computers in Human Behavior*, *51*, 1303–1313. https://doi.org/10.1016/j.chb.2014.11.057

Khan, S., Liu, X., Shakil, K. A., & Alam, M. (2017). A survey on scholarly data: From big data perspective. *Information Processing and Management*, *53*(4), 1339–1351. https://doi.org/10.1016/j.ipm.2017.03.006

Kim, S. J., Hong, J. Y., & Suh, E. H. (2012). A diagnosis framework for identifying the current knowledge sharing activity status in a community of practice. *Expert Systems with Applications*, *39*(18), 13093–13107. https://doi.org/10.1016/j.eswa.2012.05.092

Kitchenham, B. A. (2004). *Procedures for performing systematic reviews*. Keele University Technical Report TR/SE-0401 (Joint Technical Report). Keele, United Kingdom: Keele University. Retrieved from https://pdfs.semanticscholar.org/2989/0a936639862f45cb9a987dd599dce9759bf5.pdf

Kitchenham, B. A., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*. EBSE Technical Report (EBSE-2007-01). United Kingdom: Keele University & University of Durham. Retrieved from http://www.academia.edu/download/35830450/2_143465389588742151.pdf

Kuah, C. T., Wong, K. Y., & Tiwari, M. K. (2013). Knowledge sharing assessment: An ant colony system based data envelopment analysis approach. *Expert Systems with Applications*, *40*(8), 3137–3144. https://doi.org/10.1016/j.eswa.2012.12.027

L'Huillier, G., Ríos, S. A., Alvarez, H., & Aguilera, F. (2010). Topic-based social network analysis for virtual communities of interests in the Dark Web. *ACM SIGKDD Workshop on Intelligence and Security Informatics2*, *12*(2), 1–9. ACM. https://doi.org/10.1145/1938606.1938615

Lai, H. F. (2010). Applying fuzzy AHP to evaluate the sustainability of knowledge-based virtual communities in healthcare industry. *Proceedings of the 7th International Conference on Service Systems and Service Management (ICSSSM' 10)* (pp. 1033–1038). Tokyo, Japan: IEEE. https://doi.org/10.1109/ICSSSM.2010.5530091

Lakhmani, S., Oppold, P., Rupp, M. A., Szalma, J. L., & Hancock, P. A. (2016). Heterogeneous knowledge distribution in MMO player behavior: Using domain knowledge to distinguish membership in a community of practice. *Computers in Human Behavior*, *55*, 455–467. https://doi.org/10.1016/j.chb.2015.09.032

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Lee, J. (2001). The impact of knowledge sharing, organizational capability and partnership quality on IS outsourcing success. *Information and Management*, *38*(5), 323–335. https://doi.org/10.1016/S0378-7206(00)00074-4

Lee, J., Suh, E., & Hong, J. (2010). A maturity model based CoP evaluation framework: A case study of strategic CoPs in a Korean company. *Expert Systems with Applications*, *37*(3), 2670–2681. https://doi.org/10.1016/j.eswa.2009.08.011

Lei, G., & Xin, G. Q. (2011). Social network analysis on knowledge sharing of scientific groups. In *LISS 2011: Proceedings of the 1st International Conference on Logistics, Informatics and Service Science, Volume 3* (pp. 71–76). Retrieved from https://pdfs.semanticscholar.org/9292/9d07a5236d77ccca416de62db55bfe404448.pdf

Leon, R. D., Rodríguez-Rodríguez, R., Gómez-Gasquet, P., & Mula, J. (2017). Social network analysis: A tool for evaluating and predicting future knowledge flows from an insurance organization. *Technological Forecasting and Social Change*, *114*, 103–118. https://doi.org/10.1016/j.techfore.2016.07.032

Lev-On, A., & Steinfeld, N. (2014, June). Managers and members in online communities of practice: What are they talking about? *Proceedings of the 15th Annual International Conference on Digital Government Research* (pp. 118–123). ACM. https://doi.org/10.1145/2612733.2612771

McDermott, R. (2002). Measuring the impact of communities: How to draw meaning from measures of communities of practice. *Knowledge Management Review*, *5*(2), 26–29. Retrieved from https://toolkits.knowledge-success.org/sites/default/files/Measuring%20the%20Impact%20of%20Communities.pdf

McKellar, K. A., Pitzul, K. B., Yi, J. Y., & Cole, D. C. (2014). Evaluating communities of practice and knowledge networks: A systematic scoping review of evaluation frameworks. *EcoHealth*, *11*(3), 383–399. https://doi.org/10.1007/s10393-014-0958-3

