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Theories in the Communication Context in Distributed Software Development Teams in Computer Science Literature: A Systematic Mapping Study



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ABSTRACT

Communicating effectively in Distributed Software Development teams is a lingering challenge, and researchers have proposed interventions in the form of new models, frameworks, and tools to support these teams' communication. In this context, by considering the historical nature of scientific theories in the literature, this study aims to identify the theories used to support research works in Distributed Software Development Teams in the Communication context. To achieve this goal, we performed an Extensive Literature Review in the format of a Systematic Mapping Study, according to Kitchenham and Charters' guidelines. Results include a list of 21 referred theories, discussions on the identified tendency of using theories as references for the media and social aspects, and considerations on the proximity of some of those theories to Distributed Software Development teams.



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INTRODUCTION:

Several organizations have been adopting the Distributed Software Development (DSD) despite the odds of its benefits and challenges, including communication breakdowns that impose risks for implementing development projects and affect the software process quality (1). The research community has identified effective communication in distributed teams as a challenge for some time (2-3), mostly when performed globally(4-5), i.e., in Global Software Development Teams. At this point, researchers have been developing interventions to support the improvement of communication for some time (6), using the literature as a reference for their works. Still, by considering the historical nature of Scientific Theories in the literature, we argue that the current status of the usage of theories in DSD and Communication works is not clear. Theories are important researchers, as they offer a common conceptual framework for allowing the organization and structuring of facts and knowledge in a concise and precise manner (7). The absence of underlying theories in Software Engineering studies leads to difficulties in interpreting results; it is recognized as a barrier for studies' comparison (8) and may lead to the oversimplification or over rationalization of reality (9-10). This study aims at identifying the theories used to support studies that include the Communication phenomenon in Distributed Software Development Teams in Computer Science Literature. Thereby we expect to establish a reference for future works in academia on improving communication in Distributed Software Development Teams.

MATERIALS AND METHODS:

We performed the Systematic Mapping Study (SMS) according to the guidelines from Kitchenham and Charters (11) for extensive literature reviews. We choose this methodology for being an extensive approach to the identification of evidence in a domain at a larger scale of granularity (11), which is in line with our primary goal of identifying the maximum number of referred theories in our research context. Kitchenham and Charters (11) also state the need for the definition of a search strategy, including the consultation with individuals with relevant experience, defining synonyms for structural terms from the research questions, choosing the adequate search engines, and construct search strings. Therefore, to proceed with this research, we elicited four researchers in total, two Senior researchers (a D.Sc. and an M.Sc.) and two

Junior researchers with a Major in Computer Science related area each. After that, we proceeded by applying our *Search Strategy*, which we describe in the subtopics as follows.

Research Question

Kitchenham and Charters (11) state that the research question's specification is of the utmost importance of any systematic review, as those questions will drive the overall research methodology, including the identification of primary studies, the data extraction, and the analysis process. Therefore, we constructed the following research question according to our main objective: SMS-RQ1: Which are the Theories included in works on Distributed Software Development Teams and Communication?

Academic databases

We performed our search in six academic databases, i.e., Search Engines, for automatic search and snowballing procedures. We selected our academic databases based on the selection of relevant ones indicated by Dybå and coauthors (12) and the opinion of our fellow researchers and ours as well to get to our selection, which we present in Table no 1. We selected six relevant and popular academic databases, including the IEEE Xplore and ACM Digital Library. We also considered using the Google Scholar database, but we discarded this option due to limitations on the search mechanism for better filtering our target results.

Table No. 1: Academic databases

Id	Academic Database	URL
1	IEEE Xplore	http://ieeexplore.ieee.org
2	ACM Digital Library	http://dl.acm.org
3	Scopus	http://www.scopus.com
4	Wiley Online Library	http://onlinelibrary.wiley.com
5	Web of Science	http://webofknowledge.com
6	Engineering Village	https://www.engineeringvillage.com

Key Terms

To better support our search string’s construction, we defined a list of structural elements (11), followed by the specification of relevant terms and synonyms, as derived elements, which we present in Table no 2.

