Empirical software product line engineering
Why and how?

David Benavides together with Ana E. Chacón,
Antonio M. Gutiérrez and José A. Galindo
benavides@us.es

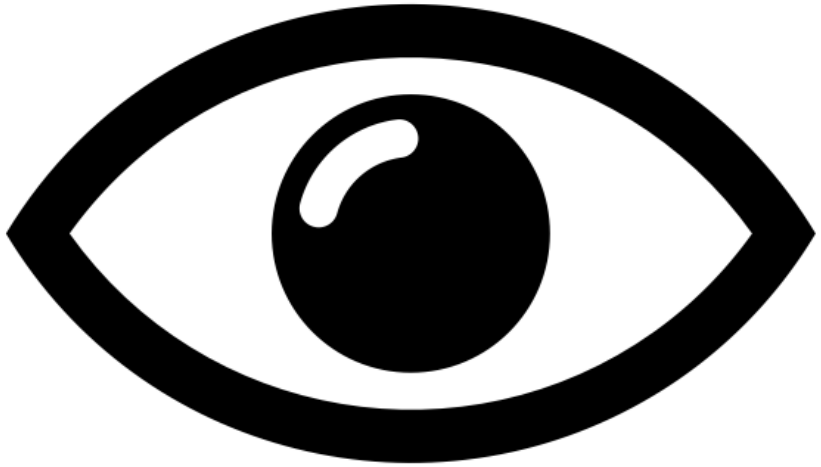
"Montreal" – October 2020

@davbencue

First thing to say:
I am a little skeptical about empirical methods in software engineering

Second thing to say: I am NOT empirical expert!

An observation/conjecture…



There is more practice in variability management than awarness on the practices described in Software Product Line Engineering body of knowledge

The origins

Variability Management in an unaware software product line company. An experience report

David Benavides and José A. Galindo
Departamento de Lenguajes y Sistemas Informáticos
Universidad de Sevilla
{benavides,jagalindo}@us.es

ABSTRACT

Software product line adoption is a challenging task in software development organisations. There are some reports in the literature of how software product line engineering has been adopted in several companies using different variability management techniques and patterns. However, to the best of our knowledge, there are no empirical reports on how variability management is handled in companies that do not know about software product line methods and tools. In this paper we present an experience report observing variability management practices in a software development company that was unaware of software product line approaches. We briefly report how variability management is performed in different areas ranging from business architecture to software assets management. From the observation we report some open research opportunities for the future and foster further similar and more structured empirical studies on unaware software product line companies.

strategic decision [3]. There some reports on how companies transitioned towards a product line approach [4, 9, 14, 16, 20, 26]. According some of these reports, for product line adoption success, a strong management commitment is needed as well as a long-term vision. According to [15] smooth transition strategies eliminate many adoption barriers. In this sense, a first step in a smooth transition strategy can be to observe the current product-line-related practices inside an unaware product line organisation, i.e. reporting the existing approaches of the organisation without giving too much details on software product line engineering methods or tools.

To the best of our knowledge, there are no empirical reports of what kind of product line practices are handled in companies that do not know about software product line engineering but that have a positive potential characteristics for the transition. To push forward in this direction, in this paper we present an experience report observing variability management practices in a software development company

Philippe Collet
Andrzej Wąsowski
Thorsten Weyer (Eds.)

Proceedings of the
Eighth International Workshop on Variability Modelling of Software-intensive Systems

VaMoS '14, January 22–24, 2014
Nice, France

Conclusions of the reviews/discussions:

Nice idea, but weak methodological approach

The origins

Empir Software Eng (2016) 21:1579–1585
DOI 10.1007/s10664-016-9439-3

EDITORIAL

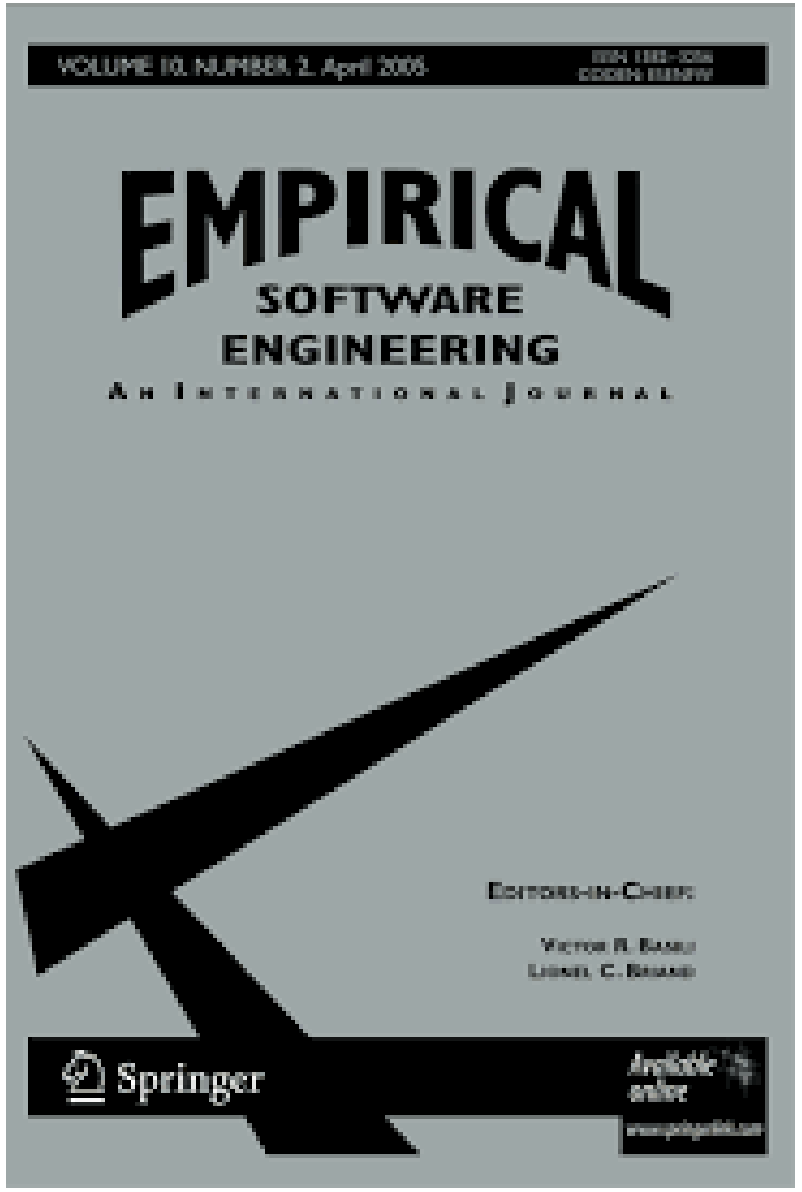
Foreword to the special issue on empirical evidence on software product line engineering

Ebrahim Bagheri[1] · David Benavides[2] · Klaus Schmid[3] · Per Runeson[4]

Published online: 9 June 2016

The software product line engineering paradigm promotes sharing common core assets for building similar software systems. Researchers have argued that the deployment of product line techniques can lead to lower development costs as well as improved delivery time. There has also been some indication that, if systematically executed, products derived from a software product line can enjoy higher quality levels given repeatedly tested core assets are used in the development process (van der Linden et al. 2007). Researchers have explored many exciting research challenges at different levels of abstraction ranging from high-level metamodels for commonality and variability representation (Chen et al. 2009) to low-level pre-processor directives for incorporating variability in the code base (Liebig et al. 2010).

There is also a significant body of knowledge on experiences in practically transferring or deploying software product line research outcomes to industrial partners and real-world



a student to “cheat”

UNIVERSIDAD ESTATAL DE MILAGRO

7 de Febrero 2001

UNEMI

One of the results

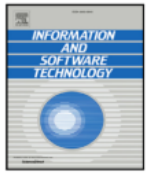
Ana Eva Chacón-Luna, Antonio Manuel Gutiérrez, José A. Galindo, David Benavides: Empirical software product line engineering: A systematic literature review, Information and Software Technology, Volume 128, 2020

Information and Software Technology 128 (2020) 106389

Contents lists available at ScienceDirect

Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof



Check for updates

Empirical software product line engineering: A systematic literature review

Ana Eva Chacón-Luna [a,*], Antonio Manuel Gutiérrez [b], José A. Galindo [c], David Benavides [c]

[a] Universidad Estatal de Milagro, Km. 1 1/2 vía km. 26, Milagro, Ecuador
[b] ISIS Papyrus, Papyrus Platz 1, 2345, Brunn am Gebirge, Austria
[c] Dept. Lenguajes y Sistemas Informáticos, University of Seville, Avda. Reina Mercedes s/n, 41012, Seville, Spain

ARTICLE INFO

Keywords:
Software product lines
Empirical strategies
Case study
Experiment
Systematic literature review

ABSTRACT

Context: The adoption of Software Product Line Engineering (SPLE) is usually only based on its theoretical benefits instead of empirical evidences. In fact, there is no work that synthesizes the empirical studies on SPLE. This makes it difficult for researchers to base their contributions on previous works validated with an empirical strategy.
Objective: The objective of this work is to discover and summarize the studies that have used empirical evidences in SPLE limited to those ones with the intervention of humans. This will allow evaluating the quality and to know the scope of these studies over time. Doing so, research opportunities can arise
Methods: A systematic literature review was conducted. The scope of the work focuses on those studies in which there is human intervention and were published between 2000 and 2018. We considered peer-reviewed papers from journals and top software engineering conferences.
Results: Out of a total of 1880 studies in the initial set, a total of 62 primary studies were selected after applying a series of inclusion and exclusion criteria. We found that, approximately 56% of the studies used the empirical case study strategy while the rest used experimental strategies. Around 86% of the case studies were performed in an industrial environment showing the penetration of SPLE in industry.
Conclusion: The interest of empirical studies has been growing since 2008. Around 95.16% of the studies address aspects related to domain engineering while application engineering received less attention. Most of the experiments and case study evaluated showed an acceptable level of quality. The first study found dates from 2005 and since then, the interest in the empirical SPLE has increased.

