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Investigating Research on Teaching Modeling in Software Engineering
-A Systematic Mapping Study

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ABSTRACT

Context Modeling is an important activity, which is used, in different phases of software engineering. Without models and modeling, it is nearly impossible to design and develop software systems, which demands the need for modeling to be taught in software engineering. There exist a number of reported models, methods, tools and languages to teach modeling in software engineering, which suggests the need for a classification and an overview of the area. This research investigates the state of published research on teaching modeling in software engineering in order to provide a systematic overview and classification of these different ways of teaching modeling with an insight on their importance and relevance to this research area.

Objectives The overall goal of the research was achieved with fulfilling the following objectives: understanding how systematic mapping is conducted, developing a systematic mapping process that will properly provide data for investigating the published research, applying the process, and finally reflecting on the results of the mappings, analyzing the importance and evaluating relevance of the published research.

Methods Systematic literature review was used as a tool to understand and inspect how systematic mapping was carried out in the area of software engineering. Based on the results of systematic literature review, new guidelines were formulated to conduct systematic mapping. These guidelines were used to investigate the published research on teaching modeling in software engineering. The results obtained through the systematic mapping were evaluated based on Industrial relevance, Rigor and citation count to examine their importance and identify research gaps.

Results 131 articles were classified into five classes such as Languages, Course Design, Curriculum design, Diagrams, others using semi-manual classification scheme and classification facets such as the type of audience, type of contribution, type of research, type of publication, type of publication year, type of research method and type of study setting. After the evaluation of Industrial relevance, rigor & citation ranking on the obtained results of the classification, 8 processes, 4 tools, 3 methods, 2 measurement-metrics and 1 model were extracted to teach modeling in software engineering. Also, this classification when compared with an existing classification, which is based on interviews and discussions, showed that our classification provides a wider overview with a deeper insight of the different ways to teach modeling in software engineering.

Conclusions Results of this systematic mapping study indicate that there is an increase in the research activity on teaching modeling in software engineering, with Unified Modeling Language (UML) being the widely research area. Much research is emphasized on teaching modeling to students from academia which indicates a research gap in developing methods, models, tools and processes to teach modeling to students/practitioners from the industry. Also, considering the citation ranking, industrial relevance and rigor of the articles, areas such as course and curriculum development are highly neglected, suggesting the need for more research focus.

Keywords: Teaching modeling, Systematic Literature Review, Systematic mapping Study, Classification and Systematic mapping guidelines.

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1 INTRODUCTION

In this modern era, modeling has become an essential element and a hallmark of engineering activities [19]. The construction of models and use of modeling has turned into a daily activity in human life. Models are used to create real world entities from abstract representations. Knowledge on models and modeling helps in the guidance to derive solutions for complex problems. Hence, to a student it becomes necessary and important to learn modeling.

In software engineering models are everywhere. It is a prime activity of software engineering student to create, construct and develops models. This demands the need for emphasis on teaching modeling in software engineering. There are a number of ways or methods to teach modeling in software engineering and a lot of research is being carried out in this area [19]. In order to gather all evidence related to teaching modeling in software engineering, we chose to conduct a systematic mapping, i.e. to systematically group or classify the published research.

There exists a number of ways to classify the articles and to conduct systematic mapping in software engineering. Hence, we chose to have a better understanding on the process of conducting systematic mapping in choosing proper guidelines to carry out systematic mapping on teaching modeling in this thesis. For this purpose, a systematic literature review was conducted in order to gather qualitative evidence on systematic mapping. Next section explains how this thesis is carried out with a short explanation on the contents of each chapter.

1.1 Outline of thesis

Chapter 1 contains the Introduction to the research problem and outline of master thesis. Chapter 2 contains the background and related work on teaching modeling in software engineering along with the background and related work on systematic mapping. Chapter 3 contains the Research Design with aims, objectives, research questions and research plan to our master thesis. Chapter 4 contains the design, execution and results of systematic literature review on systematic mapping in software engineering. Chapter 5 contains the improved guidelines to carryout systematic mapping in software engineering. Chapter 6 contains the design, execution and results of systematic mapping on teaching modeling in software engineering. Chapter 7 contains the comparison of classification obtained with an initial classification related to teaching modeling. This chapter is followed by Analysis, Discussion, Conclusion, References, Appendix and Glossary. Figure 1 depicts the outline of the thesis.

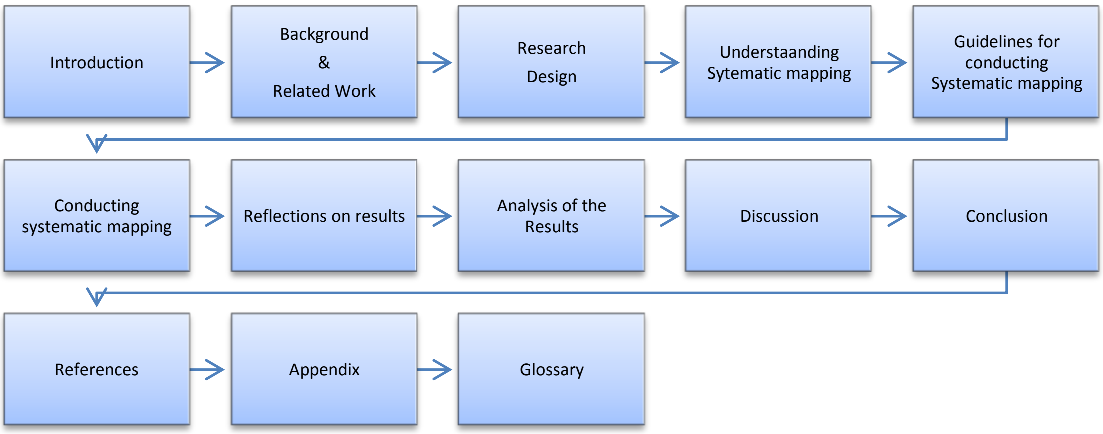


Figure 1 Chapters in thesis

2 BACKGROUND AND RELATED WORK

This chapter is divided into two sections, background and related work on teaching and the background and related work on systematic mapping.

2.1 Background & related work on teaching modeling

Now a day, software systems have become more complex with virtual and distributed teams, the need for constructing a proper model of the system under development is growing [46]. This construction of physical, conceptual or mathematical simulations of the real world is called as modeling [1]. It can be considered as the process of shaping the abstract representation into a real world entity. Modeling has been a distinct feature in engineering, through many years [20]. It plays a major role in software engineering; right from the requirement gathering to the delivery of the software and its maintenance, modeling is used different ways. Modeling is also used to plan the activity of software development. It becomes impossible to design and develop a software system without the usage of models and modeling [4], which is one of the main reasons to teach modeling in software engineering.

Modeling is a key activity and an essential skill for software engineers and students of software engineering [19]. Modeling is taught in different areas of software engineering, in different ways and using different methods. There are quite a number of ways to teach modeling, some of them being intuitive and easily understood even by the novices while some of them are highly complex in nature [19]. All these numerous ways of teaching make it an inquisitive field for research. Hence, it is important to collect, classify and evaluate evidence the published research, to know where more research needs to be carried out or areas where extensive research has been done or what methods of teaching or models are being used extensively. In the following section we present the related work on teaching modeling in software engineering.

Related work:

Modeling is a vast research area with a lot of research being carried out. Research on teaching modeling in software engineering can be observed in the literature obtained from books (e.g. [114, 116]), curriculum recommendations / guidelines (e.g. GSwE2009 [118] & SE2004 [119]) and research publications from conferences, workshops and journals. Published research from books, templates and technical reports was not included in the purview of this study as they include non-peer reviewed literature. Also, there are many books on introducing Unified Modeling Language (UML) than teaching modeling in software engineering, e.g. ***Amber W. Scott***, in his book ”The Elements of UML(TM) 2.0 Style” provides guidelines on how to use the UML based on his experiences, apart from introducing the UML 2.0 notation [114]. Also, there is very less published research on curriculum guidelines on teaching modeling in Software Engineerig (SE) discipline. ***Jürgen Börstler et.al,*** formulated recommendations on the inclusion of software modeling courses in CS/SE curriculum and also discusses the shortcomings of several computing curricula [117].

This study is restricted to consider research publications from conferences, workshops and journals, as there are a lot of unclassified and unevaluated published research from conferences, workshops and journals, when compared with books and curriculum recommendations. There are a number of publications related to teaching modeling as well as conferences. EduSymp on MoDELs [17] and ITiCSE [18] are sample conferences where issues related to teaching modeling are discussed.

Sample problems discussed in conferences and publications are:

1 Identifying the need to teach modeling before graduation, in order to improve the student’s knowledge on modeling [15].
2 Problems faced by graduating students to design, which explain the need to teach modeling [13].

3 Summarizing a panel discussion held at EduSymp'11, which identifies what should be taught, why should it be taught and when should it be taught [16].
4 Identifying the difficulties faced by students in learning a modeling language such as the UML [14].
5 Finding the best practices for teaching UML-based software development [12].

Apart from the above discussed problems, published research throws light on different perspectives on teaching modeling in Software Engineering discipline, such as the usage of tools, emphasis on courses, employing methods, or teaching using different techniques etc. Table 1 shows such a sample classification of articles:

Experiences	T.C Lethbridge [SMP 41] introduces how a technology called UMPLE, be used to improve teaching UML. The author based on the experiences of using UMPLE for two years on course and laboratory assignments suggests that performance of students has increased using this UMPLE [50].
	Danijela Boberic & Danijela Tesendic [SMP 9] in their study discussed the experiences and lessons that were learned from teaching object oriented modeling. In that study the authors have identified a set of problems students encounter when they are taught modeling using UML. An organization of the object oriented modeling course is provided along with solutions to the problems encountered [69].
Experiments	*L. Kuzniarz et al.* [SMP111] conduct a family of experiments to investigate the effect of structural complexity on the understandability of UML state chart diagrams [55].
Languages	*Dan Chiorean et.al.* [SMP 14] presents an approach to teach software modeling using constraints based their experiences at two different universities. The authors suggest the use of inverted curriculum benefits the students more rather than introducing the constraint language formally. Also, several examples are provided to teach modeling using OCL [70].
Techniques	*K. Beck & W. Cunningham* [SMP 81] introduces new techniques to teach object oriented design, called the CRC card technique. CRC stands for Class, Responsibility and collaboration which is beneficial to teach OOD concepts to novice programmers [98].
Courses	*Mikael Berndtsson* [SMP 7] analyses and discusses a course on object oriented modeling in three different ways, which show that changes to the course configuration do not show a major impact on the performance of students [68].

Class 1 A sample classification of articles

From the above, we can observe that many problems are being addressed using different types of research and research methods introducing different methods / tools/ models to teach modeling in software engineering.

This stimulates the researchers to investigate what research has been done and have an overall look on what has been published. But no such research has been carried out which presents the current state of art/practice in teaching modeling in software engineering.

Motivation:

To the best of our knowledge, there is no comprehensive research which gathers all the published evidence, classifies the research based on the practices used for teaching, and evaluates the published research based on rigor or industrial relevance on teaching modeling in the SE discipline. Hence, a systematic mapping study on teaching modeling is planned to provide an overview of what has been researched in this area and to evaluate the published research. We chose a systematic mapping study instead of a systematic literature review to achieve the results, as systematic mapping is used to get a prior idea on the area of interest and literature review is only used to investigate the state of evidence on the research area [2].

As our topic for thesis, teaching modeling is a vast area, and as our goal is to get an idea of what has been published in the area and categorize the publications, we have chosen systematic mapping study for our thesis. The following section discusses the background and related work on systematic mapping in software engineering.

2.2 Background & related work on systematic mapping

Systematic mapping studies or scoping studies are designed to give an overview of the research area and are used to establish the quantity of evidence on that particular area [21] [39]. It involves searching the literature in order to know what sort of literature has been published in the area of interest, where have they been published and what are the outcomes and their population [9]. Mapping studies give an idea about the relevant area and also help in assessing the quantity and nature of publications existing in the area of interest [4]. These mapping studies are one of the main methods to conduct research in the evidence based paradigms [8]. Though a systematic mapping study and a systematic literature review share some commonalities, they are different in establishing the evidence on a particular area. Systematic literature review focuses on qualitative evidence whereas systematic mapping focuses on quantity of the evidence found.

Related work:

Systematic mapping studies are used by many researchers on a number of areas using different guidelines or methods. A sample of mapping studies is mentioned below with their areas of research and the guidelines used.

- Condori-Fernandez et al. [10] provided a mapping of the research articles on software requirement specifications using custom built guidelines.
- Wohlin et al. [11] performed mapping of the literature available on Global software Engineering considering Petersen et al. [2] guidelines.
- Barreiros et al. [12] constructed systematic maps on the published research on software engineering test beds based on Kitchenhamn et al. [21] guidelines.
- Qadir et al. [13] conducted a mapping on curriculum in software engineering using custom built guidelines.

As there are many methods or guidelines being used by researchers to conduct systematic mapping in software engineering, we chose to have a proper understanding of these different methods which discuss about conducting systematic mapping and then adopt or develop a method which suits our area of research.

3 RESEARCH DESIGN

In this section, we present the aim of our master thesis which is divided into feasible objectives, research questions and research methods. Research plan for this study is also provided.

3.1 Aim

The goal of our master thesis is to provide a systematic mapping on the state of published research on teaching modeling in software engineering.

3.2 Objectives

The above stated aim shall be achieved through the following objectives which were categorized into four groups:

1) To understand how to conduct systematic mapping.
    1) To enquire the existing research publications on systematic mapping
    2) To identify the methods or ways to classify and categorize published articles.
    3) To inspect and reflect on the process of conducting systematic mapping study.

2) To choose proper systematic mapping guidelines that suits our research context.

3) To employ the chosen systematic mapping guidelines on published articles on teaching modeling.
    4) To identify the similarities, groups and clusters among the research publications in the area of teaching modeling.
    5) To analyze what features do the groups possess.
    6) To construct a map from the obtained results.

4) To reflect on the results of systematic mapping on teaching modeling.

3.3 Research Questions

Here, research questions are formulated and documented which drive our research and are structured according to the objectives stated in the above section.

1) **How is systematic mapping in software engineering carried out?**
   This question is divided into sub research questions such as:
   1.1) What guidelines are suggested to conduct systematic mapping in software engineering?
   1.2) What classification and categorization schemes are used to cluster the research articles?
   1.3) What methods/tools are used to carry out the classification of research publications?

2) **What systematic mapping guidelines are appropriate to be employed in our research context?**

3) **What published research exists on teaching modeling in software engineering, how can it be classified?**
   1.1) What is the state of research activity on teaching modeling in software engineering?
   1.2) What categories or groups can be identified from these publications?

1.3) What are the contents of the groups identified?
1.4) What relations can be drawn between the identified groups?

4) What reflections can be made on the obtained mappings?

3.4 Research Plan

The aim of our thesis is to provide a systematic mapping on the state of published research on teaching modeling in software engineering. Figure 2 provides a pictorial representation of the research plan, with outputs of each activities and each phase in the master thesis.

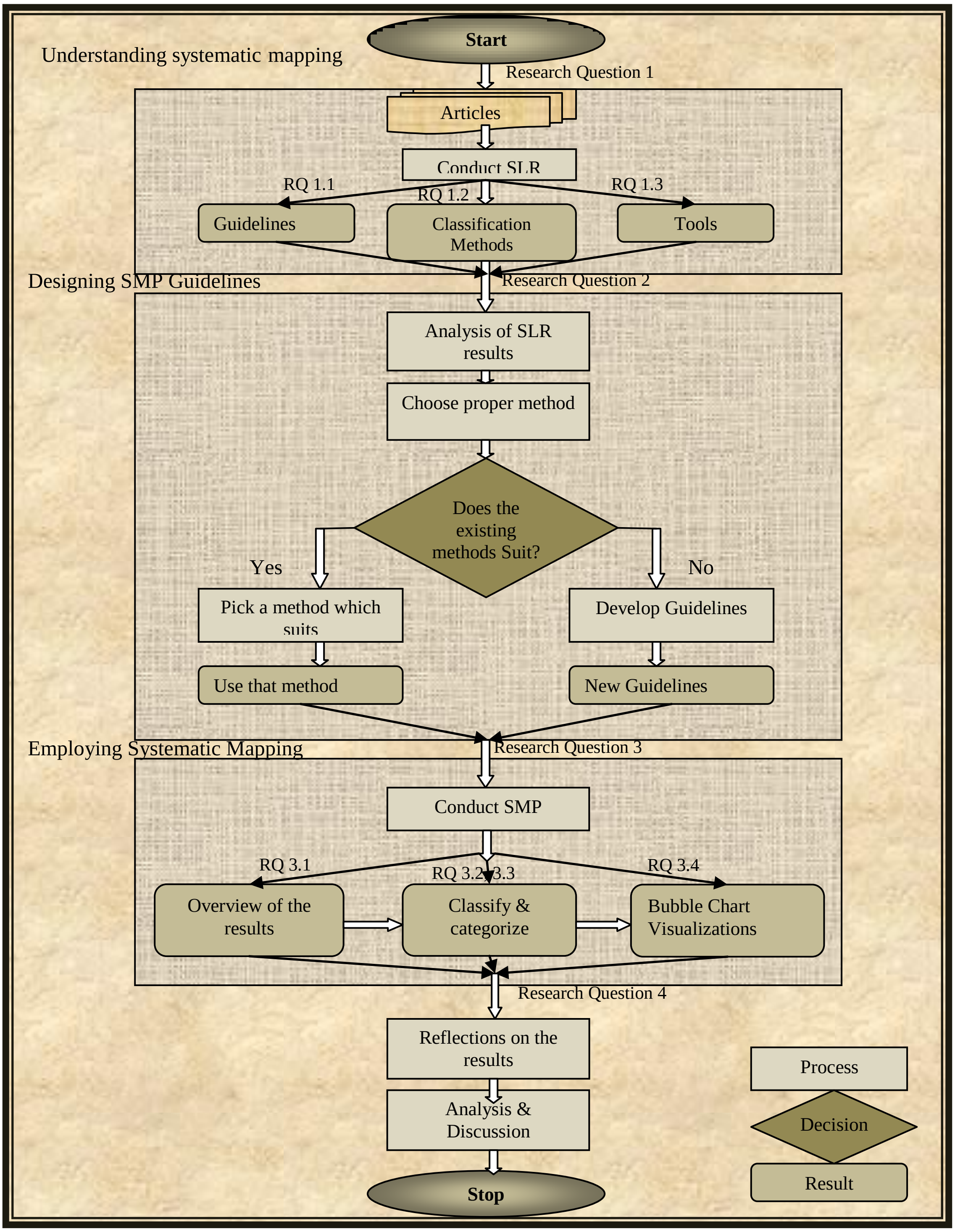


Figure 2 Research Plan

As there exist many ways (refer Section 2.2 Background and related work on teaching modeling) to conduct systematic mapping, we planned a systematic literature review to choose a proper way for conducting systematic mapping in our research context. A systematic literature review was chosen as it provides quality evidence related to a particular topic [21].

While conducting Systematic Literature Review (SLR) and Systematic mapping study (SMP) we feared that we might encounter a large number of search results. As a mitigation strategy, we chose to divide the number of articles into two and work parallel on selecting the articles. To ensure that both of us had similar opinions and to assess the strength of our decisions, we conducted a kappa coefficient analysis on a random sample of 10 articles, which showed that we had similar decisions. Refer section 4.2.2.1 for kappa results.

The results of the SLR, guidelines to conduct mapping study answer research question 1.1. Results related to classification methods, answer question 1.2 and articles related to tools used in conducting systematic mapping answer research question 1.3. An analysis of the results is carried out, once all corresponding results to research questions 1 are obtained. Based on the analysis of SLR results, a proper method is chosen for conducting Systematic mapping in our research context, which answers research question 2. If there exists a proper method which suits our research context, we chose to employ that method, to conduct systematic mapping, else decided to develop a new method.

These guidelines, selected after the analysis are chosen to be employed on systematic mapping on teaching modeling, to answer research question 3 and 3.1 Based on these guidelines, search for articles is carried out and the resulting articles are classified based on the selected classification strategies, this classification and categorization answers research question 3.2 and 3.3. Once classification of data is done, visualization of data is carried with an overview of the results which answers research question 3.4. An analysis of results is made which results in reflections on the results obtained from systematic mapping on teaching modeling, this reflections answer research question 4.The table 1 shows the research questions, research methods and the results.

Research Questions	Research method	Results in
RQ1, RQ1.1, RQ1.2, RQ 1.3	Systematic Literature review	Understanding Systematic mapping
RQ 2	Analysis on the results SLR	Need for the development of guidelines to conduct systematic mapping
RQ3, RQ3.1, RQ3.2, RQ 3.3, RQ 3.4	Systematic mapping study	Mapping and classification of articles
RQ 4	Analysis on the results of SMP	Reflection on the results

Table 1 Research questions, research methods and results

4 UNDERSTANDING SYSTEMATIC MAPPING

There are different ways of conducting systematic mapping in software engineering (refer section 2.2). A systematic literature review was conducted, to know all available methods of conducting a mapping study and to choose an appropriate one for this research. Systematic literature review was chosen as a research method over empirical methods such as surveys, case studies or experiments, as they are based on opinions, discussions or hypothesis [111]. While, systematic literature reviews investigate the published evidence and also provide an insight on how systematic mapping is being conducted in real.

Systematic literature Review (SLR) is a tool for the identification, evaluation and interpretation of the published research which is relevant to a particular research question or topic or phenomenon of interest [21].There are many guidelines and templates suggested by different authors Petticrew and Roberts [6], Kitchenhamn et al [21], Jorgenson and Shepperd [26], Biolchini et al [27] to conduct systematic literature reviews in software engineering. Only Kitchenhamn's guidelines [21] were chosen for this study, as they offer a complete template to conduct systematic literature reviews in software engineering, right from beginning of the search process, background analysis to documenting the results, every step is clearly explained. Also, these guidelines provide a well-defined review protocol and make it easy for other researchers to assess the quality of the review, when compared with the other guidelines [22].

Systematic literature review according to Kitchenhamn [21] consists of three phases, planning the review protocol, executing the review protocol and documenting the results.