Table No. 2: Key terms

Structural Element	Relevant Term	Synonyms*
Intervention	Theories	Theory(ies); Theorizing; Theorization.
Outcomes	Communication	Communication; Communicate; Communicating; Communicative; Information Sharing; Information Transfer.
Population	DSD	Distributed Software Development; DSD; Distributed development; Distributed Team(s); Global Software Engineering; GSE; Global Software Development; GSD; Global Team(s); Global Software Team(s); Globally Distributed Development; Globally Distributed Work; Offshore; Offshoring; Outsourcing; Geographically; Distributed Software Development; Collaborative Software Development; Cooperative Software Development; CSD; Collaborative Software Engineering; Cooperative Software Engineering; CSE.

*Including substantives, adjectives, and plurals (when applicable).

Search String

Next, we present our based proposed search string in the boolean logic structure and based on the key terms as synonyms (Table no 2).

SM-SS1:(*“theory”* OR *“theories”* OR *“theorizing”* OR *“theorization”*) AND (*“communication”* OR *“communicate”* OR *“communicating”* OR *“communicative”* OR *“information sharing”* OR *“information transfer”*) AND (*“distributed software development”*)

OR “dsd” OR “distributed development” OR “distributed team” OR “distributed teams” OR “global software engineering” OR “gse” OR “global software development” OR “gsd” OR “global team” OR “global teams” OR “global software team” OR “global software teams” OR “globally distributed development” OR “globally distributed work” OR “offshore” OR “offshoring” OR “outsourcing” OR “geographically distributed software development” OR “collaborative software development” OR “cooperative software development” OR “csd” OR “collaborative software engineering” OR “cooperative software engineering” OR “cse”

Search Design

We structured the Search Design for this work in two main steps: The first one consisted of an Automatic Search in six search engines (see Table no 1) based on our search string (see “Search String” Section) applied for a title and abstract search. The second consists of a snowballing search based on the selected papers from the automatic search as “seeds.” We proceed by detailing our search design in the subtopics as follows.

Snowballing

After the automatic search and the first run of the selection of studies, we performed an additional snowballing search based on the selected studies from the automatic search as seeds. The reason behind this methodological choice is to diversify our source (identification) of studies, in which we expect to include non-previously identifiable ones. Therefore, performed a one-level forward work inclusion, that is, to include exclusively the studies included in the references section of the selected works, i.e., seeds, and proceed by applying the inclusion and exclusion criteria for further selection.

Selection Strategy

The selection strategy was based on a three-step process, which we applied first for the results for the Automatic search and later on to the Snowballing initial selection as well. We detail our selection strategy steps as follows.

- [SL-1] Two researchers applied the inclusion and exclusion criteria based on reading the Title and Abstract of each work from the initial selection to discard or include studies for the next selection step.

- [SL-2] Two researchers continued to apply the inclusion and exclusion criteria based on reading the Introduction and Conclusion and thereby filter the list of selected studies for the next step.
- [SL-3] Finally, two researchers continued to apply the inclusion and exclusion criteria based on the full-text reading and thereby get to the final selection.

Discrepancies between selection decisions were discussed between the researchers. If a mutual agreement could not be reached, a third associate researcher judged the situation and decided the most appropriate outcome. We used the same list of inclusion and exclusion criteria on each selection step, which we detail in the subtopic as follows.

Inclusion and Exclusion Criteria

We defined a set of inclusion and exclusion criteria to, as stated by Kitchenham and Charters (11), identify the primary studies that provide direct evidence about the research question. Therefore, our inclusion and exclusion criteria are based on the research questions of this work, as suggested by Kitchenham and Charters (11) and Travassos as well (13). Next, we present our Inclusion and Exclusion criteria in Tables no 4 and 5, as follows.

Table No. 3: Inclusion criteria

Acronym	Criteria
IC-01	Primary studies that include Theories in the context of the Communication phenomenon in DSD teams helping to answer the research question SMS-RQ1.

Table No. 4: Exclusion criteria

Acronym	Criteria
EC-01	Studies that are not included in any of the inclusion criteria
EC-02	Studies that are not accessible for downloading from search engines via open and institutional access from our university.
EC-03	Duplicated studies, i.e., the same study from different search engines. Just one incidence will be considered.
EC-04	Replicated studies, i.e., studies that are very similar in content and authorship. The less detailed study will be discarded.
EC-05	Studies that are not in the English language.
EC-06	Studies that are not included in the Computer Science Literature.
EC-07	Secondary studies.
EC-08	Tertiary studies.
EC-09	Studies in the format of Posters.
EC-10	Studies that are not in the format of Conferences, Workshop papers, or Scientific Journals.
EC-11	Studies including the first author of this document.