AGENDA

Our Goal

Some methodological aspects

Findings

Discussion

Conclusions

The main goal

to discover and summarize the studies that have used empirical evidences in SPLE

BUT

limited to those ones with the intervention of humans

AGENDA

Our Goal

Some methodological aspects

Findings

Discussion

Conclusions

Research questions

RQ1: Are there empirical studies on SPLE with human intervention?

- RQ1.1. What empirical strategies have been used?
- RQ1.2. What processes of the SPLE framework have been studied?
- RQ1.3. In what context is empirical research done?

RQ2 What is the quality of the empirical studies reported in SPLE?

RQ3 What is the scope of empirical research in SPLE?

- RQ3.1. In which journals or conferences are these types of articles published?
- RQ3.2. What is the temporal evolution in this type of studies?
- RQ3.3. What authors do research in this area?

AGENDA

Our Goal

Some methodological aspects

Findings

Discussion

Conclusions

RQ1: Are there empirical studies on SPLE with human intervention?

- RQ1.1. What empirical strategies have been used?
- RQ1.2. What processes of the SPLE framework have been studied?
- RQ1.3. In what context is empirical research done?

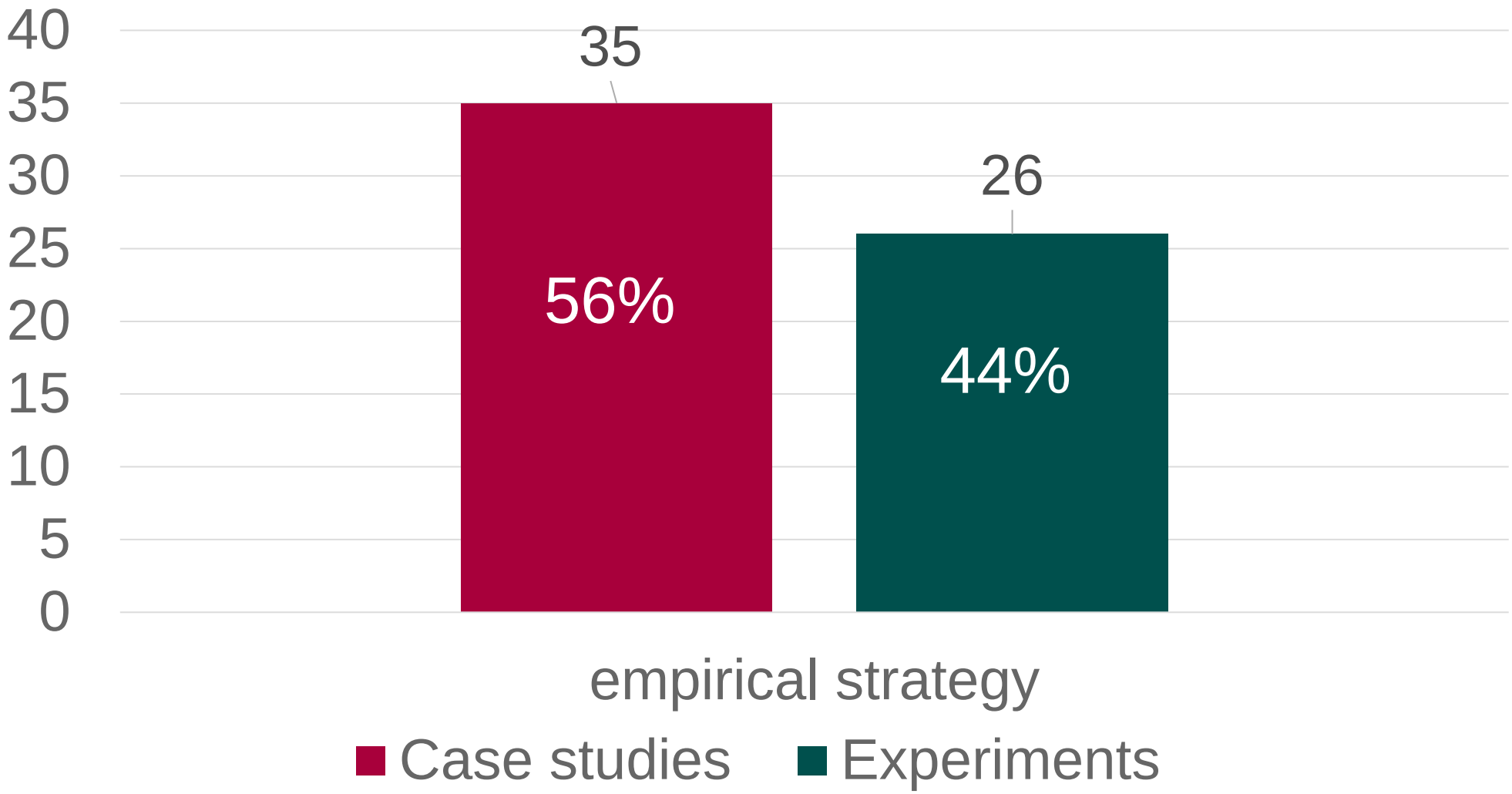
RQ1: Are there empirical studies on SPLE with human intervention?