- Planning the review protocol
- Executing the review protocol
- Documenting the results

Each of these phase mentioned above has their own set of activities which are depicted in figure 3

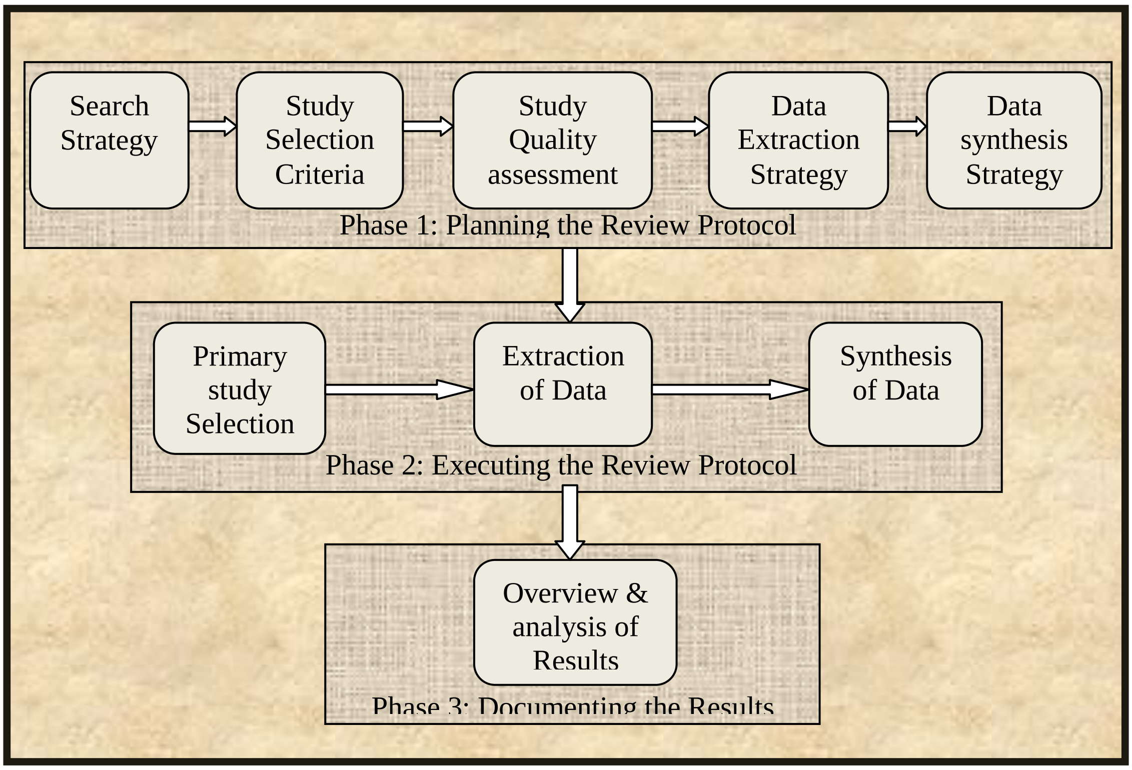


Figure 3 Phases in Systematic literature review

These phases and activities of systematic literature review are explained in the next section which begins with planning the review protocol.

1. **Phase 1: Planning the review Protocol:**
   This phase addresses and produces a review protocol which defines the basic review procedure for the study [22]. This review procedure consists of the following activities

   1.1. *Search Strategy*
   A procedure for performing a search for primary studies is developed here. This includes developing a search string and choosing the databases [22].

   1.2. *Study selection criteria*
   This step involves developing a criterion to include or exclude articles for the literature review [22].

   1.3. Study Quality Assessment
   A procedure to assess the quality of primary studies is developed; also a description of how conflicts between the assessors are resolved is given [22].

   1.4. Data Extraction strategy
   This defines how the required information from primary studies is extracted. Data extraction forms are developed and used for this purpose [22].

   1.5. Data synthesis Strategy
   A synthesis procedure is defined which includes techniques and methods used for synthesis [22].

2. **Phase 2: Executing the review protocol**
   Once the protocol has been agreed, it is executed in accordance with the design [22].

   2.1. Primary study selection
   Search strings defined in the search strategy of phase1 are employed on the databases, study selection criteria and quality assessments procedures are executed to limit the results and to obtain the primary studies.

   2.2. Extraction of data
   Data is extracted from the primary studies according to the data extraction procedure designed in the phase1.

   2.3. Synthesis of data
   Synthesis of data is carried out using the techniques specified in phase 1. The results of this phase are documented in next phase.

3. **Phase3: Documenting the results**
   This is the final phase of a systematic literature review which involves documenting the results obtained from earlier phases.

   3.1. Overview and analysis of the results
   Overview of results is presented; answers related to research questions are documented and analyzed.

In the following sections we present how guidelines suggested by Kitchenhamn [22] are used in this study to perform a systematic literature review.

4.1 Planning the review protocol

This is the first phase of conducting a systematic literature, where a plan for the review protocol is drawn. The systematic literature review is designed in a step by step manner starting with the formulation of search strategy, followed by study selection criteria, quality assessment procedure, data extraction strategy and the design of data synthesis strategy.

4.1.1 Search strategy

The following search strategy was be used to search for primary studies which includes construction of search strings, including search terms and resources to be searched.

- **Constructing Search string**

This step consists of identification of keywords and selection of connectors in order to formulate search string.

4.1.1.1.1 Identifying keywords:

PICOC (Population, Intervention, Comparison and Outcomes, Context) suggested by Kitchenhamn [21], which was developed to formulate research questions as a strategy for selecting proper keywords in order to formulate a search string. Apart from PICOC we also extracted keywords from research questions

Research Questions from section 3.3
1) What **guidelines** are suggested to conduct **systematic mapping** in **software engineering**?
2) What **classification** and **categorization** schemes are used to cluster the research articles?
3) What **methods/tools** are used to carry out the classification of research publications?
From the above research questions, we identified keywords such as **guidelines, systematic mapping, categorization, classification, methods, tools and software engineering.**

Using PICO:
PICOC [21] suggested by Kitchenhamn et al [22] consists of Population, Intervention, Comparison and Context as mentioned earlier but we excluded Context as it is not suitable in this study.
Population: In software engineering, population may refer to specific software engineering role, category of software engineer, an application area or an industry group [22]. In our context, population is the field or the domain which is **software engineering**.

Intervention: In software engineering, intervention refers to software Methodology /tool /technology /procedure [22], which in our context refers to the area which is **systematic mapping**.

Comparison: In this study we compare the process of conducting the review [22]. Hence comparison made here is on the **process or procedure** for conducting the review

Outcomes The outcomes of the study are the **guidelines** which suggest the process of conducting systematic mapping

The identified keywords are **guidelines, systematic mapping** and **software engineering** which were grouped into sets and their synonyms were considered to formulate search string. As the keywords identified from research questions and keywords identified from PICO criteria are similar, we grouped them into sets.

Keyword set 1) This set contains keywords related to the domain of our research i.e. **Software Engineering**.

Keyword set 2) This set contains keywords identified from PICO criteria and RQ's which are concerned with **Systematic mapping**

- Systematic mapping
- systematic map
- systematic maps
- systematic mapping study
- systematic mapping studies

Keyword set 3) This set contains keywords identified from PICO criteria and RQ's which are concerned with the **process of classification and categorization** of articles.

- Methods
- tools
- classification
- framework
- techniques
- grouping
- model
- tool
- guidelines
- practice
- categorization
- rules

These keywords are connected with Boolean operators mentioned in the following section to formulate search string.

4.1.1.1.2 Boolean Operators

Boolean operators AND, OR were considered as connectors for the search string.

- AND
- OR

The keyword sets obtained earlier in section 4.1.1.1 were combined using Boolean operators which resulted in the following search strings mentioned in Table 2.

- Set 1
  (Software engineering)
- Set 2
  (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps)
- Set 3
  (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)

Number	Combinations of keyword sets with Boolean operators	Search Strings
1	(Set 1) and set (2)	(Software engineering) and (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps)
2	(Set 2) and set (3)	(Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) and (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or

		grouping) or (guidelines or rules)
3	(Set 1) or set (3)	(Software engineering) or (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
4	(Set 1) and set (2) and (set 3)	(Software engineering) and (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) and (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
5	(Set 1) or set (2) and (set 3)	(Software engineering) or (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) and (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
6	(Set 1) and set (3)	(Software engineering) and (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
7	(Set 1) or set (2)	(Software engineering) or (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps)
8	(Set 2) or set (3)	(Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) or (Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
9	(Set 1) and set (2) or (set 3)	(Software engineering) and (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)
10	(Set 1) or set (2) or (set 3)	(Software engineering) or (Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)

Table 2 Search strings

A specific search string (refer Table 47 under Appendix 12.1 for the search strings used to obtain the primary studies) from Table 2 was employed on the databases mentioned in the following section.

- **Databases**

The following electronic databases were identified for this study. Databases such as Google scholar were left out as they contain non peer reviewed articles.

- IEEE,
- ACM,
- SCOPUS,
- ENGINEERING VILLAGE (Compendex / Inspec).

EndNote X6 [34], a reference management tool was used to remove duplicates and manage the large number of references.

4.1.2 Study selection criteria

To limit the related results, we adopted a twofold Screening criterion, where a basic inclusion/exclusion criterion is followed by a full text/ Title + abstract reading. The basic inclusion criteria is described below

- **Basic Inclusion Criteria**

The following criteria mentioned in Table 3 are used to include the necessary articles related to our study.

No.	Inclusion Criteria
1	Include articles which were published only between 2004- 2012
2	Studies related to the domain of software engineering were only considered

Table 3 Basic Inclusion Criteria

The first article on systematic mapping was published in the year 2007 [39]. Not to miss out on any article which might have shown some intent on developing systematic mapping, we have included those articles which have been published from 2004.

- **Basic Exclusion Criteria**

The following criteria mentioned in Table 4 are used to exclude the unnecessary articles which are not related to our study.

No.	Exclusion Criteria
1	Exclude those articles which were non-peer reviewed
2	Exclude books as they are non-peer reviewed studies.
3	Exclude those studies which were not in English.
4	Exclude summaries, templates, project reports etc.
5	Exclude articles that are unable for full text access

Table 4 Basic Exclusion Criteria

We excluded all articles which were not in English as well as those which were not peer reviewed and those which were just templates, summaries of conferences or project reports.

- **Screening by Reading**

A basic screening criterion is not sufficient to limit the results. In order thoroughly screen the articles, we conducted full text reading i.e. the article was read for title and abstract, if the abstract was not clear then the introduction was read, still if there was some kind of ambiguity, the whole article was read.

- **Snowball sampling**

Snowball sampling was conducted on the resultant articles from the automated search, to make sure that we do not miss out on any important articles on systematic mapping.

Snowball sampling for the articles was carried out in an iterative fashion; an article was checked for its citations first, if any related articles were found, not included in studies resulting from manual or automated, they were added to new list else left. After checking for citation, references were checked, and the same procedure of including and excluding a study was repeated.

Once all articles were snowballed, the resultant articles from snowball sampling were checked for references. This step was repeated until there were no new articles to be added onto a list.

The criterion to include or exclude an article was taken from the two fold inclusion and exclusion criteria discussed earlier. After this step we obtain the final set of studies which were considered for study quality assessment. Refer to Appendix 12.3 for a detailed picture of this process.

In addition to the incl/excl criteria defined above, we considered to assess the quality of the obtained primary studies [22].

4.1.3 Study Quality Assessment

To assess and determine the quality of articles selected, we considered to ask the following questions:

- Is the motivation for conducting systematic mapping clearly stated?
- Is the process of conducting systematic mapping clearly defined?
- Is there any empirical evidence for the mapping process defined?

. These questions were answered with

- Yes, if the selected study fully satisfies the above criteria.
- No, if doesn't satisfy the criteria and
- Partially, if the result was in-between an yes and a no.

Once the quality assessment criterion was specified, the strategy to extract data from the articles was considered, mentioned in following section.

4.1.4 Data Extraction Strategy

To extract data from the identified primary studies, we considered the following template with the fields shown below. Each data extraction field has a data item and value for the data items. For example, the first field of the data extraction template contains data item study ID which is supplied with a value which is an integer.

Generic data extraction template		
Data Item	Value	Research Question
General Information		
Study ID	Integer	
Article Title	Name of the article	
Author Name	Name of the author	
Year of Publication	Calendar year	RQ 1
Area in SE	Knowledge areas in SWEBOK	
Specific Information		
Guidelines	Which guidelines were adopted	RQ 1, RQ 1.1
Search strategy	What search strategy is followed	
Search type	Manual or automated or both	
Visualization type	What visualization types were used in order to present the day in a pictorial manner	
Classification schemes	How were articles classified	RQ 1, RQ 1.2
Tools	What methods/tools were used to automate the process	RQ 1, RQ 1.3

Table 5 Data Extraction Template

Data extraction fields and their relevance to research questions:

1. How is systematic mapping carried out in software engineering?

To extract data related to research question 1, we analyzed the frequency and areas where systematic mapping is conducted in software engineering.

1.1. What guidelines are suggested to conduct systematic mapping in software engineering?

To extract data related to research question 1.1, which is to identify the guidelines adopted to conduct systematic mapping in software engineering we placed a field in the data extraction which extracts the data related to guidelines, author's name is entered as the value for this field. As we were talking about guidelines as a whole, we wanted to inspect different areas of systematic mapping such as the search strategy used, type of search employed i.e. automated or manual, type of visualization chosen etc.

1.2. What classification and categorization schemes are used to cluster the research articles?

To extract data related to research question 1.2, which is to identify the categorization and classification techniques used in systematic mapping we inserted a field which extracts the classification techniques or types and their categories.

1.3. What methods/tools are used to carry out the classification of research publications?

To extract data related to research question 1.3, which is to identify the usage of tools / techniques / methods to automate the systematic mapping process, we positioned a field in the data extraction sheet which extracts data related tools. Author's name and study id were supplied as values to this field.

4.1.5 Data Synthesis Strategy

Thematic analysis [23] was chosen to analyze the data obtained from the extraction process as it suits our research context rather than any other qualitative analysis methods such as Narrative synthesis [42] or Content analysis [44]. Thematic analysis is a procedure which is used to identify, analyze or report patterns in the articles [23] [43]. It is used to present categorical data in detail with an interpretation of various groups under the primary studies [23].For this thematic analysis we chose method adopted by Cruze & Dyba [23], which involves the following steps

- Extracting data
  Extracting the data involves obtaining the data from primary studies, for which we have used a data extraction template.
- Coding the data
  This step involves adding names to different data segments which were extracted from the above step [24].
- Translating codes into themes
  Here, clustering the codes into themes is carried out based on the relationships between them.

Figure 4 shows the Data analysis strategy followed in this thesis which was adopted from Cruze et al [23].

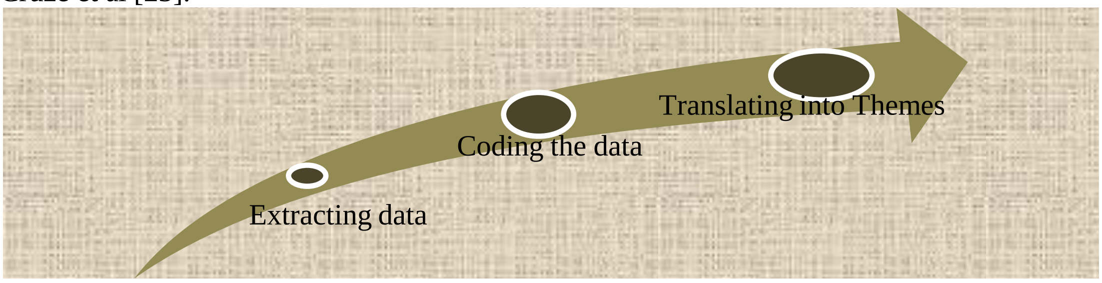


Figure 4 Data Synthesis Strategy adopted from Cruze et al [23]

Planning the review protocol is followed by its execution, which is described in the following sections

4.2 Executing the review protocol

The execution of systematic literature review which is designed in the earlier phase is presented in this section. This phase starts with the selection of primary studies and ends with extracting the data from studies.

4.2.1 Primary studies selection

The review protocol was executed systematically according to the design described in the above section. In order to obtain primary studies, we employed the search strings on databases mentioned earlier (see Appendix 12.2 for data bases and search strings). A basic inclusion and exclusion criterion was applied on these search results which provided us with primary studies. These primary studies were checked for duplicates manually and using EndNote [34], a reference management tool.

After removing duplicates these primary studies were considered for full text reading and irrelevant articles were removed. After the removal of irrelevant studies, these primary studies considered for snowball sampling. Any article which was missed in the electronic search process but relevant to the study was added. Thus, we have selected relevant studies which were considered at a later step for quality assessment.

A total of 7752 results were found when the selected search strings were employed on electronic databases. As mentioned earlier, we considered articles which were published after 2004 which resulted in the removal of 2666 studies leaving us with a total of 5086 articles. Basic inclusion and exclusion criteria were applied on these 5086 articles by reading title and abstracts. At the end of this step we were left with a total of 131 primary studies. The table below shows the databases, search results and primary studies obtained.

Database	No of search results	Primary studies
IEEE	5610	26
ACM	360	30
SCOPUS	1215	37
INSPEC / COMPENDEX (Engineering village)	567	28
TOTAL	7752	131

Table 6 Databases, hits & primary studies obtained

These articles were checked for duplicates with EndNote X6[34] and 34 of the duplicates were eradicated. These were again checked manually for duplicates as the tool cannot detect inconsistently stored names in databases. After manual checking 34 of the duplicates were removed leaving 63 articles. These 63 articles were considered for full text reading where 17 articles (see Appendix 12.6) were removed, leaving 46 primary studies.

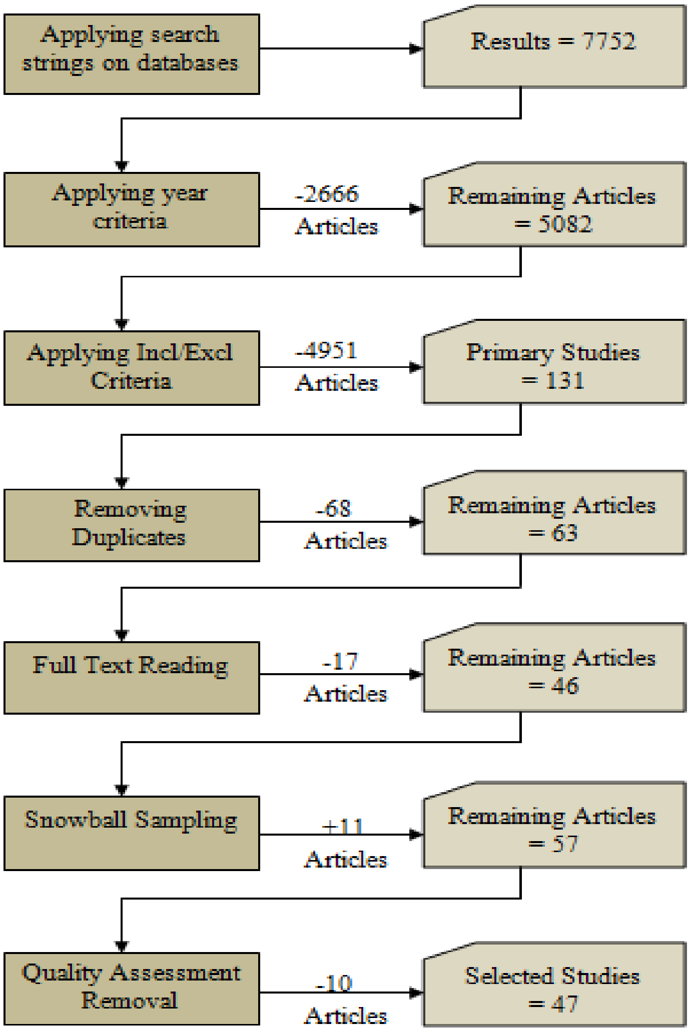


Figure 5 Systematic Literature Review study selection process

These 46 primary studies were chosen for snowball sampling where 11 new studies (see Appendix 12.7) were obtained. These 57 studies were considered for Quality assessment (see Appendix 12.4).

4.2.2 Quality Assessment of studies

Table 7 and 8 show the results of quality assessment of the primary studies. From table 7 we can observe that there are 17.54% of 57 articles, i.e. 10 articles do not have any empirical evidence. Hence these articles are removed.

Quality Assessment Question	Yes %	No %	Partially %
1) Is the motivation for conducting systematic mapping clearly stated?	94.73%	0%	5.27%
2) Is the process of conducting systematic mapping clearly defined?	91.22 %	0%	8.78%
3) Is there any empirical evidence for the defined mapping process?	78.95%	17.54%	3.51%
Average Conformance to the Quality assessment	88.3 %	5.84%	5.85%

Table 7 Quality Assessment

Study ID	Question 1	Question 2	Question 3
[SLR 1]	YES	YES	YES
[SLR 2]	YES	YES	YES
[SLR 3]	YES	YES	YES
[SLR 4]	YES	YES	YES
[SLR 5]	YES	YES	YES
[SLR 6]	YES	YES	YES
[SLR 7]	YES	PARTIALLY	YES
[SLR 8]	YES	YES	YES
[SLR 9]	YES	YES	YES
[SLR 10]	PARTIALLY	YES	YES
[SLR 11]	YES	YES	YES
[SLR 12]	YES	YES	YES
[SLR 13]	YES	YES	PARTIALLY
[SLR 14]	YES	YES	YES
[SLR 15]	YES	YES	YES
[SLR 16]	YES	PARTIALLY	YES
[SLR 17]	YES	YES	YES
[SLR 18]	YES	YES	YES
[SLR 19]	YES	YES	YES
[SLR 20]	YES	YES	YES
[SLR 21]	YES	YES	YES
[SLR 22]	YES	YES	YES
[SLR 23]	YES	YES	YES
[SLR 24]	PARTIALLY	YES	YES
[SLR 25]	PARTIALLY	YES	YES
[SLR 26]	YES	YES	YES
[SLR 27]	YES	YES	NO
[SLR 28]	YES	YES	NO
[SLR 29]	YES	YES	NO
[SLR 30]	YES	YES	NO
[SLR 31]	YES	YES	NO
[SLR 32]	YES	YES	YES
[SLR 33]	YES	YES	YES
[SLR 34]	YES	YES	YES
[SLR 35]	YES	PARTIALLY	YES
[SLR 36]	YES	YES	YES
[SLR 37]	YES	YES	YES
[SLR 38]	YES	PARTIALLY	YES
[SLR 39]	YES	YES	NO
[SLR 40]	YES	YES	NO
[SLR 41]	YES	YES	YES
[SLR 42]	YES	YES	YES
[SLR 43]	YES	YES	PARTIALLY
[SLR 44]	YES	YES	YES
[SLR 45]	YES	PARTIALLY	YES
[SLR 46]	YES	YES	YES
[SLR 47]	YES	YES	NO
[SLR 48]	YES	YES	YES
[SLR 49]	YES	YES	NO
[SLR 50]	YES	YES	YES

[SLR 51]	YES	YES	NO
[SLR 52]	YES	YES	YES
[SLR 53]	YES	YES	YES
[SLR 54]	YES	YES	YES
[SLR 55]	YES	YES	YES
[SLR 56]	YES	YES	YES
[SLR 57]	YES	YES	YES

Table 8 Quality Assessment results

We have observed that 10 articles (see Appendix 12.5) in the quality assessment process did not satisfy the required criteria though they were relevant to this study. Hence we considered to remove these 10 articles as mixing them with the other 47 articles would bias the results. At the end of this step we have 47 selected studies for data extraction (See Appendix 12.8).

- **Kappa coefficient for inter rater agreement**

In order to measure the level of agreement between the two authors on the inclusion and exclusion of a particular article after the full text reading, in this research, we have used kappa coefficient. 10 articles were chosen randomly and the agreements or disagreements to include or exclude an article are presented in the table 10.
Kappa coefficient is calculated using the following formulae

$$K = [P(A) - P(E)]/[1 - P(E)]$$

Table 9, shows the ranges of kappa and strength of agreement [30]

Kappa values	Strength of agreement
K <=0.44	Poor
0.44<=K<=0.62	Moderate
0.62<=K<=0.78	Substantial
K>0.78	Excellent

Table 9 Kappa coefficient ranges

Where,
P (A) is the probability of observed agreement

$$P(A) = \frac{\text{(No of articles where both authors agree + no of articles where both authors say diasgree)}}{N}$$

= 0.9
P (E) is the probability of expected agreement

$$P(E) = \left\{\frac{\text{No of articles where author 1 agrees}}{\text{N}} \times \frac{\text{No of articles where author 2 agrees}}{\text{N}}\right\} + \left\{\frac{\text{No of articles where author 1 disagrees}}{\text{N}} \times \frac{\text{No of articles where author 2 disagrees}}{\text{N}}\right\}$$

= 0.54
N is the total number of articles= 10

ID	Author 1	Author 2
1	YES	YES
2	YES	YES
3	YES	YES
4	YES	YES
5	YES	NO
6	YES	YES
7	YES	YES
8	NO	NO
9	NO	NO
10	NO	NO

Table 10 Strength of Inter rater agreement

The kappa value obtained from the random sample shows a value of 0.78 which indicates that the strength of agreement between two authors is substantial.