Menchaca, M. P., & Cowan, J. E. (2016, December). Value creation stories in a community of practice: Assessing value in an online Masters' program. *Future Technologies Conference (FTC) 2016* (pp. 1340–1349). San Francisco, CA: IEEE. https://doi.org/10.1109/FTC.2016.7821640

Nistor, N., Baltes, B., Dascălu, M., Mihăilă, D., Smeaton, G., & Trăuşan-Matu, Ş. (2014). Participation in virtual academic communities of practice under the influence of technology acceptance and community factors. A learning analytics application. *Computers in Human Behavior*, *34*, 339–344. https://doi.org/10.1016/j.chb.2013.10.051

Nistor, N., Trəuşan-Matu, Ş., Dascəlu, M., Duttweiler, H., Chiru, C., Baltes, B., & Smeaton, G. (2015). Finding student-centered open learning environments on the internet: Automated dialogue assessment in academic virtual communities of practice. *Computers in Human Behavior*, *47*, 119–127. https://doi.org/10.1016/j.chb.2014.07.029

O'Dell, C., & Jackson, G. C. (1998). If we only knew what we know: Identification and transfer of internal best practices. *California Management Review*, *40*(3), 154–174. https://doi.org/10.2307/41165948

Paavola, S., & Hakkarainen, K. (2005). The knowledge creation metaphor – An emergent epistemological approach to learning. *Science & Education*, *14*(6), 535–557. https://doi.org/10.1007/s11191-004-5157-0

Pattinson, S., Preece, D., & Dawson, P. (2016). In search of innovative capabilities of communities of practice: A systematic review and typology for future research. *Management Learning*, *47*(5), 506–524. https://doi.org/10.1177/1350507616646698

Pérez-López, K., Cambridge, D., & Byers, A. (2013). Simple and computational heuristics for forum management in the NSTA learning center: A role for learning analytics in online communities of practice supporting teacher learning. *Proceedings of the 46th Hawaii International Conference on System Sciences* (pp. 3088–3097). Wailea, Maui, HI: IEEE https://doi.org/10.1109/HICSS.2013.481

Reagans, R. E., & Zuckerman, E. W. (2008). Why knowledge does not equal power: The network redundancy trade-off. *Industrial and Corporate Change*, *17*(5), 903–944. https://doi.org/10.1093/icc/dtn036

Ríos, S. A., Aguilera, F., Nuñez-Gonzalez, J. D., & Graña, M. (2017). Semantically enhanced network analysis for influencer identification in online social networks. *Neurocomputing*, *326–327*, 71-81. https://doi.org/10.1016/j.neucom.2017.01.123

Sapountzi, A., & Psannis, K. E. (2018). Social networking data analysis tools & challenges. *Future Generation Computer Systems*, *86*, 893-913. https://doi.org/10.1016/j.future.2016.10.019

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97–116). Cambridge, United Kingdom: Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.008

Schlattmann, S. (2017). Capturing the collaboration intensity of research institutions using social network analysis. *Procedia Computer Science*, *106*, 25–31. https://doi.org/10.1016/j.procs.2017.03.005

Smith, E. P., Wise, E., Rosen, H., Rosen, A., Childs, S., & McManus, M. (2014). Top-down, bottom-up, and around the jungle gym: A social exchange and networks approach to engaging afterschool programs in implementing evidence-based practices. *American Journal of Community Psychology*, *53*(3–4), 491–502. https://doi.org/10.1007/s10464-014-9656-0

Sohn, D. (2014). Coping with information in social media: The effects of network structure and knowledge on perception of information value. *Computers in Human Behavior*, *32*, 145–151. https://doi.org/10.1016/j.chb.2013.12.006

Stewart, S. A., & Abidi, S. S. R. (2017). Leveraging medical taxonomies to improve knowledge management within online communities of practice: The knowledge maps system. *Computer Methods and Programs in Biomedicine*, *143*, 121–127. https://doi.org/10.1016/j.cmpb.2017.03.003

Tanwar, M., Duggal, R., & Khatri, S. K. (2015). Unravelling unstructured data: A wealth of information in big data. In *4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO) (Trends and Future Directions)* (pp. 1–6). Noida, India: IEEE. https://doi.org/10.1109/ICRITO.2015.7359270

Teo, H. J., Johri, A., & Lohani, V. (2017). Analytics and patterns of knowledge creation: Experts at work in an online engineering community. *Computers and Education*, *112*, 18–36. https://doi.org/10.1016/j.compedu.2017.04.011