- RQ1.1. What empirical strategies have been used?
- RQ1.2. What processes of the SPLE framework have been studied?
- RQ1.3. In what context is empirical research done?

www.menti.com/
ndv18fej6x
www.menti.com
CODE: 26 48 45 6

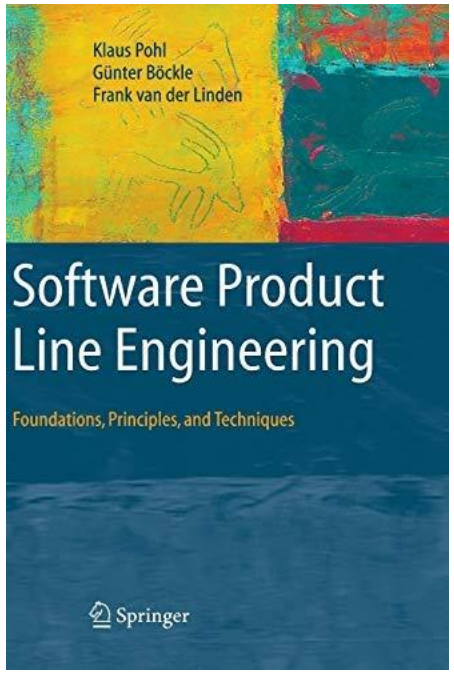
ment

RQ1.1. What empirical strategies have been used?



Conjecture

a possible cause of the higher number of case studies is that industrial contexts are closer to the SPL community

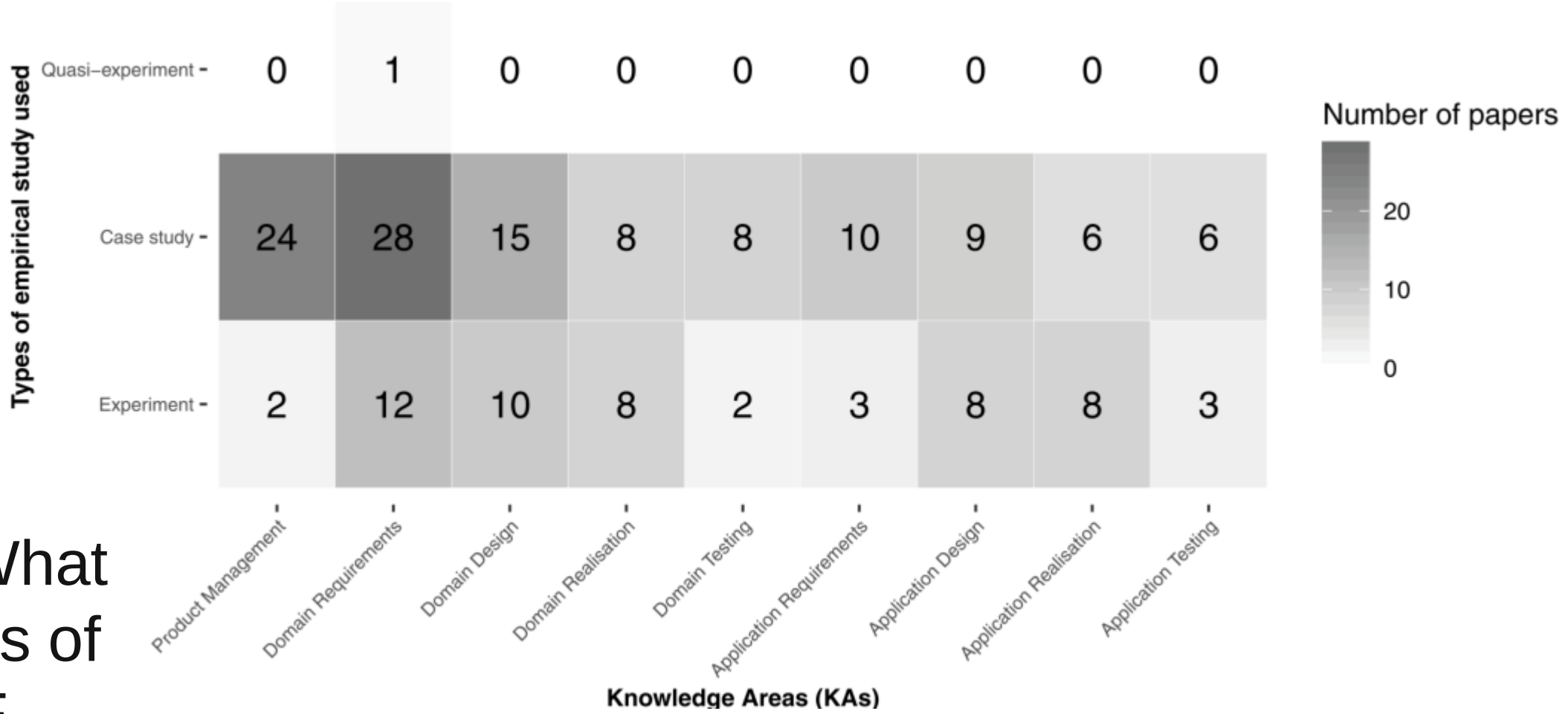


RQ1.2. What processes of the SPLE framework have been studied?