4.2.3 Extraction of Data

As mentioned earlier, data extraction is done according to the data extraction template. To extract data from the studies and to fill the template with suitable data values, we used Microsoft excel sheets.

4.2.4 Synthesis of data

To analyze data, we have used thematic analysis adopted by Cruzes et al [23] which consists of three steps, as mentioned earlier.

- **Extracting data**
  Data is extracted from the primary studies according to the data extraction sheet mentioned in the above step.

- **Coding the data**
  A priori or a deductive approach [23] [25], was used to code the data, where we created a list of codes which were designed from research questions, research problems, keywords etc. [23]. Data items in the data extraction sheet were chosen in order to create the provisional list. Unique codes were assigned to data items mentioned in the data extraction sheet, which is shown in the table 11.

Assigning Codes to data items	
Code	Data Items
C1	Study ID
C2	Article Title
C3	Author Name
C4	Year of Publication
C5	Area in SE
C6	Guidelines
C7	Search strategy
C8	Search type
C9	Visualization type
C10	Classification schemes
C11	Tools

Table 11 Coding data items

- **Translating codes into themes**

Codes were translated into themes based on the relationships. We have translated 11 codes into 4 themes.

Assigning Codes to data items		
Themes	Code	Data Items
T1:Publication Information	C1	Study ID
	C2	Article Title
	C3	Author Name
	C4	Year of Publication
T2: Context	C5	Area in SE
T3: Guidelines	C6	Guidelines
	C7	Search strategy
	C8	Search type
	C9	Visualization type
T4: Classification Methods	C10	Classification schemes
	C11	Tools

Table 12 Translating Codes into themes

- T1:Publication Information
- T2: Context
- T3: Guidelines
- T4: Classification Methods

Codes C1, C2, C3, and C4 provide data related to the publication information. Code C5 provide information related to the context of this study i.e. which area of software engineering does the study take place in, code C6, C7, C8 and C9 provide information regarding the guidelines to conduct systematic mapping in software engineering. Code C10 and C11 concentrate on the methods which classify studies. The themes are used for the analysis and comparison in systematic literature review.

The results obtained from this phase are documented and analyzed. The overview of these results is presented in the following section.

4.3 Documenting Results

In this section, we present the overview of the results obtained from the earlier phases. Results corresponding to each research question are presented. Refer Appendix 12.9 for publications under each category

4.3.1 Results corresponding to Research Question 1)

- **How is systematic mapping carried out in software engineering?**

To answer this research question, the results of systematic literature review on systematic mapping in software engineering are presented. As the first step in portraying the results, we wanted to know the trends in the usage of systematic mapping study. Hence, we analyzed the frequency of usage of systematic mapping studies in software engineering. Equation 1 shows the frequency of usage.

$$Frequency\ of\ usage = \frac{No{:}\ of\ articles\ publised}{Per\ calender\ Year}$$

Equation 1 Frequency of usage

We have found that systematic mapping study was first carried out in 2007 [39]; the later year saw only two research publications which have systematic mapping study as their research method. Year 2010 saw an increase in the number of research publication using systematic mapping with 6 articles and this uptrend continued with a steep rise of 19 publications using systematic mapping in the year 2011 and also 19 publications in the 2012. This shows that there is a growth of research carried out by using systematic mapping as a research method. Figure 6, shows a rise in the frequency of publications from the year 2010.

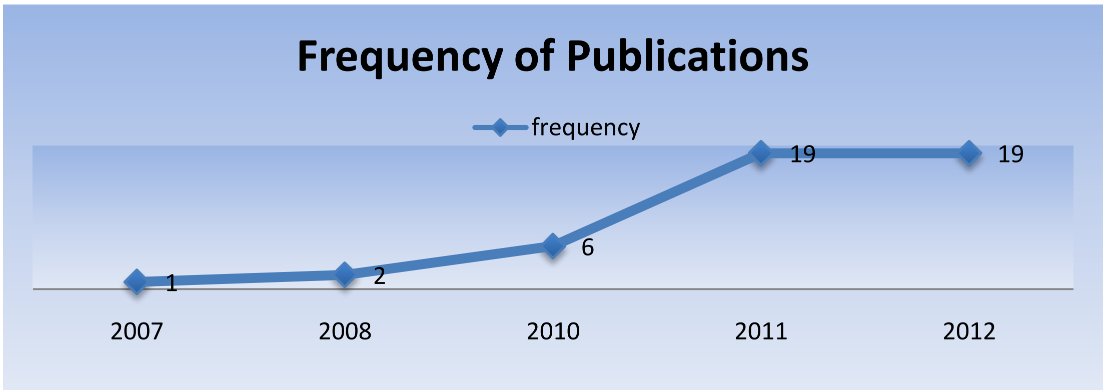


Figure 6 Frequency of mapping studies

We mapped the research publication which have used systematic mapping in software engineering to knowledge areas mentioned in SWEBOK [45]. We have mapped 9 knowledge areas mentioned in SWEBOK [45] to our selected studies such as software testing, software quality, software construction, software design, software requirements, software configuration management, software tools and methods, software engineering process, software engineering management, software requirements. Most of the research was carried out in the area of software tools and methods.

27 selected studies were mapped to software tools and methods, software engineering process and software testing with 9 selected studies in each knowledge area. 6 selected studies have been mapped to software construction and software quality with 3 selected studies in each category. 8 selected studies were mapped to software engineering management and software requirements with 4 selected studies in each knowledge area. There were 5 selected studies associated with the knowledge area of Software design and 1 selected study with software configuration management. Figure 7, portrays the publication in each knowledge area.

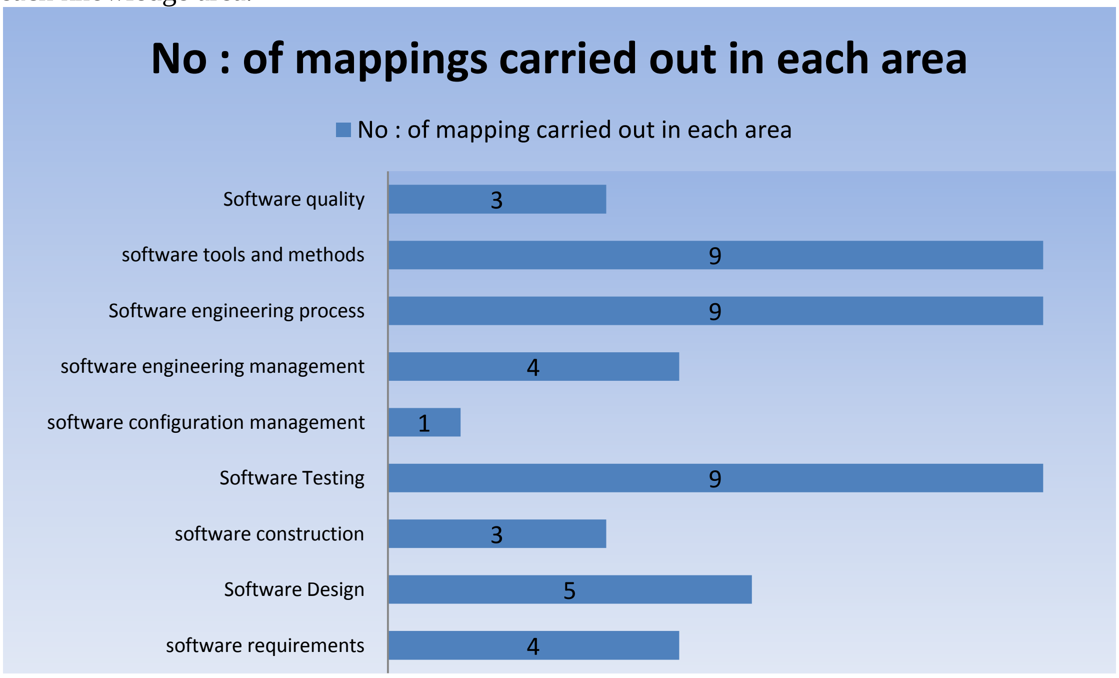


Figure 7 Areas where systematic mapping is conducted

- **Results corresponding to Research question 1.1)**

What guidelines are suggested to conduct systematic mapping in software engineering?

We have extracted data related to the guidelines to conduct systematic mapping study. We have observed that 7 different guidelines are present in the literature to conduct systematic mapping in software engineering. They are Petersen[2], Aarskey [29], Jorgenson[26], Bailey [39], Biolchini[27], Kitchenhamn[21] and Durhams template [28]. Figure 8, shows the guidelines. These guidelines are described in the table 13.

Guidelines to conduct systematic mapping in software engineering	
Guidelines	Description
Kitchenham et. Al [21]	These are guidelines as how to conduct literature reviews in software engineering. This is a technical report which has a comparison of systematic literature review with systematic mapping in the concluding pages.
Petersen et. Al [2]	This study provides a set of guidelines to conduct systematic mapping in software engineering. It also compares systematic maps with systematic literature reviews and points out the differences between them.
Bailey et. Al [39]	This study introduces what a mapping study is and performs a mapping study on Object oriented paradigm.
Aarskey et. Al [29]	This study reports a framework which discusses about the guidelines for conducting scoping studies in software engineering
Jorgenson et. Al [26]	These guidelines consists of classification of articles for systematic literature review, adopted by SLR[36]
Durhams Template [28]	This is mapping template designed at Durham university which consists of a list of requirements which were not to be missed out while conducting systematic mapping in software engineering, adopted by SLR [27]
Biolchini et. al. [27]	This is a technical report on the process of conducting systematic literature reviews in software engineering, which extends Kitchenhamn's guidelines [21] to conduct systematic literature reviews. These guidelines were adopted to conduct systematic mapping in software engineering by SLR [47]

Table 13 Description of systematic mapping guidelines

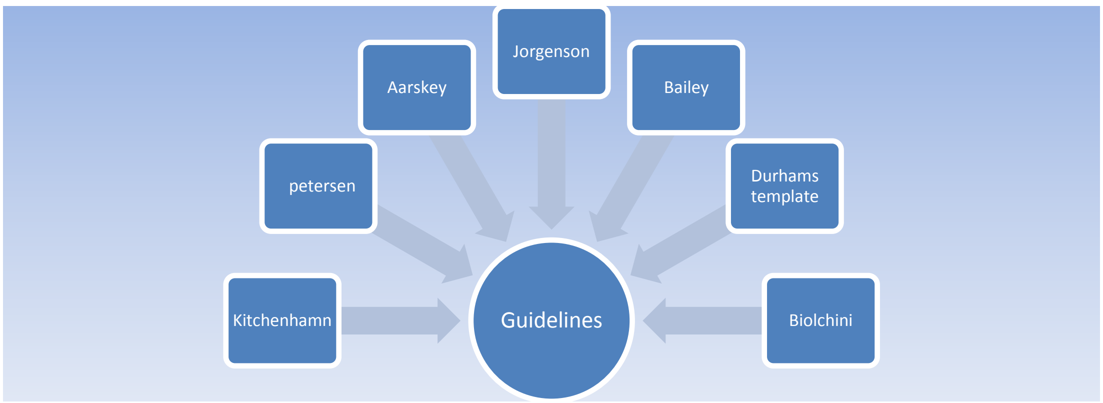


Figure 8 Systematic mapping guidelines

We have observed that 37% of 47 selected studies, i.e.18 selected studies have used Petersen guidelines [2] to conduct systematic mapping studies in software engineering, 19% of 47 selected studies i.e. 9 selected studies use Kitchenhamn guidelines [21] and 15% of 47 selected studies i.e. 7 selected studies use both Kitchenhamn [21] and Petersen guidelines [2]. 4% of 47 i.e. 2 selected studies use Aarskey guidelines [29] and 2% of publication use jorgenson guidelines[26], 2% use Bailey's guidelines [39], 2% use Durhamstemplate [28] and 2% use Biolchini guidelines[27]. 17% of 47 i.e. 8 selected articles use their own guidelines. Refer Appendix 12.9 for articles under each guidelines. The figure ,9 depicts the systematic mapping guidelines usage.

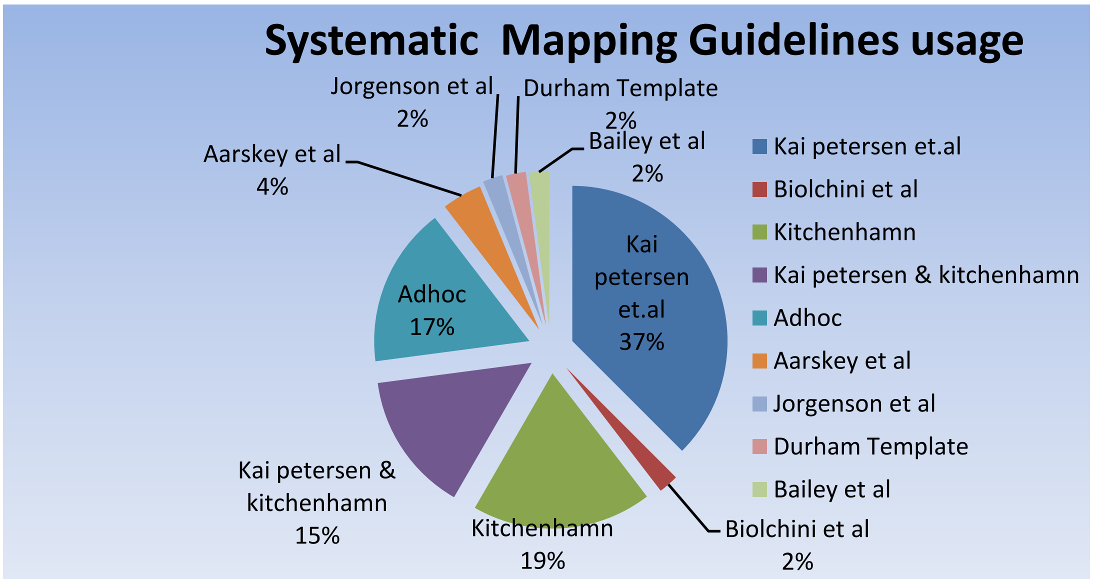


Figure 9 Systematic mapping guidelines and their usage

To have a better understanding of the search process used in different guidelines, we extracted data related to search process and the visualization of results. To analyze the data related to search process we have chosen different parts of search process such as search strategy, i.e. what type of search strategy has been followed, search type, whether an electronic automated search or electronic manual search or a manual search has been employed. We also wanted to see if snowball sampling has been conducted by the authors to ensure that all articles related to research were collected.

4.3.1.1.1 Search strategy used by researchers:

We have observed that some of the researchers used PICOC strategy which was originally developed to formulate research questions by Petticrew and Roberts[9], adopted by Kitchenhamn[21]for usage in software engineering. PICOC stands for Population, Intervention, Context, Outcomes and Comparison.

PICOC criteria according to kitchenhamn [21] are described in the table 14.

PICOC Terms	Description
Population	Population refers to specific role, category, group or an application area in software engineering [21].
Intervention	Intervention refers to a software methodology/ procedure / technology/ tool that address a problem or a specific issue in software engineering [21]
Comparison	Comparison refers to the comparison between two interventions in software engineering [21].
Outcomes	Outcomes refer to the set of results about which the participants of a research in software engineering were interested [21].

context	Context refers to the setting in software engineering where the comparison takes place [21].

Table 14 Description of PICOC

This PICOC strategy is being used to identify keywords for search string. There were 17 studies i.e. 36% of 47 selected studies where, researchers used PICOC strategy for search string formulation and 64% of 47 selected studies, i.e. 30 researchers had their own strategy for search string formulation. Refer Appendix 12.9 for articles under each strategy.

Figure 10 Usage of PICOC in search strategy

4.3.1.1.2 Type of search performed:

There are two types of search mechanisms employed by researchers in the selected studies. A set of researchers chose to use only automated search i.e. search on electronic databases and others chose to conduct a manual search in addition to the automated search. Manual search is a look up made for research articles without the use of search engines, carried out on electronic/ hard copies of journals or conferences proceedings etc. This manual search is employed to ensure that important articles relevant to study were not missed while using an automated search mechanism. Most articles reported the usage of Automated search mechanism to obtain the primary studies.

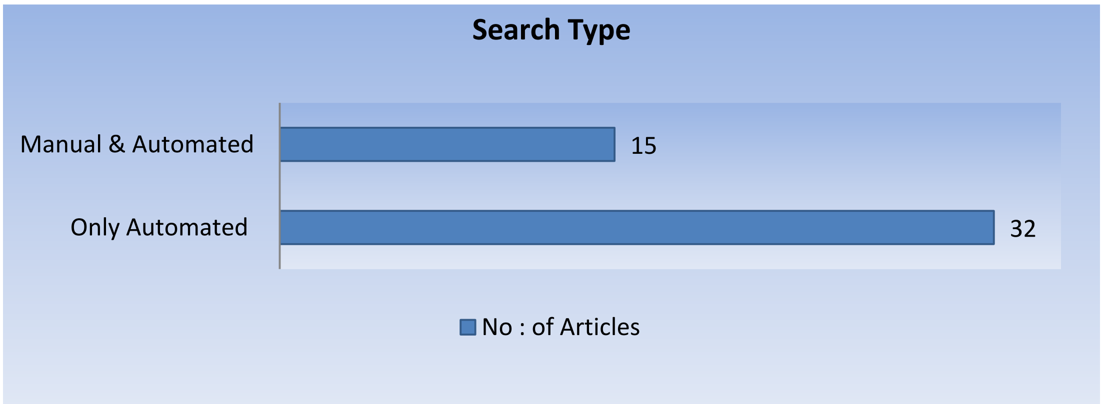


Figure 11 Type of search mechanism

32 of 47 selected studies used only electronic automated search, whereas 15 of 47 selected studies used both manual and automated electronic search mechanisms. There were no reports of manual non-electronic search mechanisms in the selected studies.

4.3.1.1.3 Usage of Snowball Sampling

Most of the articles did not use snowball sampling technique, to assure the coverage of all related articles to their study. 85% of 47 selected studies conducted snowball sampling to ensure that all articles related to the research area were collected, whereas 15% of 47 selected studies did not conduct snowball sampling. Refer Appendix 12.9 for articles under snowball sampling.

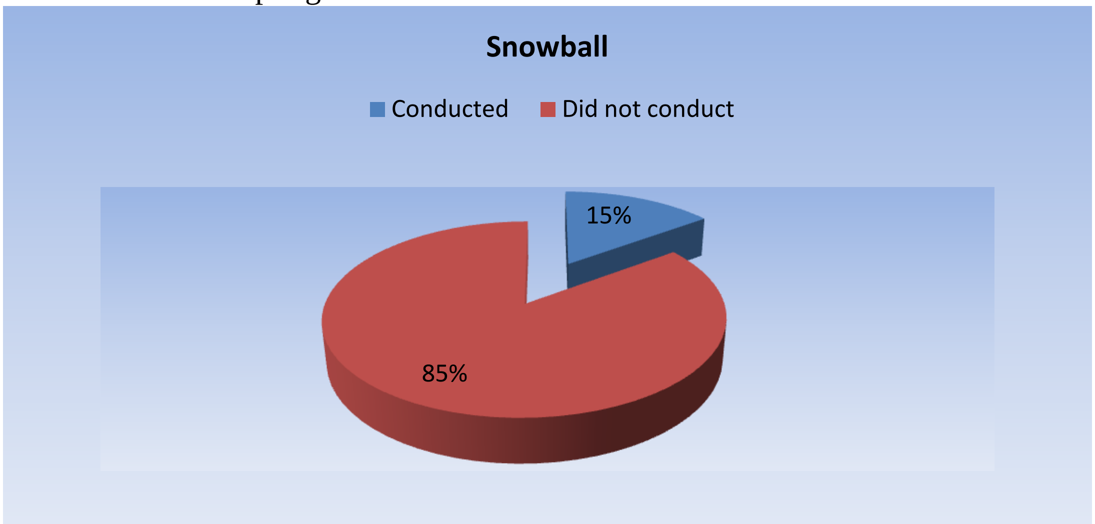
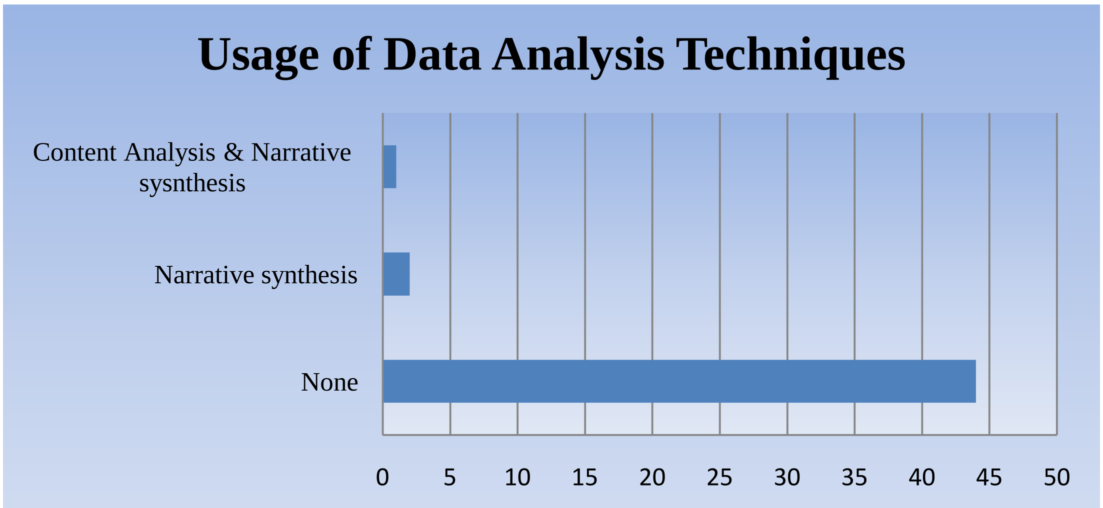


Figure 12 Snowball sampling in systematic mapping

4.3.1.1.4 Usage of Data analysis Techniques

There are two types of data analysis techniques used in systematic mapping studies. They are Narrative synthesis [42] and Content analysis [43]. Most of the selected studies did not report the usage of data analysis techniques. The reason provided for not using any analysis technique was that, analysis of data in systematic mapping studies is concerned with counting the findings related to a domain than a proper analysis of the results.

44 articles did not report the usage of data analysis technique, two articles used narrative synthesis [42] as a data analysis techniques and only one article used content analysis [43] along with narrative synthesis [42] for data analysis. Refer Figure 13 for the usage of data analysis techniques. Refer Appendix 12.9 for articles under each analysis technique.



	None	Narrative synthesis	Content Analysis & Narrative sysnthesis
Usage of Data Analysis Techniques	44	2	1

Figure 13 Usage of Data Analysis Techniques

4.3.1.1.5 Type of visualization chosen

There are 5 diagrams reported in the literature, which were used to visualize the results of systematic mapping process. Line diagram, pie diagram, Bar graph, bubble plot and Venn diagram were used for graphical representation of systematic mapping results. The diagrams used, their representation and descriptions were given in the table below.