Data extraction

The data extraction procedure is an important part of an extensive literature review, in which researchers obtain essential text and data from the primary studies in a consistent way according to a defined extraction strategy (14). In this context, researchers apply different ways for extracting data from their selected works (14), including using direct structured forms according to their research needs (11). For this research, we adopted an approach based on a template from Cruzes e Dybå(14), which is based on the aggregation of findings according to its context in an identified study, i.e., one study containing one or more contexts and each context containing one or more findings. Thereby, we better placed the identified excerpts as evidence on their respective original logical dispositions by using this approach.

RESULT AND DISCUSSION:

We proceeded by performing the Search Strategy as described in the previous sections. This effort resulted in selecting 17 studies from the initial list of 423 (obtained by the automatic search) and 2 from 56 (obtained via snowballing). As previously planned, we performed the selection process in a three-step stage and pairs of researchers on each step (see “Selection Strategy”). Table no 5 presents a more detailed view of the selection numbers according to each selection step as follows.

Table No. 5: Selection Numbers

	I*	SL1: Title and Abstract		SL2: Introduction and conclusion		SL3: Full Text	
		R*	S*	R*	S*	R*	S*
Automatic Search	423	359	64	36	28	11	17
Snowballing	56	35	21	18	3	1	2
* I: Initial; R: Rejected; S: Selected.							

As detailed in Table no 5, this research effort resulted in selecting 19 studies, which we present as follows.

1. *ST-004*: Extending Survivability Models for Global Software Development with Media Synchronicity Theory(15).
2. *ST-011*: Near-Synchronicity and Distance: Instant Messaging as a Medium for Global Software Engineering(16).
3. *ST-023*: On the Need for Mixed Media in Distributed Requirements Negotiations(17).
4. *ST-027*: Agile Software Development with Distributed Teams: Senior Management Support(18).
5. *ST-040*: Overcoming Challenges in Global Software Development: The Role of Brokers(19)
6. *ST-088*: Why Does Site Visit Matter in Global Software Development: A Knowledge-based Perspective (20).

7. *ST-090*: Building a Socio-Technical Theory of Coordination: Why and How (Outstanding Research Award)(21)
8. *ST-105*: Intra-organizational Information Asymmetry in Offshore(22).
9. *ST-123*: Computer-mediated Communication to Support Distributed Requirements Elicitations and Negotiations Tasks(23).
10. *ST-132*: The Impact of Media Selection on Stakeholder Communication in Agile Global Software Development: A Preliminary Industrial Case Study(24).
11. *ST-143*: Exploring the Media Mix During IT-offshore Project (25).
12. *ST-158*: Flexible Global Software Development (GSD): Antecedents of Success in Requirements Analysis(26).
13. *ST-184*: The Impact of Time Separation on Coordination in Global Software Teams: A Conceptual Foundation(27).
14. *ST-227*: Effects of Four Distances on Communication Processes in Global Software Projects(28).
15. *ST-321*: Temporal Distance, Communication Patterns, and Task Performance in Teams(29).
16. *ST-347*: Investigation of Knowledge Sharing Behavior in Global Software Development Organizations Using Social Cognitive Theory(30).
17. *ST-401*: Reflecting the Choice and Usage of Communication Tools in Global Software Development projects with Media Synchronicity Theory (31).
18. *ST-452*: Factors Affecting Audio and Text-based Communication Media Choice in Global Software Development Projects(32).
19. *ST-479*: The Role of Communication and Trust in Global Virtual Teams: A Social Network Perspective(33).

Within the selected studies, we performed the extraction process (see “Data Extraction”), and by analyzing the data extracts, we identified 21 referred theories, which we present in Table no 6, as follows.