Table 4
Empirical studies on SPLE with case study.

#Paper	Product Management	Dom. Requir. Eng.	Domain Design	Domain Realization	Domain Testing	App. Requir. Eng.	Application Design	Application Realization	Application Testing	What is evaluated	Empirical objective	Study Environment	No. Participants	Type of sample	Topic
Ahmed [36]	✓	–	–	–	–	–	–	–	–	P	E	I	M	C	Organizational management, Org. behavior
Berger [37]	✓	✓	–	–	–	–	–	–	–	P	E	I	–	–	SPL, Variability Modeling, Empirical Soft. Engineering, Soft. Ecosystems
Classen [38]	–	✓	–	–	–	–	–	–	–	TO	S	I	–	–	Feature models, Code, Modeling, Language
Costa [39]	–	–	–	✓	–	–	–	–	–	TE	S	I	L	–	Ontology, Feature model
Da Silva [40]	✓	✓	–	–	–	–	–	–	–	P	E	I	L	C	Requir. engineering, Agile methods, SPL. scoping
Da Silva [41]	✓	✓	–	–	–	–	–	–	–	P	E	I	L	C	Agile, Multi-method approach
Deelstra [42]	✓	✓	✓	–	–	✓	✓	✓	–	P	E	I	–	–	Prod. derivation, Variability management
Deelstra [43]	✓	✓	–	–	–	–	–	–	–	P	S	I	–	–	Variability, Assessment, Evolution
Dey [44]	–	✓	–	–	–	–	–	–	–	P-TO	S	I	L	–	Requir. elicitation, Adaptive systems
De Souza [45]	✓	✓	✓	–	–	✓	✓	–	–	P	E	I	L	C	Prod. derivation
Díaz [46]	–	–	✓	–	–	–	–	–	–	P	S	I	L	–	Agile product-line engineering.
Díaz [47]	✓	✓	✓	–	–	–	–	–	–	TE	S	I	L	–	Traceability M., Prod.-line archit.,Variability
Echeverría [48]	–	–	–	–	✓	–	–	–	–	TE	E	I	L	–	SPL, Variability Modeling, Usability
Eklund [49]	–	–	✓	–	–	–	✓	–	–	P	E	I	L	–	Architecting, Process
Engström [50]	–	–	–	–	✓	–	–	–	✓	P	E	I	L	–	Soft. testing, Overlay, Redundancy, Efficiency
Eriksson [51]	–	✓	–	–	–	–	–	–	–	P	S	I	L	–	Feature model, Variability management
Ferreira [32]	✓	✓	✓	✓	✓	✓	✓	✓	✓	P	E	I	L	C	SPL adoption, Multi-method approach
Figueiredo [52]	✓	✓	–	–	–	–	–	–	–	TE	E	A	L	–	SPL, aspect-oriented programming, empirical evaluation.
Galster [53]	✓	✓	✓	–	–	–	–	–	–	P	E	I	L	–	Variability, Enterprise software systems
Ganesan [54]	✓	✓	✓	✓	✓	✓	✓	✓	✓	TE	E	I	L	–	SPL Applying Monte-Carlo Simulation
Hanssen [55]	✓	✓	✓	✓	✓	✓	✓	✓	✓	P	E	I	L	–	Soft. prod. development, Agile soft. development
Hanssen [56]	✓	✓	✓	✓	✓	✓	✓	✓	✓	P	E	I	L	–	Agile soft. development, Qualitative research
Kim [33]	–	✓	✓	–	–	–	–	–	–	P-TO	S	I	L	SR	Domain requir.,Domain archit.,Quality attribute
Koziolek [57]	✓	–	–	–	–	–	–	–	–	P	S	I	–	–	Domain analysis , Business case
Martínez [58]	✓	✓	–	–	–	✓	–	–	–	TE	E	A	L	–	SPL, Reverse-engineering, Extractive SPL Adoption
Myllärniemi [59]	✓	✓	✓	–	–	✓	✓	–	–	TE	S	I	L	C	SPL, variability, architecture
Oliveira [60]	✓	✓	–	–	–	–	–	–	–	P	S	A	L	C	Requir. Specification, Reuse
Pardo [61]	✓	✓	✓	✓	✓	✓	✓	✓	✓	P	E	I	L	–	Agile software development, Design thinking
Patzke [62]	✓	✓	✓	✓	–	–	–	–	–	P	S	I	–	–	SPL Code Evolution, Goal-Based SPL Measurement, Variability Code Smells
Rubin [63]	✓	✓	✓	✓	✓	–	–	–	–	P	E	I	–	–	Legacy SPL, cloned product variants.
Souza [64]	✓	✓	–	–	–	–	–	–	–	TE	E	I	L	C	Soft. quality control, Soft. inspection
Thurimella [65]	✓	✓	–	–	–	–	–	–	–	TE	S	A	H	SR	Variability management,variability modeling
Usman [66]	–	✓	–	–	–	–	–	–	–	P-TO	S	I	–	–	Mobile applications, Feature model
Wille [67]	✓	✓	–	–	–	–	–	–	–	TE	S	I	L	–	Variability mining, technical architecture, enterprise architecture
Zhang [68]	–	✓	–	–	–	✓	–	–	–	TE	S	A	L	–	Non-functional requir. framework, Feature M.