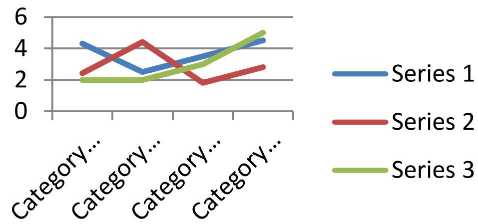
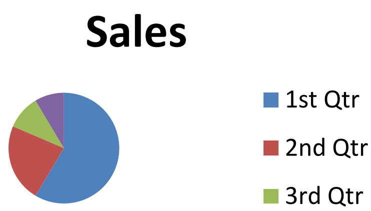
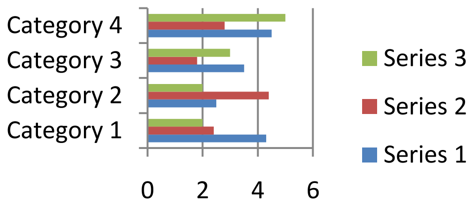
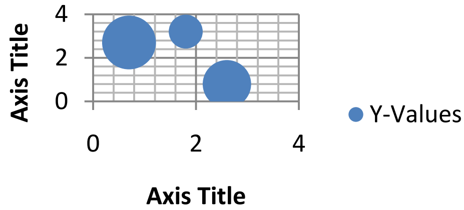
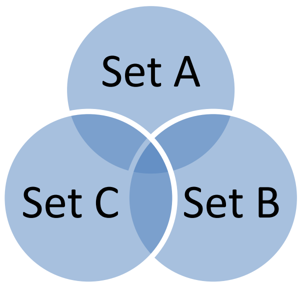
Name of the representation	Description	Example Representations
Line diagram	A line diagram is used to show the trend of a particular item over a period or over a given range.	
Pie Diagram	A pie diagram shows the relationship between a part and whole.	
Bar graph	A bar graph gives a graphical representation of categorical data.	
Bubble Plot	A bubble plot depicts the occurrences of a selected item for a given value	
Venn diagram	A venn diagram shows the interrelation between two or more sets.	

Table 15 Visualization types, description & examples

27 selected studies used bubble charts to visualize the mapping, 20 selected studies used bar graphs to visualize their results, 11 used pie charts to present their results, 3 selected studies also had Venn diagrams as to represent their results and 2 selected have made used line

plotting to visualize their results, Whereas 10 studies did not visualize their mappings. Refer Appendix 12.9 for articles under each diagram.

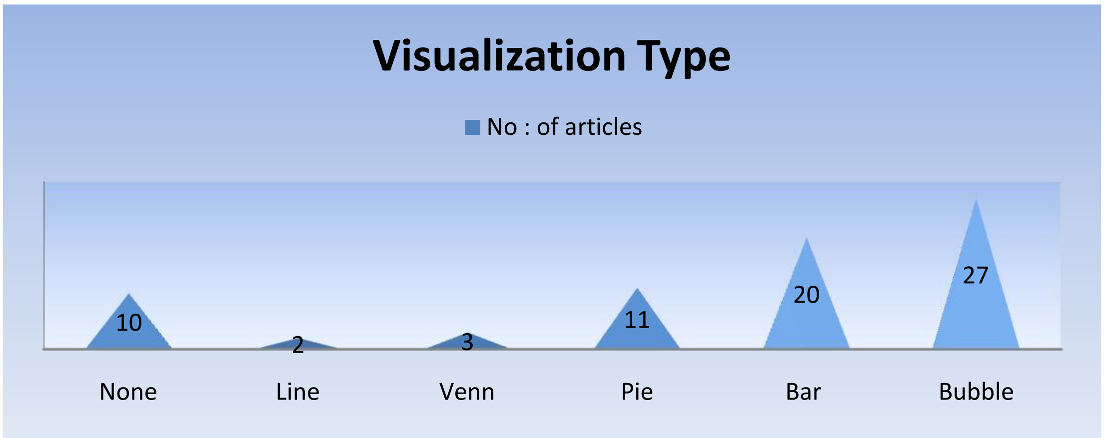


Figure 14 Visualizations used

- **Results corresponding to Research Question 1.2)**

What classification and categorization schemes are used to cluster the research articles?

We have extracted data related to classification schemes obtained from the selected studies, which indicated that there two types of classification schemes. They are Manual classification where articles were classified manually and automated classification, i.e. usage of tool for clustering results. There are two types of classification mechanisms under manual classification they are classification schemes and classification facets.

One classification scheme and six classification facets were identified under classification facets, such as contribution types, research type, research design, validation type, study focus, research question and key items apart from classification schemes such as publication year, publication, name, publication venue, author name etc. which were grouped into classification facets and classification strategy. There is only one tool in use to classify the studies automatically.

The figure 14, shows the classification strategy with manual and automated classification schemes and sub - categories under those classification mechanism.

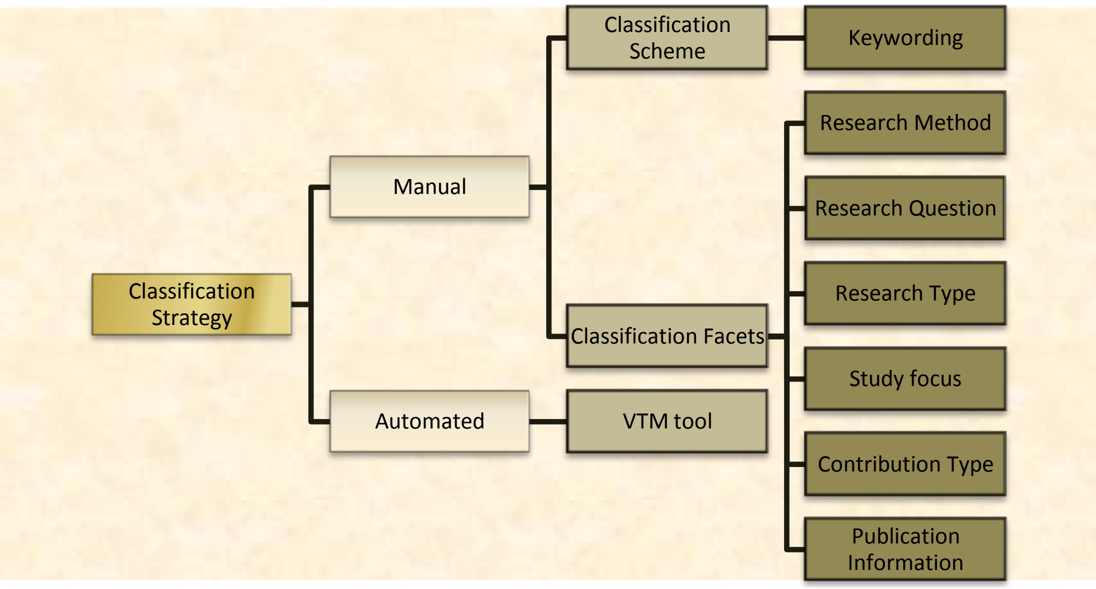


Figure 15 Hierarchical representations of classification schemes

Classification scheme:
A classification scheme refers to a step by step process through which grouping of articles is carried out. Classes and categories evolve iteratively; there were no predefined categories in a classification scheme.

Keywording:
Keywording is a classification scheme proposed by Petersen et al [2] which consists of two steps, in the first step, reviewers read abstract and search for keywords which depict the nature of the study and later these set of keywords were combined in order to develop a proper understanding of the research [2].

Classification Facet:
A classification facet refers to a view where there exist predefined classes and categories. The process of classification here requires less effort when compared with using a classification scheme as there is no need for developing classes and categories.

ResearchType:
This classification facet suggested by Weiringa et al [31], categorizes articles based on the type of research conducted.

- A study can be classified under validation research if the articles deal with investigation of techniques which were not under practice [31].
- A study can be classified under evaluation research if the article deals with the investigation of techniques which were under practice [31].
- A study can be classified as a solution research if it proposes a solution to the exiting problem [31].
- A study is considered to be having a philosophical research if new ideas were proposed [31].
- A study is said to be an opinion study if reports personal opinions such as good, bad etc [31].
- A study is classified as an experience research if it explains on something that has been done in practice [31].

Study Focus:
This classification facet categorizes articles based on the place of study or where the study takes places such as an organization, project, industry, academic etc. Also we have combined two classification facets SLR [11, 21] as they have similar categories which mean the same but have different class names.

Research Questions:
Classification is done based on the research questions. Here the classes were nothing but research questions. The number of classes in this facet is proportional to the number of research questions. Studies were assigned to Research questions and sub research questions. This classification strategy was observed in the primary study [SLR 9].

Contribution Type:
This classification facet was proposed by Petersen et al [2] for their research but was used by many researchers to classify according to the contribution of the article. Based on the type of contribution such as a tool, model, method, process or metric for evaluation or measurement, classification is done.

Research method:
This classification facet is used by many researchers [57],[58],[59] with different class names which semantically mean the same though the categories were common. Hence we

merged the research method from the articles SLR [3, 11, 8, 14, 15, 19, 21and 39] which have common categories but have a different class name. This classification facet clusters articles based on the type of research method used.

Publication Information:
This is not a single classification facet but a group of classification facets provided a common title. Classification facets such as Publication year, publication venue, Author names, publication area with respect to software engineering, Databases names etc were considered for classification of articles. All the selected studies have at least one of the classification facets mentioned under publication information. Table 16 shows the classification facets along with its categories.

Classification Facet	Categories	
Research Type	Validity research	
	Evaluation research	
	Solution proposal	
	Philosophical paper	
	Opinion paper	
	Experience paper	
Study focus	Academic	
	Mixed	
	Industrial	
	Government	
	Project	
	Organization	
Research Question	Sub- Research Questions	
Contribution type	Metric	
	Tool	
	Model	
	Method	
	Process	
Research Method	Ethnographies	Case control study
	Action research	Case series study
	Empirical study	Post mortem analysis
	Evaluation industry	Document analysis
	Validation laboratory	Experience report
	Concept analysis	Lab study
	Literature review	Randomized experiment
	Observational study	Experiment not involving human
	Quasi experiment	Experiment not involving human
	Controlled experiment	Semi structured interview
	Survey(random sample)	Survey(convenience sample)

Table 16 Manual classification types and their categories.

Most of the researchers considered publication information and research type classification facets. 38% of 47 selected studies used Publication Information classification facet such as publication venue, publication fora etc, 11% have used contribution type as a classification facet and 11 % of 47selected studies have used research method classification facet. 22 % of 47 selected studies have used research type as a classification facet. 8% of 47 selected studies used key wording as their classification scheme. 4% of 47 selected studies have used study focus. 6 % of selected studies used research questions as a classification facet. Figure 16 shows the frequency of classification facets and classification schemes under manual classification. Refer Appendix 12.9 for articles under each classification method.

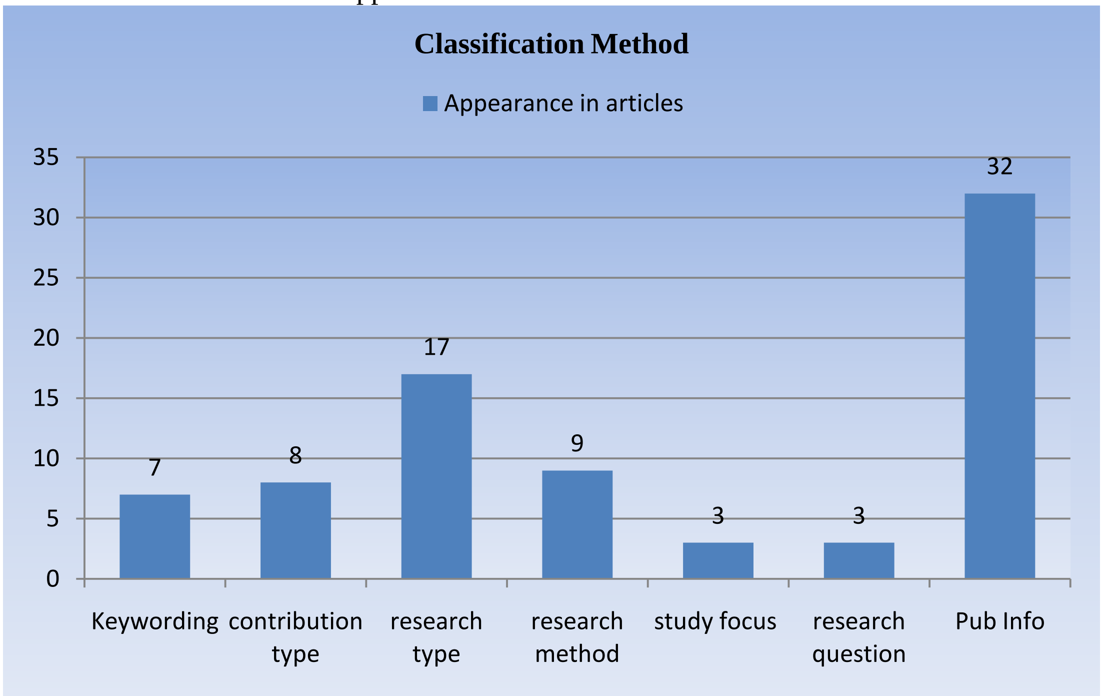


Figure 16 Classification methods in systematic mapping

- **Results corresponding to Research Question 1.3)**

What methods/tools are used to carry out the classification of research publications?

We have identified an automated tool proposed by Felizardo, K.R.; et al [32]. This tool which is also called as VTM tool uses Projection explorer PEx [86], which works on the basis of textual data mining algorithms which classify and visualize relationships between selected studies. Classifications are visualized in the form of bubble charts and maps. In order to automatically classify and visualize relationships between selected studies, we need to preprocess the selected studies in a particular format. This work of preprocessing the tool is not an easy task as one needs to understand the described format for preprocessing and then have to convert the total file into that particular format.

An analysis of the results obtained from the literature review is presented in the following section

4.4 Analysis

A thematic analysis is conducted, where results are mapped to the themes described under section 4.2.2 (Synthesis of Data). Figure 17, shows the mapping of themes and obtained results. When the themes publication information and the context of the research are analyzed, we observed an increasing in the usage of systematic mapping as research method. Also, more emphasis is made on the areas of software engineering such as tools and testing.

From the results of systematic review we can observe that there were as many as seven different guidelines used by researchers to conduct systematic mapping in software engineering. Seven, manual classification techniques and one automated tool.

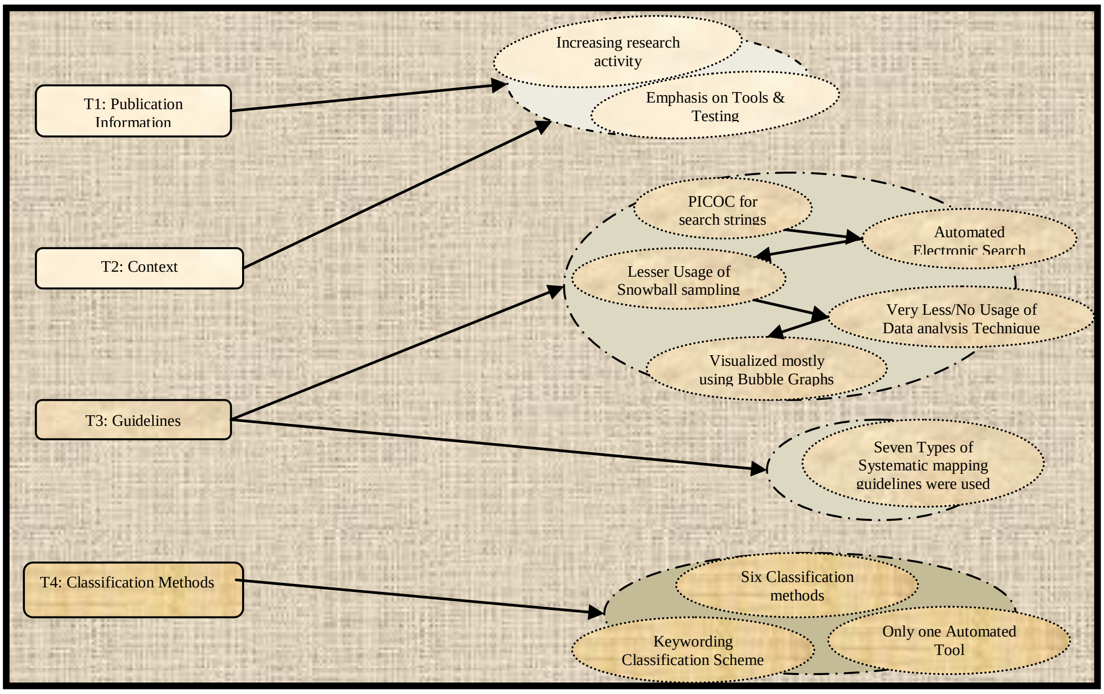


Figure 17 Thematic Analysis of the results

Most of the researchers used Petersen's [2] Keywording mechanism to classify the articles, Kitchenhamn's [2] PICOC strategy to build the keywords using both manual and automated search techniques. Though most of the studies did not report the usage of snowball sampling, to an extent snowball sampling ensures that no articles related to the study are missed out. Most of the articles did not report the usage of data analysis techniques, stating that systematic mapping does not analyze the results but only counts and summates the results.

Our main intention behind conducting a systematic literature review on the published systematic mapping studies in software engineering is to know which guidelines best suit our thesis. So, to choose proper guidelines for conducting this research we chose evaluate the identified guidelines on the basis of their suitability to this research.

4.4.1 Criteria for suitability:

In order to evaluate and choose the suitable guidelines from those available, we considered the following criteria. These criteria were chosen based on the steps in the process of conducting systematic mapping. Table 17 shows the suitability of the identified guidelines for this research.

Designed for systematic mapping:
This criterion was to chosen to check whether the guidelines under comparison were originally designed for systematic mapping or for other literature reviews.

Well defined search process:
To check whether the guidelines under comparison have a properly defined search process inclusion and exclusion criterion, this criterion was chosen.

Study coverage:
Study coverage here means ensuring that all studies related to the domain of research were collected. Use of snowball sampling or manual search process in addition to an automated search process can ensure study coverage. To check if the guidelines discuss about study coverage, we chose this criterion.

Classification Strategy:
In systematic mapping classifying the articles is one of the important tasks. To check whether the guidelines under comparison have a classification strategy for grouping the articles, we chose to include this criterion.

Visualization:
After classifying the selected studies into groups, one needs to visualize the results of mappings and has to choose a proper diagram which is suitable for visualization. This criterion is considered to see if the guidelines under comparison discuss about the visualization of results and which diagrams to use.

The criterion mentioned above is used to answer the RQ 2 i.e.

4.4.2 Results corresponding to Research Question 2)

- **Which systematic mapping guidelines are appropriate to be employed in our research context?**

To answer the above research question, we analyzed the suitability of the guidelines presented in section 4.3 based on the above defined criteria.

- **Suitability for systematic mapping:**

Suitability can be defined as to what extent does the mapping guidelines satisfy the requirements defined earlier for this research. Mapping guidelines are said to be suitable for this research if they satisfy minimum three requirements or evaluation criterion i.e. a mapping guideline has to satisfy more than 50% of the chosen criteria.

The table 17 shows the evaluation or requirement criterion and the suitability of mapping guidelines for this research. If the guidelines satisfy a criterion then it is marked with a YES else marked with a NO. If the chosen criterion is not properly defined in the guidelines or partially defined then in that case it is marked with UNCLEAR/ PARTIAL.

Evaluation		Guidelines						
ID	Criteria	Petersen	Kitchenhamn	Jorgenson	Bailey	Biolchini	Aarskey	Durhams
1	Designed for Systematic mapping	YES	NO	NO	YES	NO	YES	YES
2	Well defined Search Process	YES	YES	YES	NO	YES	YES	UNLCEAR / PARTIAL
3	Study Coverage	YES	NO	NO	NO	NO	NO	NO
4	Classification strategy	UNCLEAR / PARTIAL	NO	YES	NO	NO	NO	NO
5	Visualization	YES	NO	NO	NO	NO	NO	NO
Suitability for systematic mapping		YES	NO	NO	NO	NO	NO	NO

Table 17 Suitability of Identified guidelines

- **Guidelines and their suitability:**

Petersen et al [2]:
These systematic mapping guidelines are suitable for this research but the classification scheme suggested in these guidelines and the process of selecting keywords is not clear.

Kitchenhamn et al [21]:
These guidelines are not suitable for this research as they were not designed for systematic mapping and don't discuss on how to classify the articles and doesn't provide any discussion on study coverage and visualizations.

Jorgenson et al [26]:
Though these guidelines provide a discussion on how to classify the articles it fails to discuss aspects such as study coverage and visualization. Also, these guidelines were not designed for systematic mapping. Hence, they are not suitable for this research.

Biolchini et al [27]:
These guidelines are not suitable for this research, as there isn't any discussion on study coverage or how to classify the articles or their visualization, it is not designed for systematic mapping.

Bailey et al [39]
These guidelines are not suitable for this research, as there isn't any discussion on study coverage or the classification of articles or the visualization of the mappings. Hence, these guidelines are not suitable for this research.

Aarskey et al [29]:
Though these guidelines were designed for systematic mapping or scoping studies, it doesn't provide any discussion on how to ensure that all articles were collected or how to classify and visualize them. Hence these guidelines were not suitable for this research.

Durhams et al [28]:
These guidelines were designed for systematic mapping but this is just a template which contains a checklist of items not to miss out while conducting systematic mapping. This template doesn't have a discussion or checklist for classification, visualization or study coverage. Hence these guidelines are not suitable for this research.
Though guidelines suggested by Petersen are suitable for this research, the classification method suggested is ambiguous and difficult to understand.
Hence, we developed these guidelines to carryout systematic mapping for this research context. The design and development of these new guidelines are discussed and presented in the next chapter.

5 GUIDELINES FOR CONDUCTING SYSTEMATIC MAPPING

There exist no guidelines which are suitable for this research. This demanded a need for developing systematic mapping guidelines to be used in this research context. Hence, new systematic mapping guidelines were developed combing important aspects from the identified guidelines such as Petersen et al [2], Kitchenhamn et al [21] and Jorgenson et al [26], which were applicable to this research context. Guidelines from Kitchenhamn et.al, [21] were used to form a search strategy, while guidelines from Petersen et.al, [2] & Jorgenson et.al, [26] were used to form framework for the classification and visualization of studies.

Our systematic mapping guidelines developed for this research, has four phases which are shown in the figure 18,

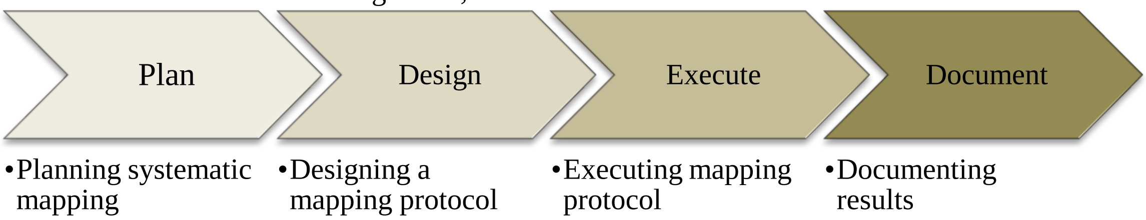


Figure 18 Steps in systematic mapping

5.1 Phase1: Planning systematic mapping

Prior to planning a systematic mapping study, a researcher has to identify the need for carrying out a systematic mapping. This is the first step, which is a precursor to the development of a systematic mapping protocol. Here, researchers plan to conduct systematic mapping. In order to conduct systematic mapping, the researcher needs have a proper understanding of the area chosen to conduct systematic mapping and needs to formulate research questions in order to have a clear idea on research problem and the boundaries of the research area.

Understand the research topic:
To understand the research topic, the researcher has to conduct a background study and inspect what research has been carried so far in that research area so as to identify the research gaps.