Thoms, B., Garrett, N., Herrera, J. C., & Ryan, T. (2008). Understanding the roles of knowledge sharing and trust in online learning communities. In *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)* (pp. 3-3). Waikoloa, HI: IEEE. https://doi.org/10.1109/HICSS.2008.481

Veenswijk, M., & Chisalita, C. M. (2007). The importance of power and ideology in communities of practice: The case of a de-marginalized user interface design team in a failing multi-national design company. *Information Technology and People*, *20*(1), 32–52. https://doi.org/10.1108/09593840710730545

Wang, G. A., Liu, X., Wang, J., Zhang, M., & Fan, W. (2015). Examining micro-level knowledge sharing discussions in online communities. *Information Systems Frontiers*, *17*(6), 1227–1238. https://doi.org/10.1007/s10796-015-9566-1

Wasko, M. M. L., & Faraj, S. (2005). Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. *MIS Quarterly*, *29*(1), 35–57. https://doi.org/10.2307/25148667

Waycott, J., Thompson, C., Sheard, J., & Clerehan, R. (2017). A virtual panopticon in the community of practice: Students' experiences of being visible on social media. *The Internet and Higher Education*, *35*, 12–20. https://doi.org/10.1016/j.iheduc.2017.07.001

Weber, J., Schmidt, W., & Weber, P. (2012). Using social network analysis and derivatives to develop the S-BPM approach and community of practice. *S-BPM ONE 2012: S-BPM ONE – Scientific Research* (pp. 205-217). https://doi.org/10.1007/978-3-642-29133-3_13

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511803932

Wenger, E. (2004). Knowledge management as a doughnut: Shaping your knowledge strategy through communities of practice. *Ivey Business Journal*, *68*(3). Retrieved from https://iveybusinessjournal.com/publication/knowledge-management-as-a-doughnut/

Wenger, E., McDermott, R. A., Snyder, W. M. (2002). *Cultivating communities of practice*. Boston, MA: Harvard Business School Press. https://dl.acm.org/doi/book/10.5555/599834.

Wenger, E., & Snyder, W. M. (2000). Communities of practice: The organizational frontier. *Harvard Business Review*, *78*(1), 139-146. Retrieved from http://www.psycholosphere.com/Communities%20of%20Practice%20-%20the%20organizational%20frontier%20by%20Wenger.pdf

Wenger, E., Trayner, B., & De Laat, M. (2011). Promoting and assessing value creation in communities and networks: A conceptual framework. *The Netherlands: Ruud de Moor Centrum (Rapport 18)*, *20*, 1–60. Retrieved from https://www.leerarchitectuur.nl/wp-content/uploads/2013/03/Value-creation-Wenger-De-Laat-Trayner.pdf

Yang, X., & Li, G. (2016). Factors influencing the popularity of customer-generated content in a company-hosted online co-creation community: A social capital perspective. *Computers in Human Behavior*, *64*, 760–768. https://doi.org/10.1016/j.chb.2016.08.002

Zhang, M., & Liu, S. (2014). Study on knowledge management behaviors in teachers' online communities of practice. *3rd International Conference of Educational Innovation through Technology (EITT 2014)* (pp. 230–235). Brisbane, Australia: IEEE. https://doi.org/10.1109/EITT.2014.44

APPENDIX

Table A1 – The list of the primary studies analyzed in this systematic mapping

Study	Title	Reference
**S01	Constructing a community of practice to improve coursework activity	(Chang, Chen, & Li, 2008)
S02	Understanding the roles of knowledge sharing and trust in online learning communities	(Thoms, Garrett, Herrera, & Ryan, 2008)
S03	Comprehend and analyze knowledge networks to improve software evolution	(Del Rosso, 2009)
**S04	Applying fuzzy AHP to evaluate the sustainability of knowledge-based virtual communities in healthcare industry	(Lai, 2010)
S05	Enhancing social network analysis with a concept-based text mining approach to discover key members on a virtual community of practice	(Alvarez et al., 2010)
S06	A maturity model based CoP evaluation framework: A case study of strategic CoPs in a Korean company	(Lee et al., 2010)
**S07	In justice we trust: Exploring knowledge-sharing continuance intentions in virtual communities of practice	(Fang & Chiu, 2010)
S08	Topic-based social network analysis for virtual communities of interests in the Dark Web	(L'Huillier, Ríos, Alvarez, & Aguilera, 2010)
S09	Social network analysis on knowledge sharing of scientific groups	(Lei & Xin, 2011)
S10	Enhancing Group Cohesion in Virtual Communities of Practice	(Gouardères & Gouardères, 2011)
S11	Enhancing community discovery and characterization in VCoP using topic models	(Cuadra, Ríos, & L'Huillier, 2011)
**S12	Individual, social, and organizational contexts for active knowledge sharing in communities of practice	(Jeon, Kim, & Koh, 2011)
S13	First Steps Towards a Social Learning Analytics for Online Communities of Practice for Educators	(Cambridge & Perez-Lopez, 2012)
S14	Using Social Network Analysis and Derivatives to Develop the S-BPM Approach and Community of Practice	(Weber, Schmidt, & Weber, 2012)
S15	A diagnosis framework for identifying the current knowledge sharing activity status in a community of practice	(Kim et al., 2012)
S16	Understanding the Continuance Intention of Knowledge Sharing in Online Communities of Practice Through the Post-Knowledge-Sharing Evaluation Processes	(Cheung, Lee, & Lee, 2013)
S17	Simple and computational heuristics for forum management in the NSTA learning center: A role for learning analytics in online communities of practice supporting teacher learning	(Pérez-López, Cambridge, & Byers, 2013)