What is evaluated: TE = Technique; P = Process; TO = Tool.
Empirical objective: S = Proposal from the same paper; E = Evaluates an existing proposal; R = Replica of an experiment.
Study Environment: A = Academic; I = Industrial.
No. Participants: L = No. participants < 20; M = 20 ≤ No. participants < 100; H = No. participants ≥ 100; - = Not specified.
Type of sample: SR = Simple random sampling; ER = Stratified random sampling; C = Convenience sampling; - = Not specified.



RQ1.2. What processes of the SPLE framework have been studied?

RQ1.3. In what context is empirical research done?

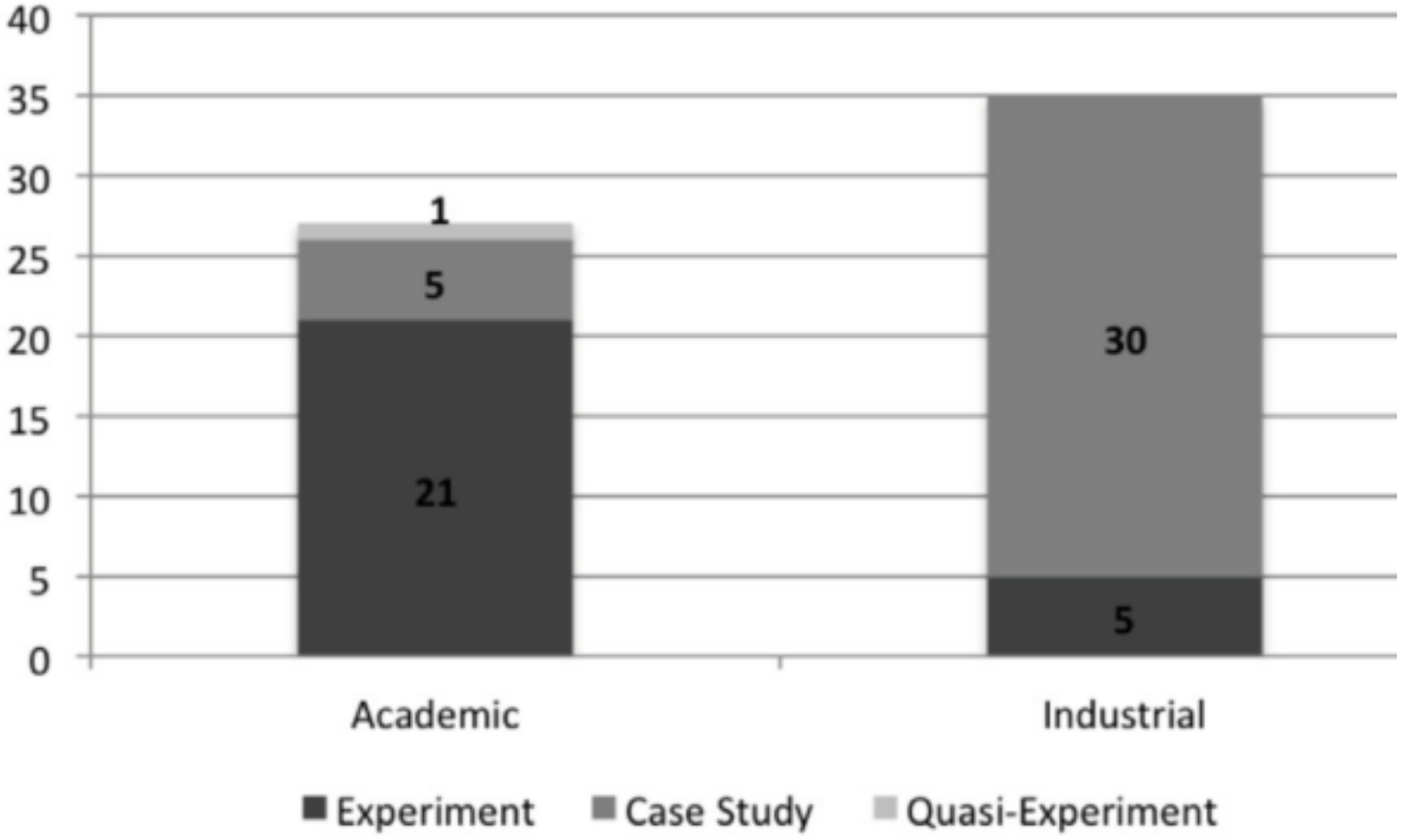


Fig. 7. Environment of study.