Formulate research questions:
Research questions form the basis of any research and drive the systematic mapping study. Hence, formulating research questions plays an important role in conducting a systematic mapping study. We identified PICOC suggested by Kitchenhamn [21], for conducting systematic literature reviews, can also be used to formulate research questions for systematic mapping study.

5.2 Phase2: Designing the mapping protocol

This phase addresses and produces the systematic mapping protocol, which involves developing a search strategy, describing selection criteria, ensuring study coverage, classifying the articles and providing an extraction strategy for the classified articles.

Search strategy:
This involves a strategy that is used in order to obtain primary studies. This search strategy includes developing keywords, search terms, search strings, resources to be searched and

choosing a search mechanism such as automated or manual search. While conducting a mapping study, one has to keep in mind to develop wider search terms or search strings in order to obtain all related results to the research area unlike, the search strategies in systematic literature review where search strings or search terms are developed in order to obtain primary studies confining to a particular research question[21]. A pilot study might help with the construction of keywords, search terms and search strings.

Study selection:
In order to remove the irrelevant studies, a study selection criterion is required. This study selection strategy consists of an inclusion and exclusion criteria to include or exclude articles from a systematic mapping study. Unlike a systematic review, systematic mapping study does not require a study quality assessment or quality evaluation instruments, to assess the quality of selected studies, as the aim of systematic mapping is only to collect quantitative evidence but not qualitative evidence on a particular topic.

Study coverage:
Study coverage ensures that all related articles to the study are covered. This can be done by conducting a manual search, along with automated search mechanism, to obtain publications related to the research area in resources such as databases, journals, conference proceeding etc. Also snowball sampling can be conducted on the studies to ensure that all studies related to the research area are collected.

Classification strategy:
This is one of the important steps of systematic mapping where articles are grouped into clusters. A cluster can either be a class or a category. A category is a set of articles that are grouped together and a class is a set of categories that are grouped together. Classification of articles in systematic mapping can be carried out in the following ways shown in figure 17.

Manual Classification:
Here, articles are grouped into clusters, i.e. classes or categories manually either by using predefined classifications or by reading the articles and finding the keywords which suit the research area and analyzing them.

Classification Facet:
These are predefined classes with predefined categories. When there are predefined classifications in a research area, these classification facets are used. When there are no predefined classifications in a research area, classification facets such as publication year, publication size, type of research method, etc. are considered along with a classification scheme. These classification facets are explained earlier in chapter 4.3.1.2 under results related to research question 1.2.

Classification scheme:
This classification scheme refers to a mechanism which is used to classify articles when no predefined classes or categories exist. Classification scheme consists of two stages.

- *Semantic Analysis*

In the first stage a semantic analysis is done, where articles are read and a look up is made for keywords which depict the primary studies. All keywords which indicate the nature of the study are documented in a list. After all articles are read and keywords are obtained, a weighted data analysis is conducted on them.

- *Weighted Data Analysis*

Weighted data analysis is a mechanism, where weights or values are assigned to keywords obtained from the semantic analysis, based on their frequency of appearance. Keywords with higher weights can be considered as classes as they represent a number of articles.

Semi Manual Classification:
This is similar to a Manual classification mechanism, where classification facets are chosen along with classification schemes to classify articles. In semi- manual classification, weighted data analysis is conducted using data visualization tools such as TagCrowd [35]. TagCrowd [35] is a data visualization tool, which produces a word cloud from a list of words based on their frequency of appearance.

Automated Classification:
Here, articles are grouped into clusters, i.e. classes or categories automatically with the help of tools such as VTM tool [32].

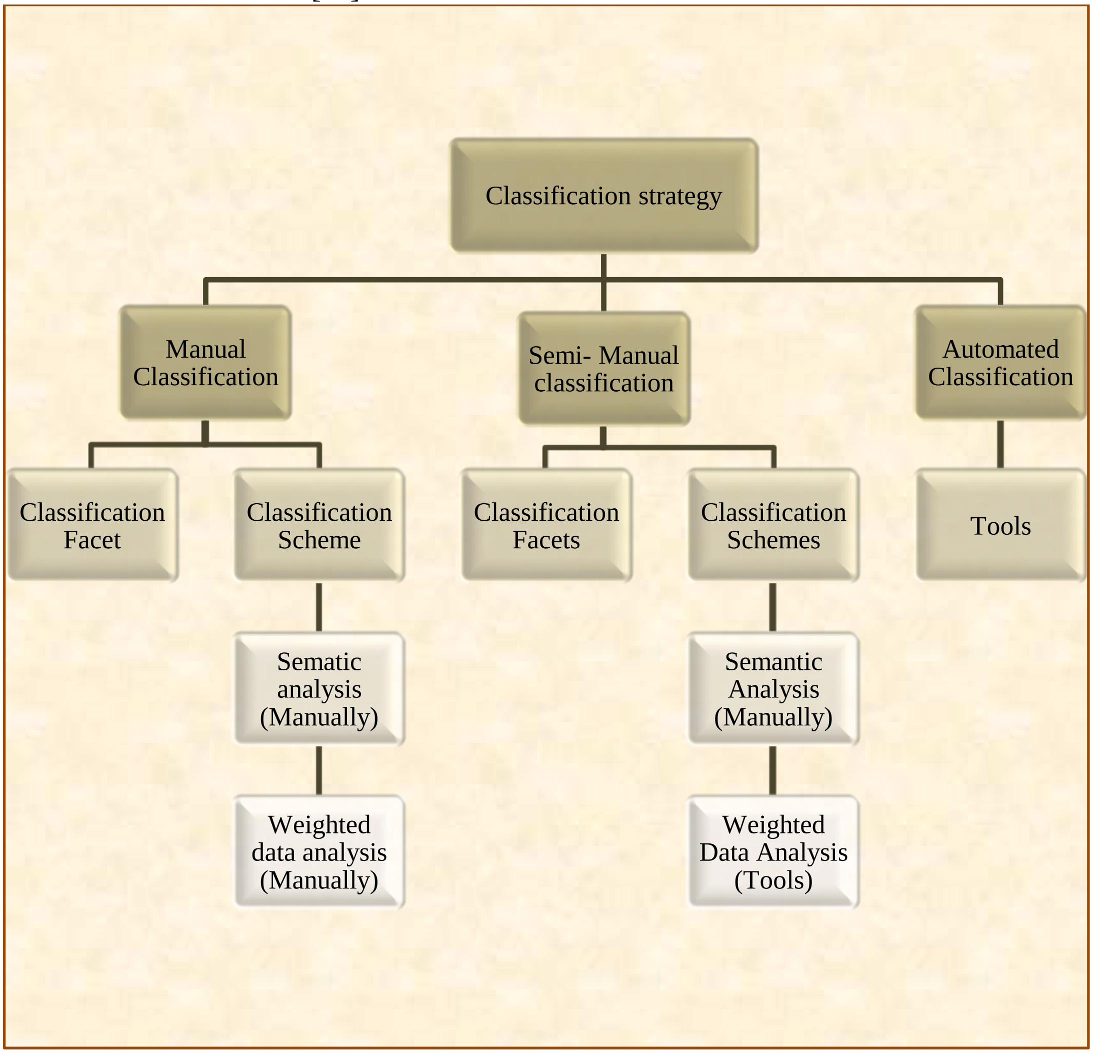


Figure 19 A classification of different classification strategies

Data Analysis Technique:
In a systematic mapping study we are only concerned about the quantity of findings related to a particular research. The results of systematic literature review also indicate that most of the articles did not report the usage of data analysis techniques (Refer 4.3.1.1.4). But taking into consideration the number of articles under classification and to identify their importance a data analysis technique might be used. Thematic analysis technique discussed in chapter 4 was used in this systematic mapping.

Data Extraction and mapping strategy:

The process of data extraction evolves with the classification of articles [2]. Keywords from articles are noted down in the data extraction sheets and articles were mapped into classes and categories mentioned in the extraction sheet. Classes and categories are considered as themes for the extraction of data. These themes are used in the data extraction sheets along with the publication information and rationale for classifying a study into a particular category is added.

5.3 Phase 3: Executing the mapping protocol

Once the mapping protocol is designed, researchers can start executing the protocol. While executing the mapping protocol, one has to strictly adhere to the design. The first step of executing the mapping protocol starts with the selection of primary studies.

Primary study selection:
Once the primary studies are obtained, there might be some irrelevant studies to the domain of research, unlike a literature review; there will not be strict study selection criteria and quality evaluation criteria.

Classification of studies:
Once the selected studies are obtained, these are classified according to the classification facets and classification schemes chosen while designing the mapping protocol.

Extraction of Data:
Extraction of data is done in using the data extraction sheets developed while designing the mapping protocol. The process of extraction of data goes hand in hand with the classification and categorization of articles.

Visualization of data:
Once the data from the studies has been extracted, visualization of the data needs to be done. Visualization of data refers to choosing a diagram for the pictorial representation of the extracted data. Table 18 explains which diagram can be chosen for which data.

Diagrams	description
LINE Diagram	To visualize data present in the categories of a single class
Bar Chart	-same as above-
Pie diagram	-same as above-
Bubble Plot	To visualize data of multiple classes and represent the relationships between them

Table 18 Diagrams and rationale for choosing

5.4 Phase 4: Documenting the results

This is the last and final phase in conducting a systematic mapping study. In this phase, all the work that has been carried out so far on systematic mapping is documented and the overview of the results is presented.

Analysis & Overview of the results:

Overview of results in systematic mapping refers to presenting frequencies and trends in the selected studies as an answer to research questions. In a systematic mapping study, analysis of results means to identify the importance and relevance of classifications to the research field. Refer figure 20 for the overview of phases and activities in the systematic mapping guidelines used in this research.

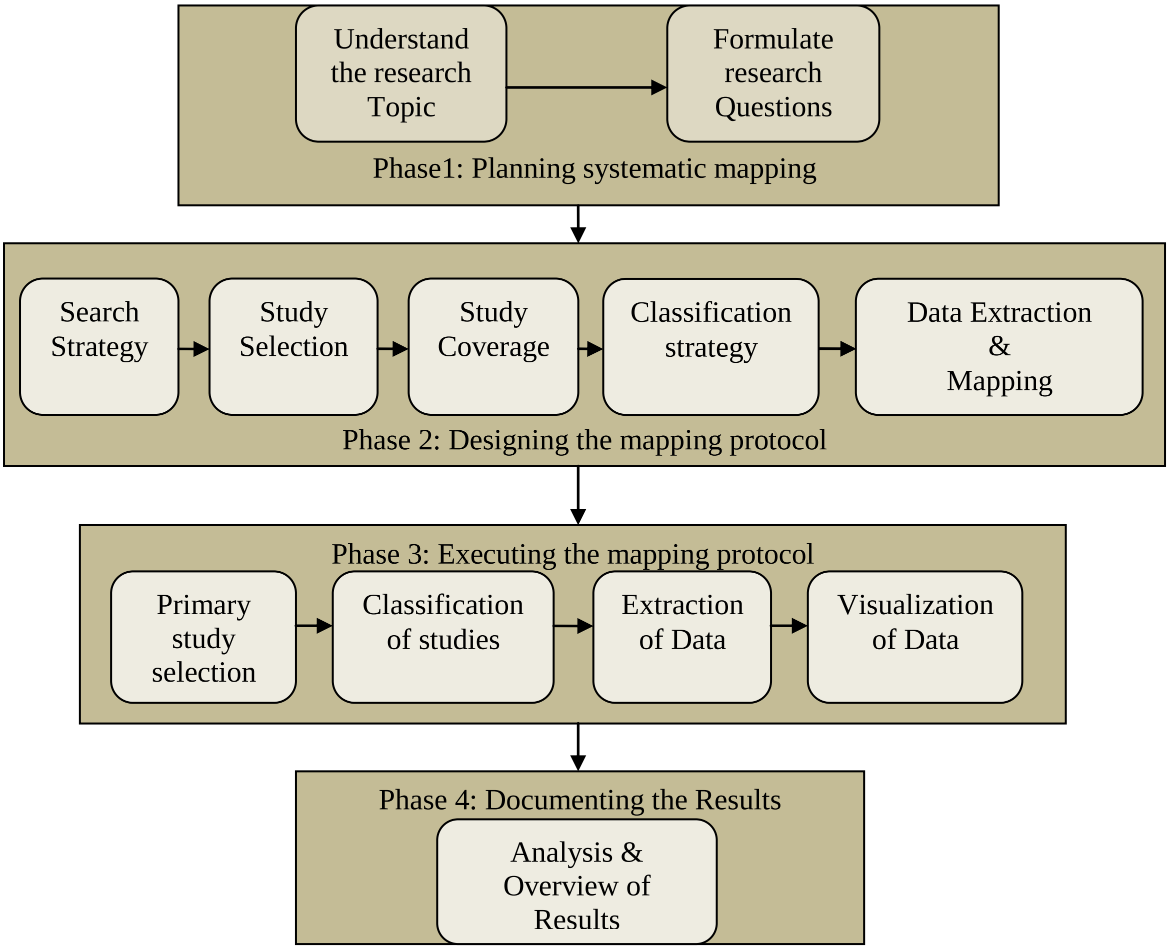


Figure 20 Phases and activities in systematic mapping

6 CONDUCTING SYSTEMATIC MAPPING

In this section, a systematic mapping study is conducted to investigate the state of published research on teaching modeling in software engineering. The guidelines discussed in the earlier chapter were employed which start with planning the systematic mapping, designing a mapping protocol, Execution of design and Documenting the results. These phases are discussed clearly in the sections below.

6.1 Planning systematic mapping

This is the first step of systematic mapping study, where an understanding of the research topic is obtained and research questions were formulated. Understanding of the research topic is presented as background and related work in the documentation and research questions were clearly explained in the Chapter 3, research design. Once the research questions were formulated, we proceeded to design a protocol to conduct systematic mapping study.

6.2 Designing the mapping protocol

A systematic mapping protocol provides a step by step procedure for conducting a mapping study. The Figure 21 shows the overview of systematic mapping protocol. Systematic mapping protocol in this study is designed on the guidelines mentioned in the previous chapter which starts with the formulations of search strategy. Search strategy consists of the construction of search strings and choosing databases to employ the search strings. This search strategy is used in conducting the search for published research on teaching modeling.

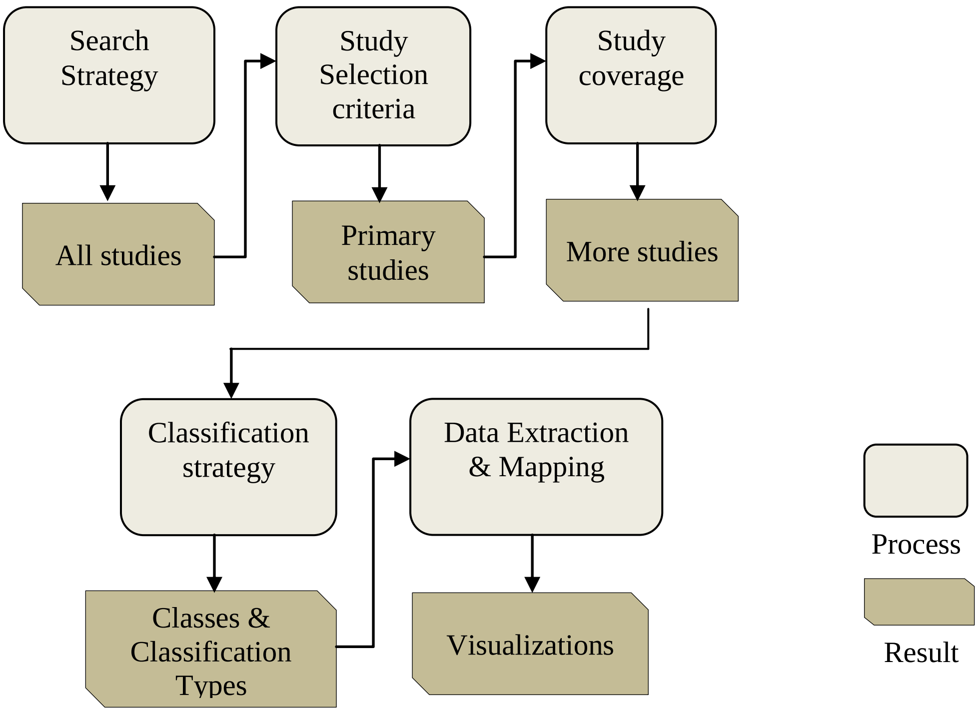


Figure 21 Systematic mapping Protocol and its results

Once the search process is documented, we executed the search strategy which resulted in obtaining articles related to our study. Study selection criteria was developed which consisted of a twofold criteria to include/exclude articles. After pruning the irrelevant articles, primary studies related to this study were obtained. To ensure that all articles were covered in this search, a procedure for study coverage such as snowball sampling and manual search was chosen.

This procedure for ensuring the coverage resulted in providing more relevant articles. A classification strategy was developed to group these articles, followed by extraction of data and visualization of results.

6.2.1 Search Strategy

Here a procedure to search for articles related to the study is documented which consists of formulation of search string and identification of databases. To identify the keywords for the search string and to identify the publication foray for the search, a pilot search was conducted.

- **Pilot search& Search String Formulation**

One of the results of the pilot search was the identification of important databases for our study such as,

- IEEE
- ACM
- SCOPUS
- INDEX
- COMPENDEX

Apart from the identification of databases, pilot search also resulted in identification of publication foray for manual search and keywords to formulate the search string.

To identify the publication flora, a pilot search was conducted on Google web search to find conferences, workshops and journals related to teaching and education in the area of computer science and software engineering. Table 19 Manual search conferences and journals lists the names of conferences and journals selected for manual search.

Conference	Journals
MODELS OOPSLA CSEET TOCE ECOOP CSERC ITS ICALT SIGCSE	Journal of Object technology IJEP TOCE IEEE Transactions on Education

Table 19 Manual search conferences and journals

Keywords such as Teaching, modeling and software engineering were identified from research questions. Table 20 shows the keywords and related synonyms.

Keyword	Synonyms
Teaching	Train, tutor, Explain, Lecture, Instruct, illustrate, guide, illustrate etc
Modeling	Uml, abstraction, object oriented, etc

Table 20 Keywords for search string

When these were employed on the identified databases, we found that using more keywords in a search string biased the search results based on those particular keywords instead of providing an elaborated overview. Hence we decided to use minimal number of keywords in the search string in order to obtain a wide number of results related to the area of teaching modeling.

After many ramifications, the following keywords were used to build the search string

- Teaching
- Modeling
- Software Engineering

These keywords were connected with Boolean AND operator, in order to formulate the search string which is a combination of these keywords and operators. The following search string was obtained, which is employed on the identified databases.

((Teaching modeling) AND (Software engineering))

6.2.2 Study selection criteria

To limit the related results to our domain of research, a twofold Screening criterion was considered, where a basic inclusion/exclusion criterion is followed by a full text reading. The basic inclusion criteria are described in Table 21.

No.	Inclusion Criteria
1	Include articles which were published only between 1990- 2012
2	Include articles which discuss on teaching modeling Computer science along with software engineering

Table 21 Inclusion criteria

Articles published between 1990 and 2012 were considered for this study, as we wanted to search for the published research in the domain which is new and not obsolete. Also during our trail searches we have found that there were not many articles on modeling in software engineering earlier than 1990. Hence, we chose 1990 as the beginning year for our article search.

In order to exclude the irrelevant articles to our study, the following exclusion criteria presented in Table 22 was considered,

No.	Exclusion Criteria
1	Exclude those articles which are non-peer reviewed
2	Exclude books as they are not peer-reviewed studies.
3	Exclude those studies which are not in English.
4	Exclude summaries, templates, project reports etc.
5	Exclude those articles which belong to teaching modeling and simulation in software engineering.

Table 22 Exclusion criteria

We chose to exclude all articles which were not in English as well as those which were not peer reviewed and those which were just templates, summaries of conferences or project reports. We chose exclude those articles which belong to software engineering but to the domain of simulation.

This Basic was followed by a full text reading of the articles in order to exclude those articles which flaunt to be having those characteristics of a related article to the study.

- **Duplicate Removal**

In order to remove duplicate results from the automated search, EndNote X6[34] a reference management tool was used. To ensure all duplicates were removed, we manually checked for duplicated and removed, any if found. While removing the duplicated article, the article which had a proper reference such author, title, publication venue name, date etc was included and the other was deleted.

6.2.3 Study coverage

To make sure that we did not miss out on any important articles in the domain of teaching modeling, snowballing sampling was conducted on the resultant articles from automated and manual searches.

Snowball sampling for the articles is done in an iterative fashion, an article was chosen which is checked for its citations first, if any related articles were found which were not included in studies resulting from manual or automated, they were added to new list(articles obtained from snowball) else, left. After the citations were checked, references were checked, if any related articles were found, they were added to the list else we proceeded to the next article. This is repeated until there were no new articles to be added onto a list. The criteria to include or exclude and article is taken from the two fold inclusion and exclusion criteria discussed earlier. After this step the final set of studies were obtained which were considered for classification and categorization. Refer section 12.3 in Appendix for a detailed picture of this process.

6.2.4 Classification strategy

As the only tool available to automate the process of classification of articles was not easy to use, semi- manual classification process was chosen to classify the selected studies and to reduce the time taken to classify when compared with the manual classification strategy. Here, classification of articles was done by choosing classification facets along with semantic and weighted data analysis of the articles.

- **Semantic analysis**

Here, articles were read for keywords depicting the nature of the study and documented in a list. This list of keywords is considered for the next step of weighted data analysis. These list of identified keywords are shown in appendix 12.13.

- **Weighted data analysis**

Here weights were assigned to keywords depending on the frequency of their appearance of study and documented in a list (Refer Appendix 12.14). From this weighted data list, classes were identified. To reduce the time taken for this process,
We chose Word cloud tools [35] [109] [110] where weighted data analysis is carried and visualized. For this study frequency of appearance is chosen as the criterion for assigning weights. Hence, Tag crowd [35] a word cloud visualization tool, which generates a word cloud with frequencies is chosen. Though there are other word cloud tools available online such as Wordle [109] and Tagxedo [110] we chose to go with Tag Crowd as it offers a file upload feature which is not present in the others. Refer 12.14 which shows an extract from the Tag crowd [35] tool.

- **Choosing Classification facets**

We chose the following facets which have been designed for this research context. Table 23 displays the classification facets chosen for this mapping study.

Classification Facet
Research Type
Research Method
Contribution Type
Study context Type
Audience Type
Publication Type
Publication year type

Study setting focus

Table 23 Classification types chosen

Research Type:
This Classification facet was adopted from Weiringa et al[31]. We have made modifications to the categories defined in the facet. Philosophical research, a category which was present in weiringa et al [31] was removed as its definition was ambiguous. Also, to have a clear definition for each category and to avoid any overlaps between them, any combination of categories is considered as a separate category. Table 24 shows the categories under research type classification facet.

Research Type	
Category	Description
Solution proposal	An article is considered as a solution proposal if it offers solution to existing problem
Opinion paper	This is just a write-up of opinion of a particular research on a particular research problem.
Evaluation research	This deals with the investigation of particular process/model/method/technology/tool/ which already exists prior to the study.
Validation study	A validation study deals with the investigation of particular process/model/method/technology/tool/ which does not exists prior to the study.
Experience paper	An experience paper reports the experiences of a researcher for a particular period of time in a particular study setting.
*Solution proposal & Validation study	An article falls under this category if it contains the features of a solution proposal as well as a validation study.
*Solution proposal & evaluation research	An article falls under this category if it contains the features of a solution proposal as well as an evaluation research.
*Solution Proposal & Experience paper	An article falls under this category if it contains the features of a solution proposal as well as an Experience paper.
*Experience paper & validation study	An article falls under this category if it contains the features of an Experience paper as well as a validation study.