Table No. 6: Identified Theories

Acronym	Theory	In Studies
GTh	Graph Theory (34)	<i>ST-479</i>
MTC	Mathematical Theory of Communication (35)	<i>ST-004</i>
SNT	Social Network Theory (36)	<i>ST-040</i>
SPT	Social Presence Theory (37)	<i>ST-123, 401, 452, and 479</i>
CT	Control Theory (38)	<i>ST-158</i>
MRT	Media Richness Theory (39)	<i>ST-004, 023, 123, 132, 143, 184, 401, and 452</i>
SCT	Social Cognitive Theory (40)	<i>ST-347</i>
CRDT	Coordination Theory (41)	<i>ST-184</i>
CGRDT	Common Ground Theory (42)	<i>ST-123</i>
TIP	Time-Interaction-Performance Theory (43)	<i>ST-123 and 143</i>
AST	Adaptive Structuration Theory (44)	<i>ST-321</i>
KBTF	Knowledge-Based Theory of The Firm (46)	<i>ST-088 and 105</i>
BT	Boundary Theory (46)	<i>ST-479</i>
TTF	Task-Technology Fit (47)	<i>ST-123</i>
MSYT	Media Synchronicity Theory (48)	<i>ST-004, 011, 123, 132, 143, 227, 321, 401, and 452</i>
BTGP	Behavioral Theory of Group Performance (49)	<i>ST-123</i>
MSWT	Media Switching Theory (50)	<i>ST-023</i>
ST	Structuration Theory (51)	<i>ST-143</i>
AT	Agency Theory (52)	<i>ST-105</i>
TOT	The Theory of One Team (18)	<i>ST-027</i>
STTC	Social-Technical Theory of Coordination (21)	<i>ST-090</i>

DISCUSSION

Among the selected studies, we may notice that most authors in the context of DSD and Communication have been including preexisting theories from other authors to support their works, except for studies *ST-027* and *090*, which directly or indirectly proposed the TOT(18) and STTC(21) theories respectively. Furthermore, as presented in Table no 6, we may highlight the frequent references to the Media Selection theories of MRT(39) and MSYT(48), indicating that the topic of the Media of choice in DSD is common in the literature. This scenario is followed by slightly less relevant numbers of references on the SPT(37), indicating some degree of attention on the social aspect of communication in the DSD context. Still, and again based on the selected theories, other aspects that are directly or indirectly related to the communication phenomenon itself also seems to drive the attention of authors, such as coordination, performance, and cognitive aspects, as represented by the SCT(40) and TIP(43) theories.

It is also important to notice that only the TOT(18) was proposed in the context of DSD Teams among the selected theories. This theory aims at explaining how a distributed team in Agile software development adopts explicit strategies for bridging spatial, temporal, and socio-cultural distances (18). At this point, we could not identify a Communication Theory constructed for the specific context of DSD Teams. Still, we may highlight that some of the identified theories included in the selected works directly correlate with the DSD context, i.e., with more evident proximity to DSD teams. Among those, we may cite the MSYT(48), MRT(39), KBTF(45), CT(38), AT(52), and the SCT(40), which we further detail by the perspective of their usage in Table no 7, as follows.

Table No. 7: Theories and contexts

Theory	Context of usage in DSD
MSYT(48)	Survivability Models (<i>ST-204</i>) and Media Capability (<i>ST-204</i>) (<i>ST-227</i>); Evaluation of IM Messaging (<i>ST-011</i>); Media Selection (<i>ST-132, 401</i> and <i>452</i>).
MRT(39)	Media Selection (<i>ST-452</i>)
KBTF(45)	Facilitation of Knowledge during Visits between Sites (<i>ST-088</i>).
CT(38)	Antecedent Factors in Requirement Analysis (<i>ST-158</i>).
AT(52)	Minimization of Information Asymmetry between Outsourced Organizations (<i>ST-105</i>).
SCT(40)	Knowledge Sharing Behavior (<i>ST-347</i>).

Therefore, we argue that those findings suggest the need for researchers to support their DSD works in subjacent theories (Table no 7), mostly in the broader Communication context of the teams and organizations referred to in their scientific studies.

CONCLUSION

By identifying 21 theories in the DSD and Communication context in the Computer Science Literature, we answered the research question SMS-RQ1. Thereby, we conclude that Scientific Theories have their representation in DSD works that include the Communication phenomenon. We may also argue that this scenario suggests a direct or indirect usage of those theories' concepts in those works' derived interventions. We expect that this work serves as a reference and a guide for future research in academia in the context of Communication and DSD teams. This literature review is an ongoing work, and the next steps include an analysis process on the selected studies based on the Thematic Synthesis technique as described by Thomas and Harden(53), to identify the Aspects, Objectives, and Limitations mentioned by the authors on identified theories, in a taxonomical representation.

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