Key findings

- The empirical strategy mostly used in SPLE subjects is the case study with approximately 56% while the rest of the primary studies used experimentation.
- Around 95.16% of the studies address issues related to domain engineering, while application engineering received less attention.
- 86% of the case studies were performed in an industrial environment.
- 81% of the experiments were conducted in an academic environment.
- 50% of the primary studies do not specify the type of sample that was used to determine the study participants.

RQ2 What is the quality of the empirical studies reported in SPLE?

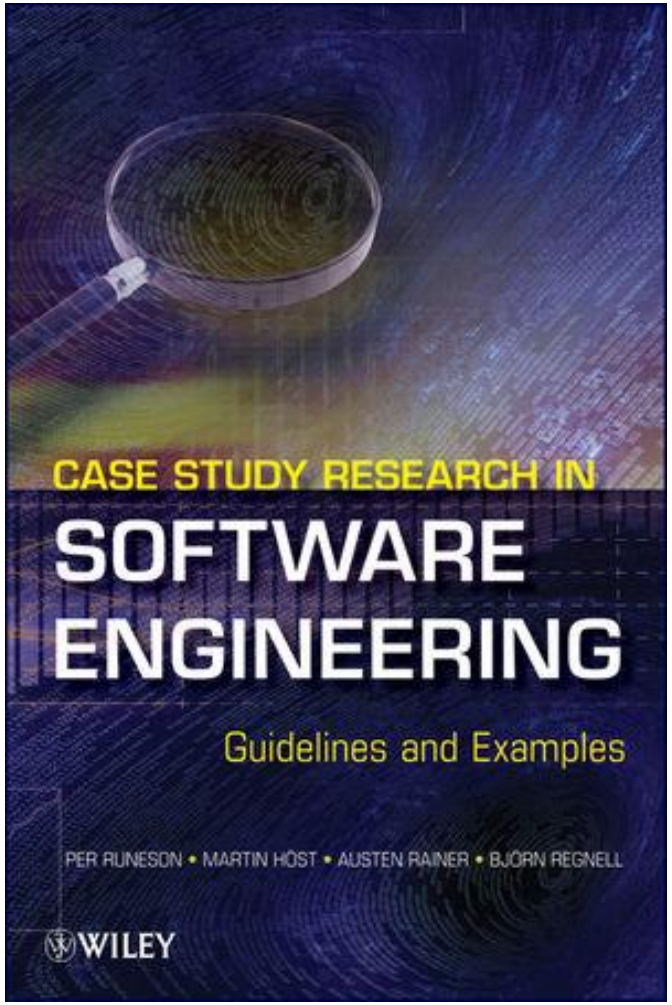


Table 11
Experiment summary.

#Paper	Goal Definition	Context Selection	Hypothesis Formulation	Variables Selection	Selection of Subjects	Experiment Design	Instrumentation	Validity Evaluation	Preparation	Execution	Data Validation	Descriptive Statistics	Data Reduction	Hypothesis Testing	Presentation and Package	**TOTAL**
Accioly [69]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Gonzalez-Huerta [77]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Kumar [35]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Reinhartz-Berger [84]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Reinhartz-Berger [85]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Asadi [71]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Dermeval [76]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Feigenspan [34]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Michalik B. [81]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Ahmed [70]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Bagheri [72]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Thüm T. [91]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Wang [93]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	14
Denger C. [75]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Saeed [86]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Santos A. [87]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	14
Bonifácio [73]	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	13
Liu [79]	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓	13
Reinhartz-Berger [83]	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	13
Schulze [88]	✓	✓	✓	-	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓	12
Pereira J. [82]	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	11
Stein J. [90]	✓	✓	-	-	✓	✓	✓	-	✓	✓	✓	✓	-	-	✓	10
Sinnema [89]	✓	✓	✓	-	✓	-	-	-	✓	✓	✓	-	-	✓	✓	9
Cetina [74]	✓	✓	✓	-	✓	-	✓	-	✓	✓	-	-	-	-	✓	8
Guana [78]	✓	✓	-	-	✓	-	-	-	✓	✓	✓	-	-	-	✓	7
Martínez J. [80]	✓	✓	-	-	-	-	✓	-	-	-	-	-	-	-	-	3
Vasilevskiy A. [92]	✓	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	3
TOTAL	27	27	21	19	25	22	22	21	25	25	24	22	7	20	24	331

Table 12
Case study summary.