Table 24 Research Type classification facet

**Note: An asterisk (*) before a category, denotes a new category, which is a combination two or more categories in a classification facet. These combinations of categories are devised, as there might be some articles which could be considered for classification into more than one category. This combination of categories was not present in the earlier classifications such as SLR [4, 9, 14, 18, 19, 24, 26 and 67].*

Research Method:
This classification facet was taken from several studies SLR [4, 9, 14, 18, 19, 24, 26 and 67] and modified to suit our research. This facet was chosen to identify the research method used in the articles. This classification facet helps researchers in easily identifying the research gaps as a literature review on a particular topic in teaching modeling can only reveal information related to the published literature i.e the state of art but does not provide any information about the state of practice. Using this classification helps researcher to easily identify the methods used in state of art and state of practice. Table 25 shows the categories under research method classification facet.

Research method	
Category	Description
Case study	If an article has a case study as its research method it can be classified under this category.
Experiment	If an article has an experiment as its research method it can be classified under this category.
Literature review	If an article deals with literature reviews as its research method it can be classified under this category.
Concept analysis	If an article analyses a particular topic or issue and does not use any formal research methods here, then it can be considered as a concept analysis.
Observational study	If an article reports observations made about a particular event for a particular period of time in a particular setting then it is considered as a observational study
Survey	If an article reports a survey conducted, as its research method it can be classified under this category.
Discussion	If an article just reports a discussion on a particular tool/ model/ method/ technology/ practice or process, it can be classified under this category.
Interviews	If an article uses interviews as its research method it can be classified under this category.
*concept analysis & Case study	If an article performs concept analysis and a conducts Case study then such an article can be classified under this category.
*concept analysis & Experiment	If an article performs concept analysis and a conducts an experiment for its research method it can be classified under this category.
*Concept analysis & Observational study	If an article briefs on a topic and reports the observation on particular event for particular period of time in a particular setting then such an article can be classified under this category.
* Concept analysis & Survey	If an article reports an issue and a conducts a survey it can be classified under this category.
*Literature review & interviews	If an article uses Literature review &interviews as its research method it can be classified under this category.
*Discussions & Interviews	If an article uses Discussions & interviews as its research method it can be classified under this category.

Table 25 Research method classification facet

Contribution type:
This classification facet was adopted from Petersen et al [2] and was chosen to identify the contribution of the articles. Contribution of the article can be a tool, process, model or metrics for measurement. This classification facet helps researchers in easily identifying the contribution of the article and its type. Table 26 shows the categories under research type classification facet.

Contribution Type	
Category	Description
Model	Studies which develop/ design or evaluate models or framework to teach modeling in software engineering fall under this category.
Measurement	Studies which provide metrics to validate or evaluate a process/

	method/model/ tool can be classified under this category.
Methods	Studies which create, investigate or report the experience of using methods which increase the effectiveness of teaching modeling in software engineering were classified under this category.
Process	If a study discusses or contributes to the processor the way of teaching modeling in software engineering then such a study comes under this category.
Tool	Studies which create, investigate or report the experience of using tools to teach modeling in software engineering were classified under this category.
*method & process	If a study discusses the process and defines a method to teach modeling in software engineering, then such a study falls under this category.
*process & tool	If a study discusses the process and uses a tool to teach modeling in software engineering, then such a study falls under this category.

Table 26 Contribution type classification facet

Audience Type:
In order to classify articles according to the type of audience involved or aimed at in the study, this classification facet was chosen. This classification helps reader to easily access articles related to a particular category of audience such as teacher, student or software engineers. Table 27 shows the categories under research type classification facet.

Audience	
Category	Description
Teachers	If the study aims or involves teachers as its audience then such a study is classified under this category.
Students	If the study aims or involves students as its audience then such a study is classified under this category.
Software Engineers	If the study aims or involves software engineers as its audience then such a study is classified under this category.
All	If the study aims or involves students, teachers and software engineers as its audience then such a study is classified under this category.
* Students & Software Engineers	If the study aims or involves students and software engineers as its audience then such a study is classified under this category.
Not specified	If the study doesn't state or indicate its audience then such a study falls under this category

Table 27 Audience classification facet

Study context:
This classification facet was chosen in order to classify the articles according to the context of the study, i.e. the setting of the study such as academic or industry. This classification facet helps researchers to easily find articles related to a particular context. Table 28 shows the categories under research type classification facet.

Study Context	
Category	Description

Academic	If the study takes place or can be applied in an academic setting then it is be classified under this category.
Industry	If the study takes place or can be applied in an industry setting then is classified under this category.
*Academic & Industry	If the study takes place or can be applied to industry and academic settings then such a study is classified under this category.
Unclear	If the study doesn't state or indicate which setting is conducted or can be applied, then such a study falls under this category

Table 28 study context classification facet

Study setting focus:
This classification facet was chosen in order to classify articles according to the sub categories of study context such as to which group of students, i.e. graduates, undergraduates etc. does an article deal with in an academic setting or to what group of employees in industry does the article belong. We chose only developers and designers as categories in industry setting as only those groups use modeling to a greater extent. Table 29 shows the categories under research type classification facet.

Academic setting	
Category	Description
Secondary school	If the study is focused on students of secondary school level, then such a study can be classified under this category.
High school	If the study is focused on students of high school level, then such a study can be classified under this category.
Graduate	If the study is focused on graduates, then such a study can be classified under this category.
Undergraduate	If the study is focused on undergraduates, then such a study can be classified under this category.
Post graduate	If the study is focused on postgraduates, then such a study can be classified under this category.
Industry setting	
Type	Description
Developers	If the study is focused on developers in a software organization, then such a study can be classified under this category.
Designers	If the study is focused on designers in a software organization, then such a study can be classified under this category.

Table 29 Academic & Industrial setting facet

Publication Year:
This classification facet is chosen to investigate the trends in research in teaching modeling in software engineering. Calendar years were considered as categories in this classification facet.

Publication Type:
This classification is chosen in order to point out which journals/conferences or workshops contribute more to teach modeling in software engineering.
Once, the classification strategy was chosen, we proceed with the formulation of strategy for data extraction and mapping.

6.2.5 Data Extraction& Mapping strategy

To extract data from the selected articles, MS-Excel sheets were used and fields such as,

- Article name
- Author names
- Year of publication
- Type of publication
- Publication name
- Keywords

Along with these, classes obtained from semi- manual classification and classification facets were chosen as fields in the spreadsheets for data extraction. The table 30 shows an unfilled data extraction sheet.

Article title	Author Name	Year	J/C/W	J/C/W Name	Keywords	Research Type	Research Method	Contribution Type	Study context Type	Audience Type	Study focus

Table 30 Data Extraction sheet for systematic mapping

After formulating a strategy for data extraction and mapping we began with the execution of systematic mapping design.

6.3 Executing the mapping protocol

After the design and strategy to conduct Systematic mapping has been formulated, the next step is the execution of the design which consists of executing each step documented in section 6.2.

6.3.1 Primary study selection

Here, the design is executed in a step by step manner, where first step is the execution of search strategy. The Table 31 shows the number of search results obtained when the formulated search string is employed on the identified databases. We had trouble employing our search string on ACM database. Hence, we divided the search string, where teaching modeling is employed as a search string and software engineering was used in keyword search so as to confine the results to software engineering.

Database	Hits	After Applying Year Criteria	Primary studies
IEEE	1443	1424	37
ACM	5655	3512	30

SCOPUS	6291	2882	34
INSPEC &COMPENDEX (Engineering village)	3531	3402	100
TOTAL	16,920	11,220	201

Table 31 Databases, hits and primary studies

A total of 16, 920 articles were found combining the results obtained from all databases. To reduce the number of results we have applied our basic criteria for screening, Year of publication. We have only included articles from 1990, which left us with 11,220 eliminating 5700 search results. These 11,220 articles were considered for a two-fold screening process where, a basic inclusion and exclusion criteria discussed earlier were employed resulting in 202 articles. These 201 articles were checked for duplicates manually and also using a reference management tool, Endnote X6 [34].

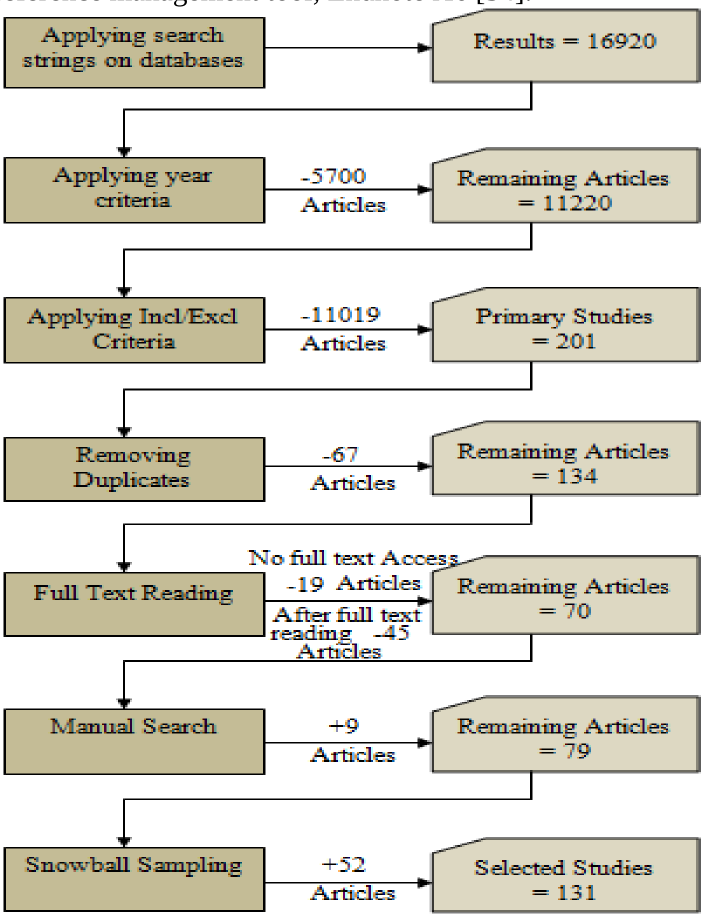


Figure 22: Study selection process for systematic mapping

67 articles were identified as duplicates and removed leaving 134 articles for the full text reading. While carrying out full text reading we have observed that 19 articles did not have full text access, remaining 115 articles were considered for full text reading.

45 articles were found irrelevant to the study and removed, leaving us with 70 selected studies/articles from automated search. After the completion of automated search, we proceeded to conduct manual search on the journals mentioned in the design part. 9 articles were found relevant to our study. Once we were finished with manual and automated searches we proceeded to conduct Snowball sampling on the selected studies.

79 articles from automated and manual search were snowballed which resulted in 43 relevant articles for the study. On these 43 articles snowball sampling is conducted

resulting in 8 relevant articles. These 8 articles were again snowballed; adding one more article, which when snowballed did not produce any further articles.

A total of 52 articles were selected from snowball sampling, which when added to the articles obtained from manual and automated search resulted in a total of 131 selected studies (See Appendix 12.10). These 131 selected studies were considered for classification and categorization. Pictorial representation of the process described is shown in figure 22.

- **Calculating inter rater agreement for Inclusion/Exclusions**

In order to measure the level of agreement between the two authors on the classification of articles, we have used kappa coefficient. 20 articles were chosen randomly and the agreements on the indentified keywords are presented in the table 33.

Kappa coefficient is calculated using the following formulae

$$K = [P(A) - P(E)]/[1 - P(E)]$$

Table 32, shows the ranges of kappa and strength of agreement [30]

Kappa values	Strength of agreement
K <=0.44	Poor
0.44<=K<=0.62	Moderate
0.62<=K<=0.78	Substantial
K>0.78	Excellent

Table 32 Kappa coefficient ranges

Where,

P (A) is the probability of observed agreement

$$P(A) = \frac{(\text{No of articles where both authors agree} + \text{no of articles where both authors say diasgree})}{N}$$

= .95

P (E) is the probability of expected agreement

$$P(E) = \left\{\frac{\text{No of articles where author 1 agrees}}{\text{N}} \times \frac{\text{No of articles where author 2 agrees}}{\text{N}}\right\} + \left\{\frac{No\ of\ articles\ where\ author\ 1\ disagrees}{N} \times \frac{No\ of\ articles\ where\ author\ 2\ disagrees}{N}\right\}$$

= 0.24

N is the total number of articles= 20

ID	Author 1	Author 2
1	YES	YES

2	YES	YES
3	YES	YES
4	YES	YES
5	YES	YES
6	YES	YES
7	YES	YES
8	YES	YES
9	YES	YES
10	YES	YES
11	YES	YES
12	YES	YES
13	YES	NO
14	NO	NO
15	YES	YES
16	YES	YES
17	NO	NO
18	YES	YES
19	NO	NO
20	YES	YES

Table 33 Strength of Inter rater agreement

The kappa value obtained from the random sample shows a value of 0.82 which indicates that the strength of agreement between two authors is substantial.

6.3.2 Classification of studies

In this step, first classification of articles is carried out using the classification facets mentioned earlier in 6.4.2.3 is carried out, which is followed by the execution of semi-manual classification scheme is carried out which consists of two steps i.e. execution of semantic analysis and the execution of weighted data analysis.

- **Execution of semantic analysis**

Here, a look up for keywords depicting the nature of the study is conducted. This is done in a three step process. First the keywords in the Title of the document are noted down. Then abstract is read in the next step, keywords identified from the abstract + conclusion is listed, this is the second step in the semantic analysis. In the final step, the total article is read for keywords and compared with the keywords from title, Abstract + conclusion. Synonyms, noun/verb forms and duplicated are identified and sorted out.
Example: A keyword such as collaboration is found in the forms, collaborating/ collaborative. This is uniformly noted as “collaboration”.
All selected studies obtained from the previous step were read for keywords or key items depicting the nature of the study, which were documented in a list shows in appendix 12.13.

- **Execution of weighted data analysis**

All the keywords in the list were checked for their frequency of appearance using the tool Tagcrowd [35]. The top 10 keywords were considered for classification (See Appendix 12.4 & 12.14). Figure 23 shows the keywords and their frequencies.

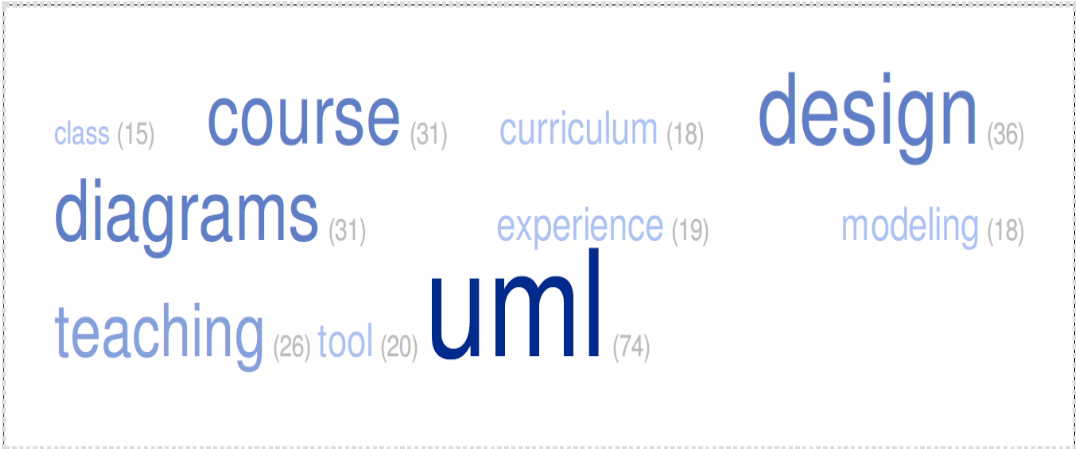


Figure 23 Extract from Tagcrowd showing frequencies

The top 10 keywords are **Class, Course, Curriculum, Design, Diagrams, Experience Modeling, teaching modeling, Tools** and **UML**. Classification scheme for articles based on tools and experience was already discussed in section 6.3.2.2. We searched for articles which had these keywords teaching and modeling and found that these keywords were used along with keywords such as course and curriculum. Similarly, keyword design is used along with keywords course and curriculum**.** We searched for articles with the keyword class and found that the keyword was used along with another keyword, Diagram. Keyword UML represents a language used to teach modeling. Hence to classify articles based on the type of modeling language used, we considered type of languages used as a class.

The remaining keywords such as Diagrams, Course Design and Curriculum Design were considered as classes. Articles which do not fall under any of these classes were grouped under a class named, Others. These classes identified from the semi- manual classification strategy are shown in the Table 34.

No	Class Name
1	Languages
2	Curriculum Design
3	Course Design
4	Diagrams
5	Others

Table 34 Classes obtained after weighted data analysis

Languages

This class deals with languages which could be graphical or textual languages used in teaching modeling such as UML, OVAL, OCL etc.

Curriculum Design

This class deals with those articles which discuss about the curriculum design for teaching modeling in software engineering.

Course Design

This class deals with those articles which discuss what to teach in modeling course in software engineering.

Diagrams

This class deals with articles which create or improve or report the experiences of teaching or using diagrams to teach modeling in software engineering can be classified under this category.

Others
This class deals with articles which do not fall under any of the classes mentioned above.

6.3.3 Extraction of Data

After the classification of articles, data extraction is carried out where the data extraction sheets specified in section 6.2.5 is used. The selected studies are mapped with the identified classes and results are documented.

6.3.4 Visualization of Data

To visualize the results, we chose data visualization techniques identified in Chapter 5 such as Bubble graphs, bar charts, pie charts.

6.4 Documenting Results

In this section, results obtained from systematic mapping study are documented. Results corresponding to each research question are presented.

6.4.1 Results corresponding to Research Question 3)

What research has been carried so far on teaching modeling in software engineering?

An overview of systematic mapping results is presented in Appendix12.11 & 12.12 showing classes and categories and the publications in each category.

6.4.2 Results corresponding to Research Question 3.1)

What is the state of research activity on teaching modeling in software engineering?

To assess the state of research activity, we have identified the frequency of research publications, i.e. number of research publications per calendar year. Frequency of research publication is shown in the figure 24.

Past decade, from 2000-12 showed a gradual increase in the number of research publications when compared with the research publications published in the years 1990-2000, which shows an increase in the research in this domain. The graph showed an increase in the frequency of research publications from the year 2005, with minimum of 10 research publications per year, whereas calendar years 1990, 1991, 1993 and 1996 showed minimum research. The calendar year 2005 noticed a maximum of 20 research publications. Refer Appendix 12.11 for articles under each calendar year.

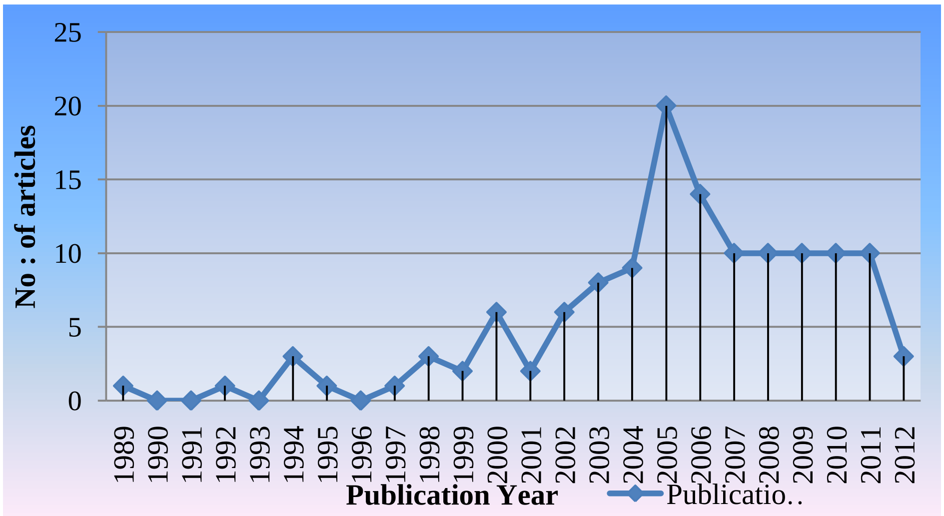


Figure 24 Publication trends in teaching modeling

These research publications ranging from 1989-2012 were identified from workshops, conferences and journals. ***Maximum numbers of research publications were from conferences***, MODELS [37] conferences contributed maximum research publication followed by Journal of Object Technology [36] refer appendix for details about number of publications in each conferences and journal.

Conferences contributed to 63% of the identified research publications, workshops contributed 22% of the research publications whereas journals contributed to 16% of research publications. Out 131 research publications, 89 publications were from conferences, 29 from workshops and 21 from journals. Figure 25 shows the number of publication under workshops, conferences and journals. Research publications related to the publication type can be seen in Appendix 12.15

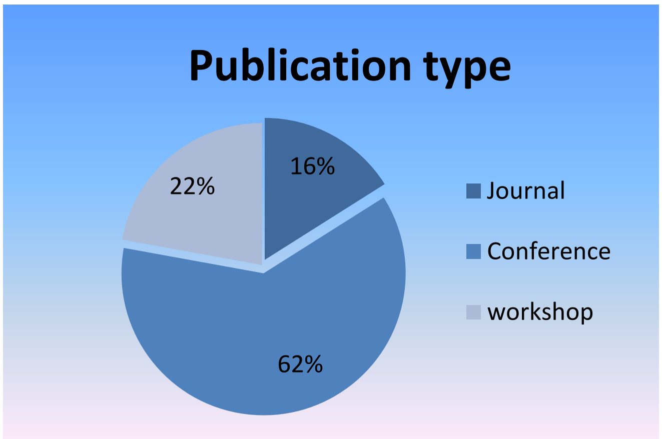


Figure 25 Publication types in teaching modeling

6.4.3 Results corresponding to Research Question 3.2 & 3.3)

What categories or groups can be identified through these publications? & what are the contents of the groups identified?

We have classified the research publications using the semi-manual classification scheme and classification facets. Three sub classes were identified under the Class Languages and eight sub classes were identified under the class Diagrams. Also, articles were classified depending on the type of audience, study setting, type of contribution, type of research, research method and validation type. Figure 26 provides a pictorial representation of the identified classifications.

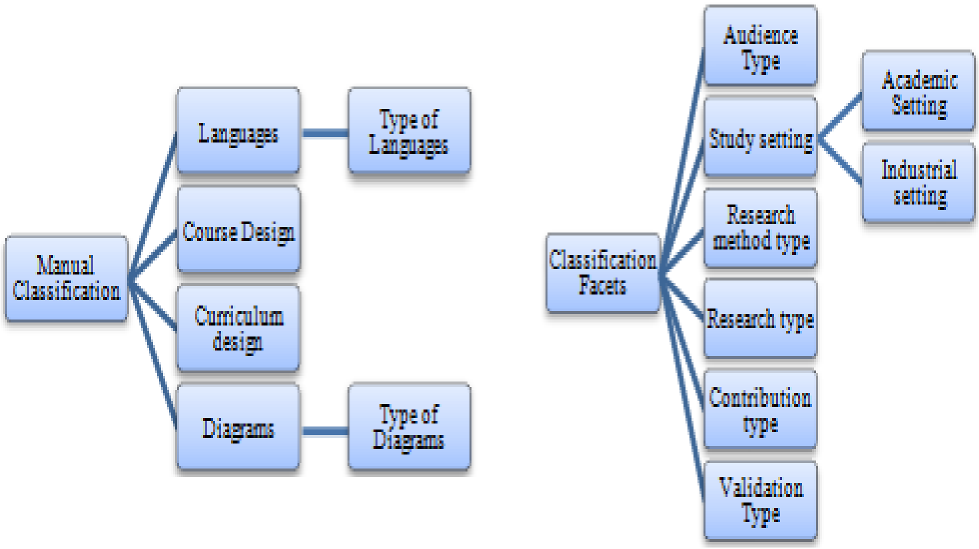


Figure 26: Classes identified from Semi- Manual Classification

- **Classification of articles using semi-manual classification scheme:**

Using the semi- manual classification scheme i.e. semantic analysis and weighted data analysis explained in chapter 5, on the primary studies, we have obtained classes namely Languages, Curriculum, course and diagrams. Figure 27 & 28 show the no of publications in each class (Refer to Appendix 12.11).