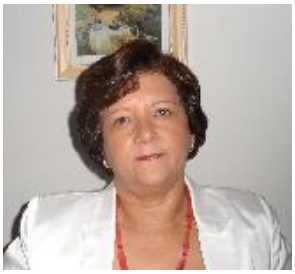
Study	Title	Reference
S18	Knowledge sharing assessment: An ant colony system based data envelopment analysis approach	(Kuah, Wong, & Tiwari, 2013)
**S19	Managers and members in online communities of practice: What are they talking about?	(Lev-On & Steinfeld, 2014)
S20	Study on knowledge management behaviors in teachers' online communities of practice	(Zhang & Liu, 2014)
S21	Participation in virtual academic communities of practice under the influence of technology acceptance and community factors	(Nistor et al., 2014)
**S22	Coping with information in social media: The effects of network structure and knowledge on perception of information value	(Sohn, 2014)
S23	Finding student-centered open learning environments on the internet: Automated dialogue assessment in academic virtual communities of practice	(Nistor et al., 2015)
**S24	The co-learning process in healthcare professionals: Assessing user satisfaction in virtual communities of practice	(Jiménez-Zarco, González-González, Saigí-Rubió, & Torrent-Sellens, 2015)
S25	Examining micro-level knowledge sharing discussions in online communities	(Wang et al., 2015)
S26	Heterogeneous knowledge distribution in MMO player behavior: Using domain knowledge to distinguish membership in a community of practice	(Lakhmani, Oppold, Rupp, Szalma, & Hancock, 2016)
S27	Value Creation Stories in a Community of Practice: Assessing Value in an Online Masters' Program	(Menchaca & Cowan, 2016)
**S28	An Investigation of Knowledge Sharing Behaviors of Students on an Online Community of Practice	(Agrawal & Snekkenes, 2017)
S29	Semantically enhanced network analysis for influencer identification in online social networks	(Ríos et al., 2017)
S30	Leveraging medical taxonomies to improve knowledge management within online communities of practice: The knowledge maps system	(Stewart & Abidi, 2017)
**S31	Designing community of practice systems: A value sensitive approach	(Alshammari & Jung, 2017)
S32	Analytics and patterns of knowledge creation: Experts at work in an online engineering community	(Teo, Johri, & Lohani, 2017)
S33	Capturing the Collaboration Intensity of Research Institutions Using Social Network Analysis	(Schlattmann, 2017)
S34	Factors affecting active participation in B2B online communities: An empirical investigation	(Gharib, Philpott, & Duan, 2017)
S35	Social network analysis: A tool for evaluating and predicting future knowledge flows from an insurance organization	(Leon, Rodríguez-Rodríguez, Gómez-Gasquet, & Mula, 2017)
**S36	A virtual panopticon in the community of practice: Students' experiences of being visible on social media	(Waycott et al., 2017)

Study	Title	Reference
**S37	An empirical investigation on knowledge use in virtual communities–A relationship development perspective	(Chou & Hsu, 2018)
S38	Knowledge management in OSS communities: Relationship between dense and sparse network structures	(Behfar, Turkina, & Burger-Helmchen, 2018)
S39	Knowledge sharing by entrepreneurs in a virtual community of practice (VCoP)	(Hafeez et al., 2019)

** = excluded study

BIOGRAPHIES

Rogério Ferreira da Silva is a doctoral candidate in the Institute of Mathematics and Computer Science, University of São Paulo, Brazil. He has M.Sc. In Computer Science, focusing in Software Engineering. His field of research addresses topics related to the development of learning objects for mobile devices, open educational resources and assessment of online communities of practice and virtual knowledge networks.



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