#Paper	Rationale	Objectives	Cases and Units of Analysis	Theoretical Frame of Reference	Research Questions	Propositions and Hypothesis	Methods of Data Collection	Methods of Data Analysis	Selection of Data	Threats to Validity	Total
Ahmed F. *et al.* [36]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Da Silva IF. *et al.* [40]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Dey S. *et al.* [44]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
De Souza LO. *et al.* [45]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Díaz J. *et al.* [46]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Díaz J *et al.* [47]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Engström E. *et al.* [50]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Eriksson M. *et al.* [51]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Galster M. *et al.* [53]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Koziolek H. *et al.* [57]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Oliveira RPD. *et al.* [60]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Costa GCB. *et al.* [39]	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	9
Ferreira J. *et al.* [32]	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	9
Souza IS. *et al.* [64]	✓	✓	✓	✓	✓	-	✓	-	✓	✓	8
Da Silva IF. *et al.* [41]	✓	✓	-	✓	✓	-	✓	✓	✓	✓	8
Berger T. *et al.* [37]	✓	✓	✓	✓	✓	✓	✓	-	✓	-	8
Echeverría J. *et al.* [48]	✓	✓	✓	✓	✓	-	✓	-	✓	✓	8
Hanssen GK. *et al.* [55]	✓	✓	✓	✓	-	-	✓	✓	✓	✓	8
Myllärniemi V. *et al.* [59]	✓	✓	✓	✓	✓	-	✓	-	✓	✓	8
Kim J. *et al.* [33]	✓	✓	✓	✓	-	-	✓	-	✓	✓	7
Hanssen GK. *et al.* [56]	✓	✓	✓	✓	-	-	✓	-	✓	✓	7
Thurimella A. *et al.* [65]	✓	✓	✓	✓	-	-	✓	-	✓	✓	7
Eklund U. *et al.* [49]	-	✓	✓	✓	-	-	✓	-	✓	✓	6
Deelstra S. *et al.* [42]	✓	✓	✓	✓	-	-	✓	-	✓	-	6
Zhang G. *et al.* [68]	✓	✓	✓	✓	-	-	-	-	✓	✓	6
Patzke T. *et al.* [62]	✓	-	✓	✓	-	-	✓	-	✓	✓	6
Wille D. *et al.* [67]	✓	✓	-	✓	✓	-	-	-	✓	✓	6
Classen A. *et al.* [38]	✓	✓	-	✓	✓	-	✓	-	-	-	5
Deelstra S. *et al.* [43]	✓	✓	✓	✓	-	-	✓	-	-	-	5
Ganeson D. *et al.* [54]	✓	✓	✓	✓	-	-	-	-	✓	-	5
Martinez J. *et al.* [58]	✓	✓	✓	✓	-	-	✓	-	-	-	5
Usman M. *et al.* [66]	✓	✓	✓	-	-	-	-	-	✓	✓	5
Pardo A. *et al.* [61]	-	✓	✓	✓	-	-	✓	-	-	-	4
Figueiredo E. *et al.* [52]	✓	✓	-	✓	-	-	-	-	✓	-	4
Rubin J. *et al.* [63]	✓	-	✓	✓	-	-	-	-	✓	-	4
TOTAL	33	33	31	34	20	8	29	8	31	26	253

Quality

18.52% of the experiments met all the criteria recommended by Wholin

37.14% of the case studies met nine of the 10 criteria recommended by Runeson

RQ3 What is the scope of empirical research in SPLE?

- RQ3.1. In which journals or conferences are these types of articles published?
- RQ3.2. What is the temporal evolution in this type of studies?
- RQ3.3. What authors do research in this area?

Venues...

Table 14
Number of papers per Journal or Conference.

Rank	No. Papers	JournalConference	EXP	CS	QUASI
1	15	International Systems & Software Product Line Conference	7	8	0
2	12	Journal of Systems and Software	2	9	1
3	12	Information and Software Technology	5	7	0
4	4	Empirical Software Engineering	3	1	0
5	3	Science of Computer Programming	1	2	0
6	3	International Symposium on Empirical Software Engineering and Measurement	2	1	0
7	2	Journal of Universal Computer Science	1	1	0
8	2	Software Quality Journal	1	1	0
9	2	Software - Practice and Experience	0	2	0
10	1	Journal of Biomedical Informatics	0	1	0
11	1	Requirements Engineering	0	1	0
12	1	User Modeling and User-Adapted Interaction	1	0	0
13	1	Expert Systems with Applications	1	0	0
14	1	Software and Systems Modeling	1	0	0
15	1	IET Software	1	0	0
16	1	International Conference on Software Engineering	0	1	0


Canada (14)
USA (5)
Colombia (1)
Brazil (53)
Finland (2)
Norway (7)
Sweden (10)
United Kingdom (6)
Denmark (5)
The Netherlands (8)
Ireland (3)
Germany (44)
Belgium (6)
Luxemburgo (4)
France (4)
Austria (1)
Italy (1)
Portugal (1)
Spain (31)
Israel (4)
Pakistan (3)
China (4)
Korea (4)
UAE (1)
Saudi Arabia (5)
Australia (5)
New Zealand (1)

AGENDA

Our Goal

Some methodological aspects

Findings

Discussion

Conclusions

Conclusions

- Empirical SPLE is in his infancy
- SPL community is close to industry
- More empiricism needed in application engineering
- No empirical evidence on non aware SPL companies

Empirical software product line engineering
Why and how?

David Benavides together with Ana E. Chacón,
Antonio M. Gutiérrez and José A. Galindo
benavides@us.es

"Montreal" – October 2020

@davbencue