Languages:
Most of the research publication discussed about using a modeling language to teach modeling in software engineering, 77 out of 131 publications discussed about modeling languages.
Unified modeling language (UML) is considered for teaching modeling along with OVAL and OCL. UML is used as a hallmark to teach modeling in software by 74 out of 77 articles, OVAL is used in two research publications, followed by OCL with only one publication discussing its usage to teach modeling in software engineering. Figure 29 shows the number of publications in each class.

Curriculum:
This class contains 18 research publications discussed the role and importance of having a proper curriculum designed to teach modeling in software engineering. In particular, which subjects on modeling need to be included or in when should they be taught etc.

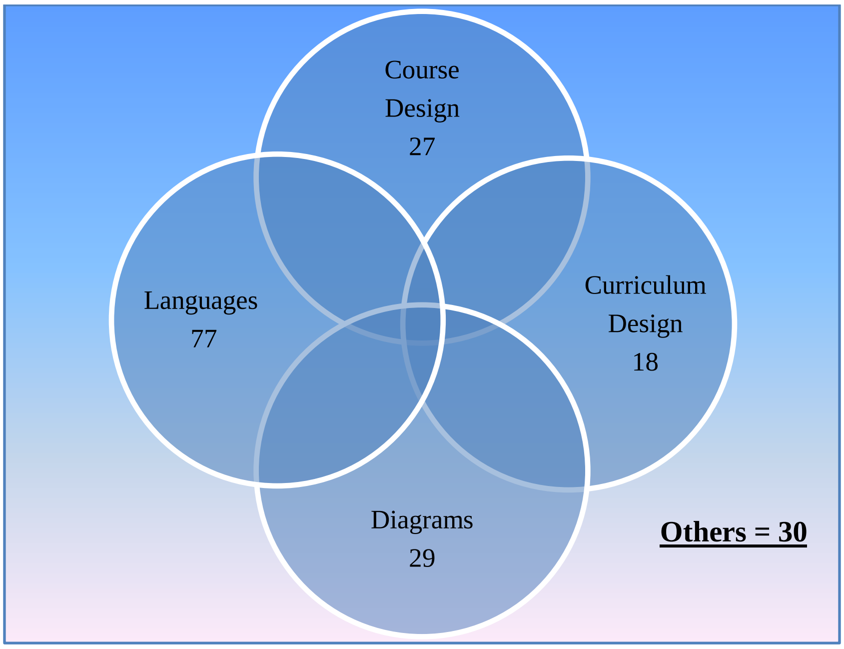


Figure 27 Classes Obtained from manual Classification Scheme

Course:

This class contains 27 publications discussed on the design of modeling courses i.e. which topics to teach, what should be the duration of a course, etc.

Diagrams:

This class contains 29 publications discussed about the usage of diagrams in teaching modeling in the domain of software engineering.11 out of 27 articles discussed about class diagrams, 3 articles discussed about state chart diagrams. There exists one article each on diagrams such as activity and sequence. Two articles were identified where, one article was identified which discusses about sequence, state chart and collaboration diagrams and one other on sequence and collaboration diagrams. 7 articles of 18 discuss about all UML diagrams. One article was identified where a new kind of diagram called as role play diagram is introduced. Figure 30 shows the no of publications in each category.

Others:

This class consists of 29 articles which are not covered under any of the classes discussed above. These publications talk about tools, models, methods, experiences, observational studies etc. Articles under this class are thoroughly classified with classification facets.

***NOTE: There are overlaps between the classes mentioned above, i.e. an article is assigned to multiple classes. Hence the total number of articles in figures 26 and 27 are higher than the selected studies.**

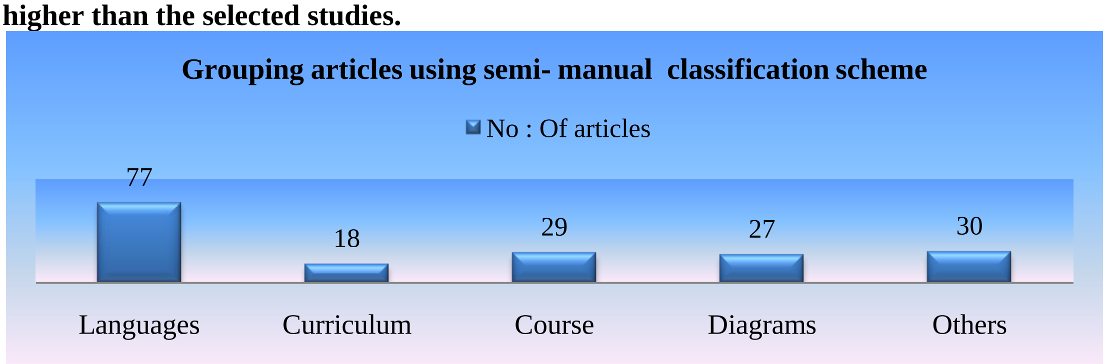


Figure 28 Classification of Research articles using semi-manual classification scheme

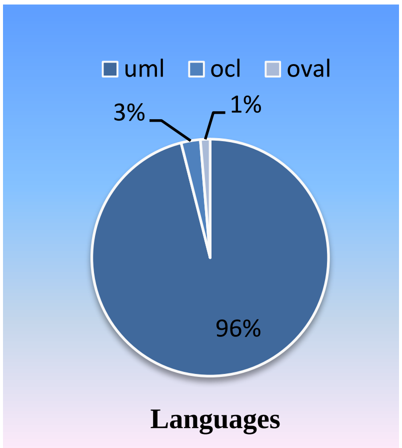


Figure 29 classification within languages

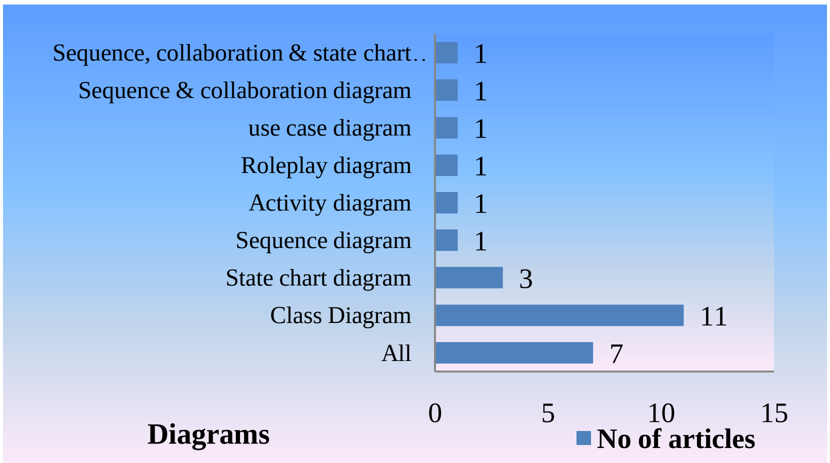


Figure 30 Classification within Diagrams

- **Classification of articles using classification facets:**

Along with the semi-manual classification scheme, classification facets were chosen to classify articles based on audience type, study setting, research method, research type, contribution type and validation type. These classifications are clearly explained in section 6.4.2.3. Refer to Appendix 12.12 for publications under each classification facet.

Audience Type:

This classification facet deals with the type of audience the study is aimed at or the group of people involved. Types of audience are teachers, students and software engineers***. Most of the research publications were aimed students, i.e. how to teach modeling to students in software engineering domain. Very few research publications were aimed at teachers.***

77% of research publications have only students as its audience, 8% of research publications have students and software engineers as its audience and 6% of research publications have only software engineers as audience, 2% of research publications have only teachers as audience, 1% of research publications have all students, software engineers and software engineers as its audience. Here 6% of research publications did not specify the audience. Figure 31 shows the no of publications in each class. Refer Appendix 12.12 for articles under each type of audience.

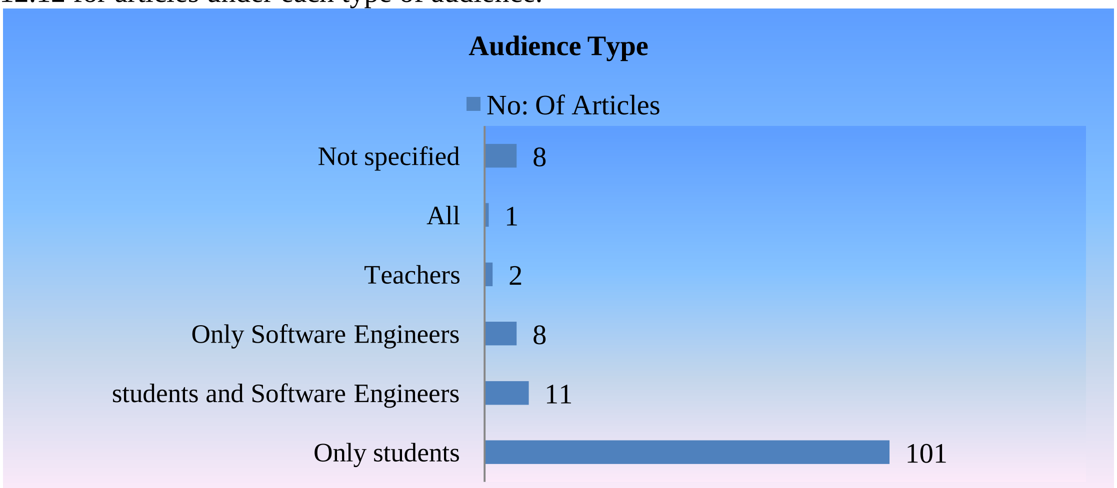


Figure 31 Audience type classification facet

Study setting:

This classification facet deals with the type of study setting or environment the research publication is associated with. The type of study setting can be either academic or industry**. *Most of the research publications were conducted in academic setting.***

86% of research publications have academic setting, 5% research publications have both academic and industry setting and 4% of research publications have only industry setting, 5% of research publications did not specify their study setting. Figure 32 shows the no of publications in each class.

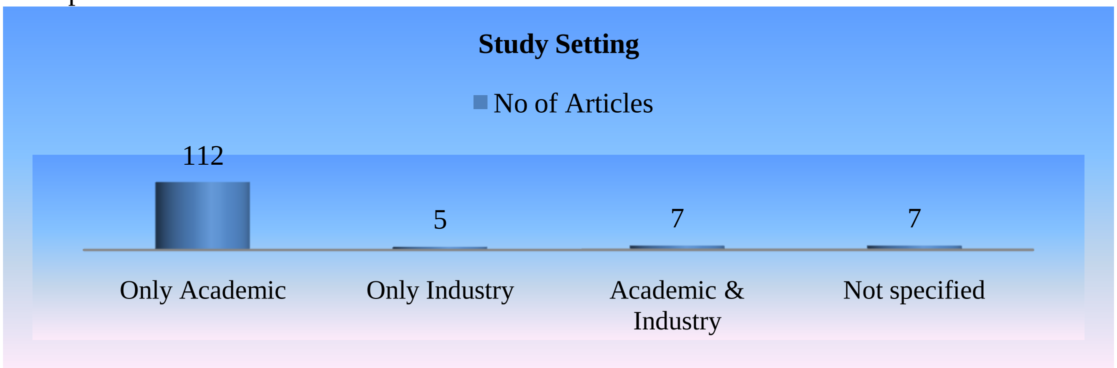


Figure 32 Study setting classification facet

Academic study setting:

This classification facet deals with the type of students involved in an academic setting or environment the research publication is associated with. The type of students which are involved in the academic setting are students from secondary school, high school, graduates, undergraduates or post graduates. ***Most of the research publications take undergraduates into consideration***.

35 publications considered undergraduates for their research while 7 studies considered graduates, 4 studies considered post graduates, 2 studies discuss about teaching modeling to secondary school student and one study discusses about teaching modeling to high school students.6 articles discuss about undergraduate and post graduates, 9 articles discuss about undergraduates and graduates and one is aimed at teaching modeling to upper secondary and undergraduate students. Figure 33 shows 125 articles and the no of publications in each category of academic setting. Refer Appendix 12.12 for articles under each study setting.

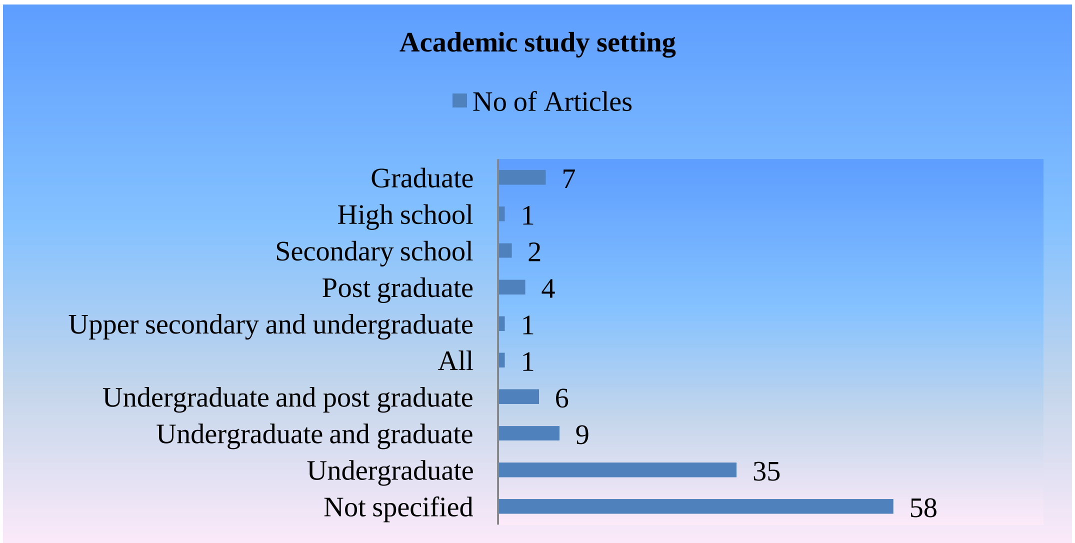


Figure 33 Academic study setting classification facet

Industry study setting:

This classification facet deals with the type of professionals involved in an industry setting or organizational environment. The type of professionals who were involved in a software organization could be developers, engineers or designers. Most of the research publications take software developers into consideration.

Four publications considered developers for their research, while 1 study considered designers and one study was aimed at both developers & designers. 2 articles were aimed at software professional irrespective of their designation while 12 do not specify the type of software professional the study is aimed at. Figure 34 shows the no of publications in each class.

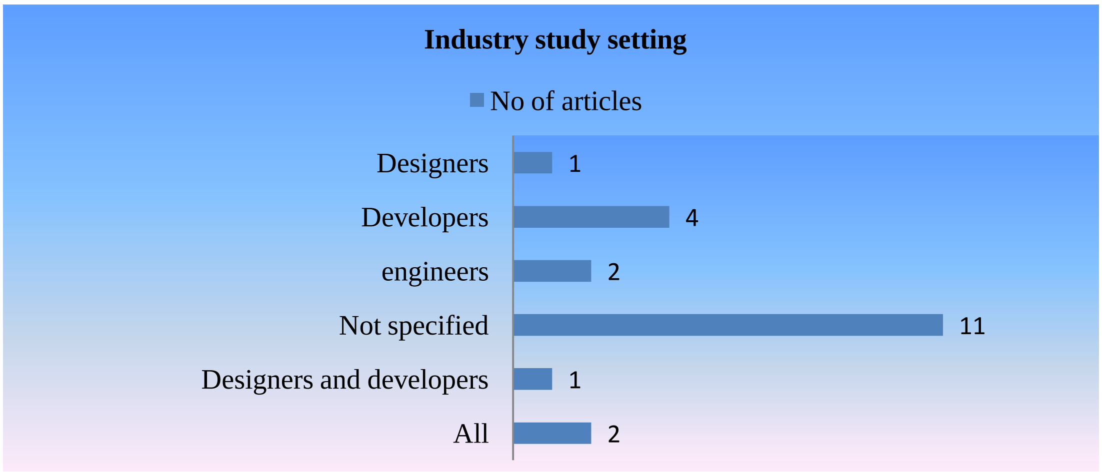


Figure 34 Industry study setting

***NOTE: There are 21 articles in industry setting and 124 articles in Academic setting which sum up to 145 articles. 7 articles did not specify the type of study setting which appear twice in academic setting as well as industrial setting, 145-2(7)=131 .**

Research Method:

This class deals with the type of research method specified in the articles. The type of research may be interviews, concept analysis, case studies, discussions, surveys, experiment and observational studies. ***Most of the research publications use concept analysis as their research method followed by observational studies in the second place***.

35% of publications used concept analysis as a research method, 27% of research publications used observational study as their research method, 11% of research publications used experiment as their research method, 6% of research publications used survey as their research method, 3% of research publications used discussion as their research method, 1% of research publications were used interviews as their research method, 11% of research publications used case study as their research method.

There were 6 research publication where 1 research publication used discussion and interviews as their research methods, 1 research publication used literature review and interviews as their research methods, 1 research publication used concept analysis and observational study as their research methods, 1 research publication used concept analysis and interviews as their research methods, 1 research publication used concept analysis and case study as their research methods and 1 research publication used concept analysis and survey as their research methods. Figure 35 shows the no of publications in each class. Refer Appendix 12.12 for articles under each research method.

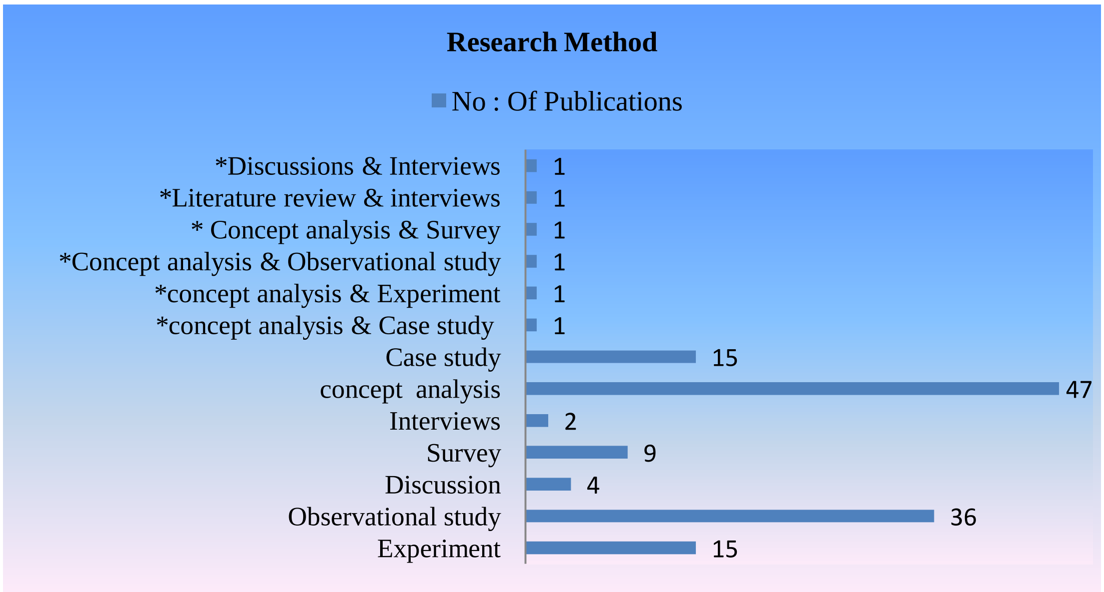


Figure 35 Research method classification facet

Research Type:

This class considers the type of research carried out in the articles. The following types of research were considered such as solution proposal, experience paper, validation study, evaluation research, opinion paper. ***Most of the research articles were based on experiences***.

42 research publications were experience articles, 27 research publications were solution proposals and 20 research publications were evaluation research, 12 research publications were opinion articles, 4 research publications were validation studies. Here 20 research publications were both solution proposals as well as validation studies, 3 research publications were both solution proposals as well as evaluation research. There were 3 research publications where 2 of the were solution proposal and experience paper and 1 was an experience paper and validation study. Refer Appendix 12.12 for articles under each research type. Figure 36 shows the number of publications in each class.

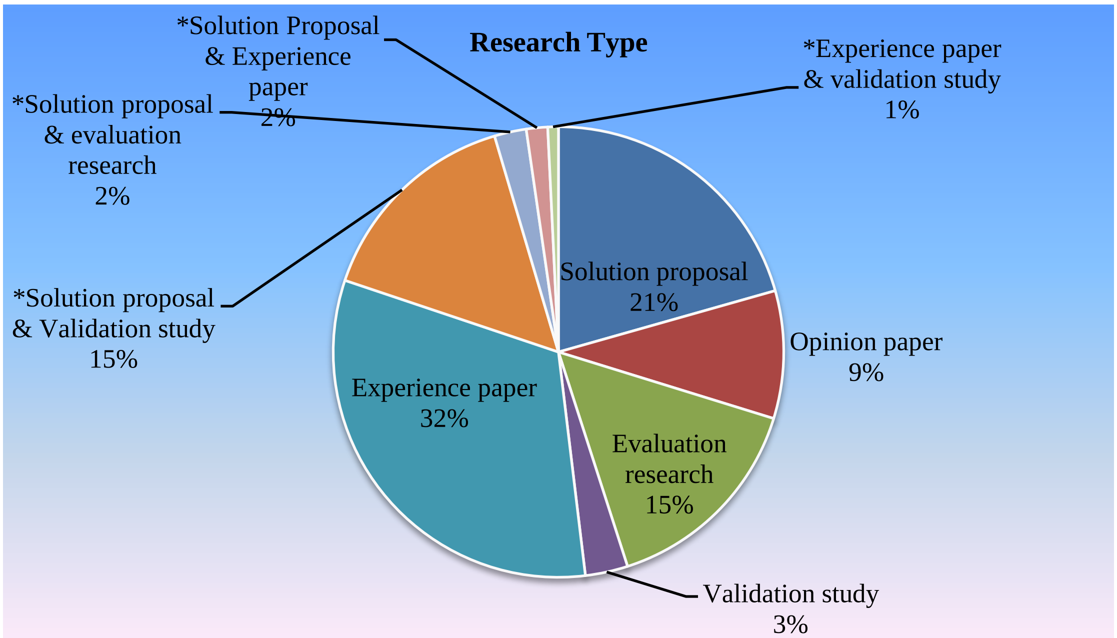


Figure 36 Research Type classification facet

Contribution Type:

This class deals with the type of contribution from the articles. The type of contribution may be model, process, method, measurement and tool. ***Most of the research publications contribute to the process of teaching modeling***.

60% of research publications contribute to process, 14% of research publications contribute to method, 13% of research publications contribute to tool, 4% of research publications contribute to measurement, 2% of research publications contribute to model, 1% of 1 research publications were used contribute to both process & tool and 6% of research publications contribute to both process & method. Figure 37 shows the no of publications in each class. Refer Appendix 12.12 for articles under each category of contribution type facet.

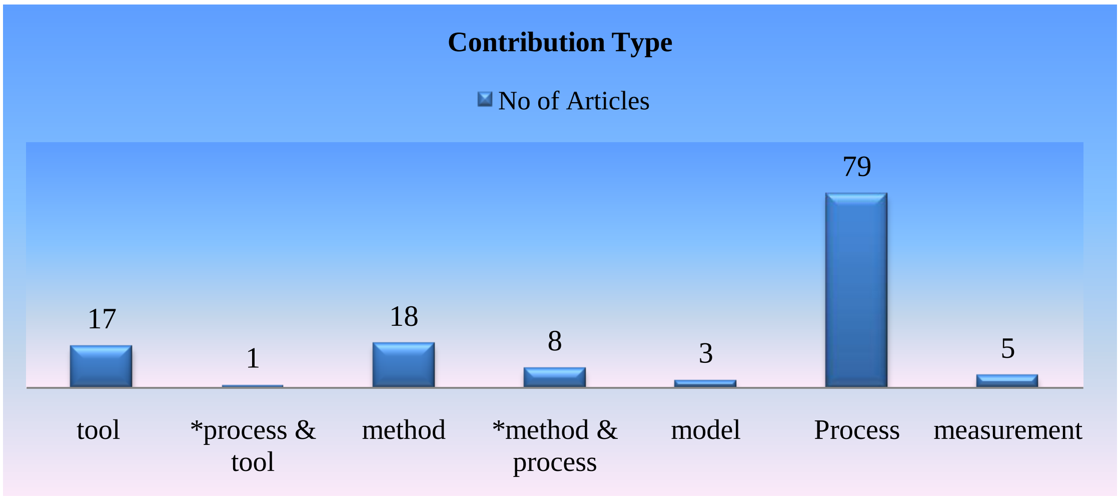


Figure 37 Contribution type facet

Validation type:

This class deals with the type of validation discussed in the article. 49 research publications have validated their results whereas 82 research publications did not validate their results. Figure 38 shows the no of publications in each class. Refer Appendix 12.12 for articles under each category of validation type facet.

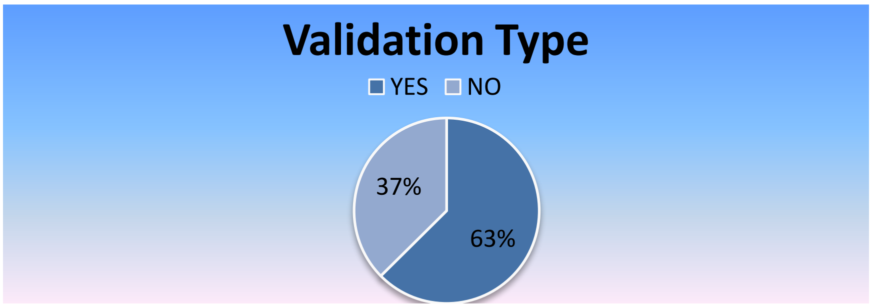


Figure 38 Validation Type classification facet

6.4.4 Results corresponding to Research Question 3.4)

What relations can be drawn between the identified categories?

To answer the research question, bubble charts were drawn to analyze the relationships between the classes obtained from semi-manual classification and the classification facets. Classes obtained from the semi-manual classification scheme such as

Languages, Diagrams, Course Design, and Curriculum Design were marked on the vertical axis whereas the categories of classification facets such as contribution type, research method and research type were marked on the horizontal axis. Refer to Appendix 12.11 & 12.12 for publications under each bubble.

- **Relationship between classes obtained from Semi- Manual Classification scheme and contribution type facet:**

A bubble chart was plotted taking contribution type facet and classes obtained from semi-manual classification scheme. Most of articles discuss about the process of teaching modeling using Languages.

From the bubble chart shown in figure 39, there were 10 articles which discussed about the process of using diagrams to teach modeling, 43 articles discussed about the process to teach modeling using languages, 28 articles deal with the process of designing modeling course in software engineering and 13 articles talk about the process of design a proper curriculum involving subjects on modeling in software engineering. There are 18 publications from others which contribute to the process of teaching modeling. Refer Appendix 12.18 for classification of articles under these relationships.

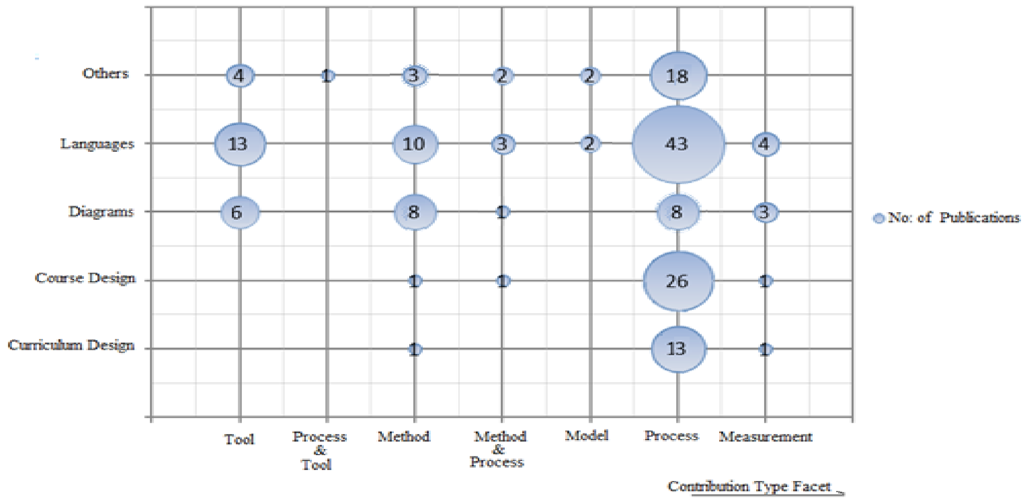


Figure 39 bubble chart for contribution type facet

Eight articles discussed the methods of teaching modeling diagrams, and ten articles discussed the methods for teaching modeling languages in software engineering. There are 3 publications from others which present the methods which can be used to teach modeling. Two articles, one each, discussed the methods to design curriculum and course to teach modeling in software engineering. Figure 39 shows the bubble chart drawn to represent the relationship between classes obtained from semi-manual classification scheme and contribution type facet.

There exist 13 articles which presented tools which aid teaching modeling with drawing diagrams in software engineering. There are 4 publications from others which present tools to teach modeling. Six articles introduced tools which help in teaching modeling languages to students or professionals in software engineering.

Three articles brief upon the methods and process used to represent and teach diagrams to model in software engineering paradigm. There are 2 publications from others which discuss the process and methods used to teach modeling. One article discussed the methods and process used to design modeling courses in software engineering.

There are four articles which discussed about metrics which could be used in diagrams to teach modeling in software engineering, 3 articles discuss the metrics involved in languages such as OCL, UML, and OVAL. Two articles discuss the metrics involved in designing curriculum and courses to teach modeling in software engineering.

Only one article introduced a new model for representing diagrams to teach modeling in software engineering and there are 2 articles which discuss the models which can be used in teaching modeling. One articles from others, discusses about the process and tools used to teach modeling in software engineering.

- **Relationship between classes obtained from Semi- Manual Classification scheme and research type facet:**

To view the relationship between the types of research carried out or the research type facet with the classes obtained from the semi- manual classification scheme. *Most of the articles are experience articles*, with 23 of them discussing about the languages used to teach modeling, and 5 of them discussing about the diagrams. There are 15 experience articles which discussed about the type of course design and 9 articles about the curriculum designs based on their experiences. Refer Appendix 12.17 for classification of articles under these relationships.

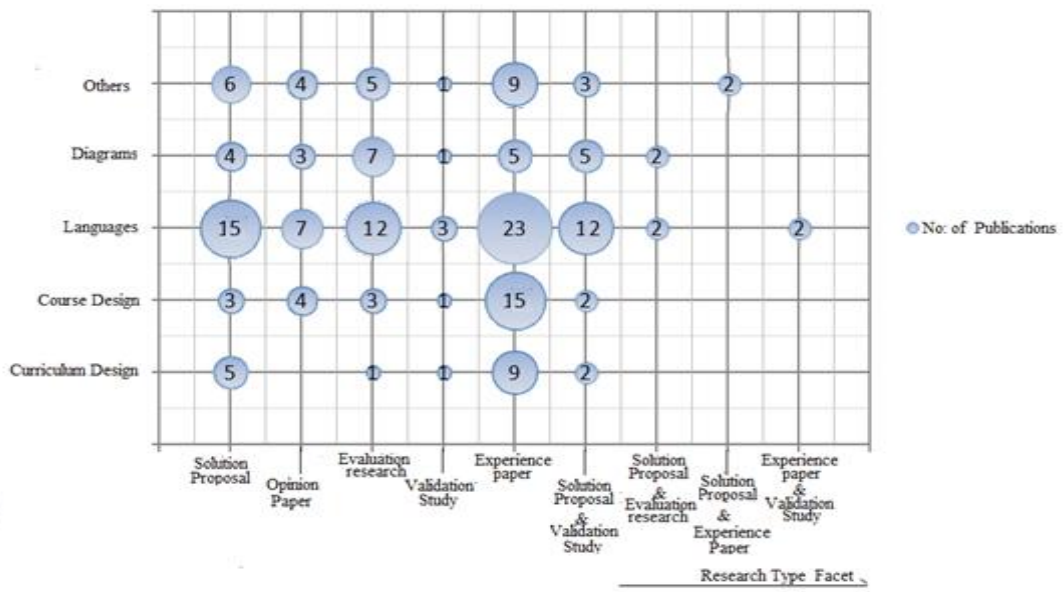


Figure 40 bubble chart for research type facet

There are 12 articles which provide solutions for the existing problems with the languages and validate the results. Five articles discuss about solutions for problems related to modeling diagrams, with validated results. Four articles discuss about solutions to problems currently being faced with course and curriculum design and validate their solutions. Three articles from others discuss about the solutions to problems related to teach modeling, with validated results. There are two articles discussed the experiences of using languages to teach modeling with validated results.

There are four articles, two on diagrams used to teach modeling and two on modeling languages, which provided solutions to the existing problem and also evaluate the existing solutions for the problems. There are 5 articles which are validation studies with one article discussing on diagrams, two articles on languages used in modeling, one article on course design and one on curriculum design. There are two validation studies from others.

Figure 40 shows the bubble chart drawn to represent the relationship between classes obtained from semi- manual classification scheme and research type facet.

There are seven articles which expressed opinions on languages to teach modeling, four articles expressed opinions about the course design, four articles expressed their opinions on models to teach diagrams and four articles expressed their opinions on course designs. There is only one article from others, which is a solution proposal to existing problems in teaching modeling based on experiences.

Twenty three articles discuss experiences with modeling languages, 15 articles present course designs for modeling languages based on previous experiences, 9 articles discuss the curriculum design for teaching modeling in software engineering based on experiences, five articles discuss the usage of various diagrams to teach modeling based on past experiences and 9 articles from others present experiences on teaching modeling in software engineering.

Twelve articles evaluated the existing ways to teach modeling languages, seven articles evaluated the existing practices to teach diagrams, three articles evaluated course designs and one article evaluated the exiting methods on curriculum design. Five articles from others evaluated previous practices to teach modeling.

Fifteen articles provided solutions to problems faced by languages; four articles discussed the problems faced with diagrams and provide solutions to them. There are six articles from others which provided solutions to existing problems. Five articles discussed problems related to curriculum design and provide solutions.

- **Relationship between classes obtained from Semi- Manual Classification scheme and research method type facet:**

Most of the research publication discussed the use of languages to teach modeling using concept analysis as a research method for their articles, followed by observational studies and experiments. Figure 41 shows the bubble chart representing the relationship between semi-manual classification scheme and research method type facet.

One article used discussions and interviews as its research method in order conduct research related to course design and one articles used concept analysis and survey as their research method to conduct research on modeling languages. There are two articles, where one discussed the use of languages to teach modeling using concept analysis and experiment, the other article is based on diagrams using concept analysis and experiment for its research. Three articles from others used concept analysis & case study, Concept analysis & observational studies and Literature reviews & discussions to carry out their research on teaching modeling in software engineering. Refer Appendix 12.16 for classification of articles under these relationships.

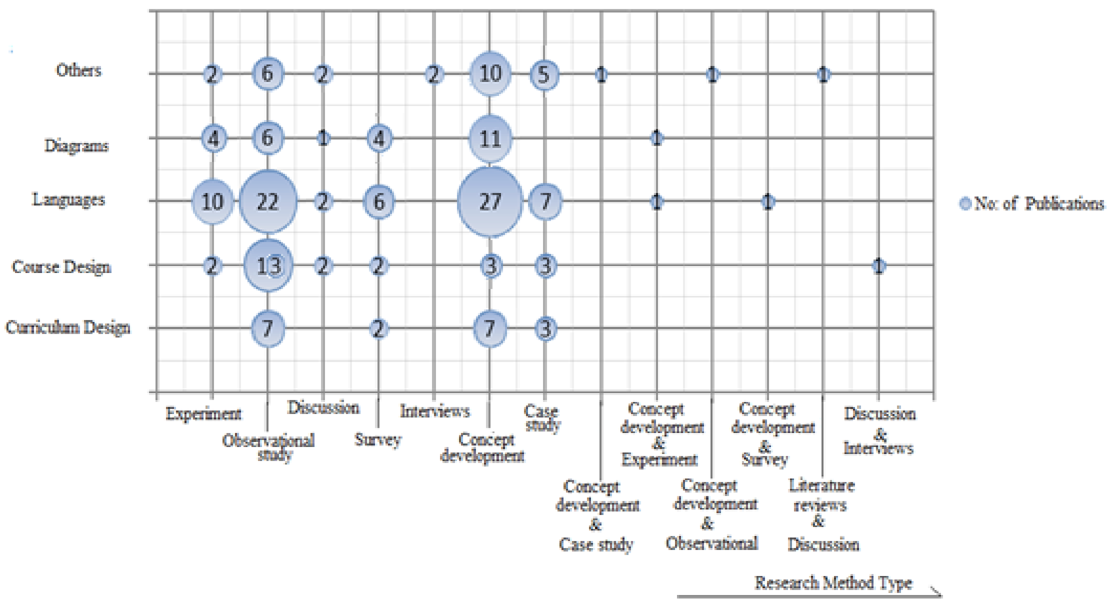


Figure 41 bubble chart for research method type facet

Seven articles discussed languages to teach modeling and used case study as a research method. Six articles used case study as their research method with 3 each discussing curriculum and course based design. There are five articles from others which used case study as their research method.

There are eleven articles which discussed about diagrams, 27 about languages, three about course design and 7 about curriculum design; all of them used concept analysis as their research method. There are ten articles from others which used concept analysis as their research method.

There are four articles which used surveys and discussed about diagrams, 6 articles which used surveys and discussed languages used in teaching modeling in software engineering, two articles each discussed about course design and curriculum design based on surveys.

There is one article which used panel discussion and discuss on diagrams used to teach modeling, 2 articles used panel discussion on languages used in teaching modeling in software engineering and 2 articles discussed about course design & curriculum design in modeling paradigm using panel discussion as a research method. There are two articles from others which used discussions as their research method.

There are 22 articles which had a discussion on languages used to teach modeling in software engineering, 13 had a discussion on the design on modeling course, 6 studies deal about curriculum design and 6 articles talk about the diagrams used to teach modeling which are all based on observation. There are nine articles from others which are observational studies.

There are 4 articles which talk about diagrams, 10 articles which discussed about languages and 2 articles which discussed about course design which are based on experiments conducted. There are two articles from others which used experiments as their research method.

Reflections and discussion on these obtained results are presented in the following chapters.

7 REFLECTIONS ON THE RESULTS OF SYSTEMATIC MAPPING

In this chapter, reflections are made on the results obtained from systematic mapping. These reflections of the results also answer research question 4. Reflections on the results comprise of evaluation of rigor of the results and their relevance to the industry, along with the calculation of citation ranking and an overall ranking of the results based on rigor, relevance and citation ranking. Figure 42, provides the structure of how reflections were made on the results.

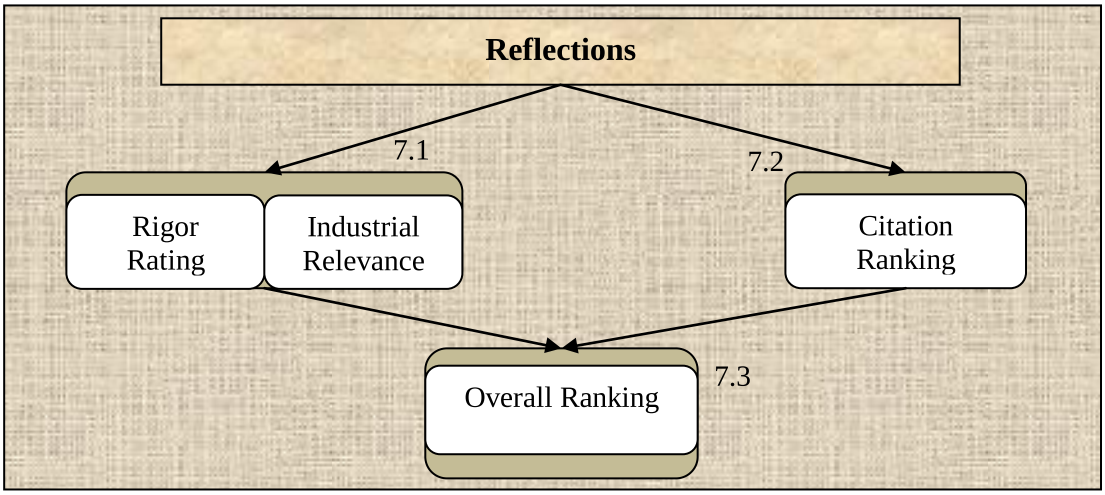


Figure 42 Structure of Reflections on the results

These reflections were made to identify the importance of the results obtained from classification and also to evaluate them qualitatively.

7.1 Evaluating the rigor and relevance

Rigor and Relevance, Suggested by Ivarrson & Gorschek [67], were considered to qualitatively evaluate the results obtained from systematic mapping. This method suggested by Ivarrson and Gorschek [67] describes a complete model (taking into consideration observations made from several studies such as Sjoberg et. al [105], Hofer and Tichy [106], Glass et. al [107] and Zelcowitz [108]) on evaluating rigor and industrial relevance of technological evaluations. This method described by Ivarrson and Gorschek [67] was applied to our context as described below:

- Rigor (R_i):

  Rigor is calculated to assess the extent to which a study includes the aspects related to rigor. Three aspects from rigor were considered, the extent to which the context of the study, design of the study and validity are discussed. These were rated on a scale of Strong description (1.0), medium description (0.5) and weak description (0) [67].

- Industrial Relevance (R_e):

  Relevance is calculated to assess the relevance of a particular study to the industry. Here, we assess how the realism of the environment in which the study is carried out effects the relevance [67]. To evaluate the industrial relevance, skill of the subjects, size of the sample, environment of the study and type of research method used were considered. These four aspects were rated on a scale of Strong description (1.0), medium description (0.5) and weak description (0) [67].

This rigor and relevance considered here holds good for technological evaluations. Also, we calculated the rigor and relevance for the studies which did not have any validations or evaluations. All the articles which did not have validated results had a zero rigor and zero relevance. As these non-validated results would bias our assessment, we chose to omit them. Hence, 89 articles were considered from the Validation type facet, which had validated results. Refer Appendix 12.19 for rigor and relevance ratings for the studies. Table 35, shows the attributes used for evaluating rigor and industrial relevance in this research.

Rigor (R_i)			**Industrial Relevance (R_e)**			
Context	Design	Validity	Research Method	Environment	Sample Size	skill
Strong Description (1.0)		Medium Description (0.5)		Weak Description (0)		

Table 35 Attributes of Rigor & Relevance

7.1.1 Rigor

The main aim of calculating the rigor of the studies is to identify a few selected studies which clearly describe the research area of interest. **The rigor rating from these suggests *that though most of the studies thoroughly discussed the context and study design, there was no description of the threats to the study*.** From the figure 43, we can observe that most of the articles had a rigor rating of 2, which is greater than the average rigor for the selected studies which was measured at 1.97.

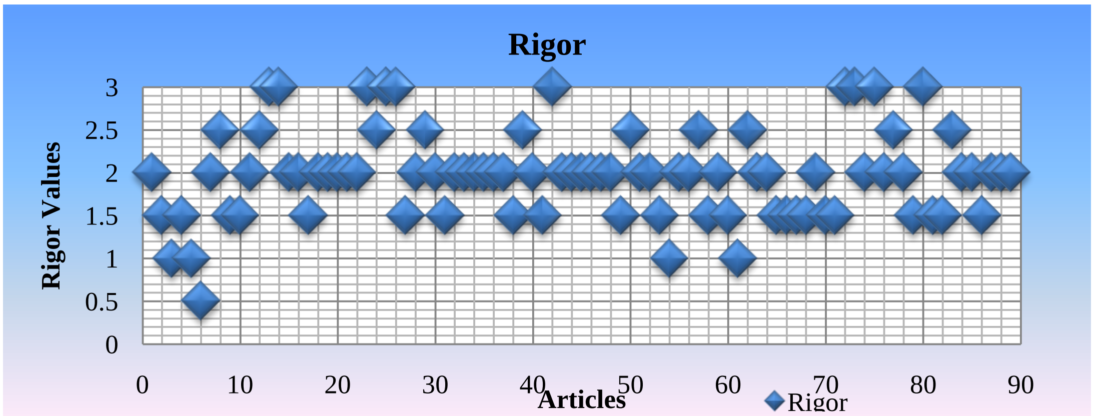


Figure 43 Rigor of the studies

19 articles had a rigor rating more than that of the average rigor. 10 articles scored a rigor of 3(refer table 36 for the articles with high rigor ratings) and 9 articles had a rigor of 2.5. 68% of 89 articles had a rigor rating greater than the average rigor, ***which indicates that the rigor of studies in this research area is mediocre and there is scope for improvement.*** Calculation of rigor resulted in the selection of 10 articles which reported a rigor rating of 3 presented in table 36. These studies are described below:

- ***C. Damm et al.*** [SMP 20]:

This article attempts to examine the tool support for software development in industry as well as academics. Based on several observations of the existing tools, KNIGHT, a new tool is developed and several evaluations were made [47].

- ***J. C. W. Debuse & T. Stiller et al.*** [SMP 22]:

This article investigates the teaching strategies and technologies that can be used to improve teaching object oriented design and programming to students [48].

- ***J. Cruz-Lemus & M. Genero et al***. SMP [37]:

This article focuses on evaluating the effect of composite state on the understandability of state chart diagrams in UML. A controlled experiment is conducted in an academic setting which suggests that using composite states would improve the understandability [49].

ID	Title	Rigor
SMP [20]	***Tool support for cooperative object-oriented design: gesture based modelling on an electronic whiteboard***	**3**
SMP [22]	***Technologies and Strategies for Integrating Object-Oriented Analysis and Design Education with Programming***	
SMP [37]	***Evaluating the Effect of Composite States on the Understandability of UML Statechart Diagrams***	
SMP [41]	***Teaching UML using umple: Applying model-oriented programming in the classroom***	
SMP [45]	***Empirical Validation of Measures for UML Class Diagrams: A Meta-Analysis Study***	
SMP [74]	***Can graduating students design: revisited***	
SMP [108]	***Does UML make the grade? Insights from the software development community***	
SMP [109]	***The impact of structural complexity on the understandability of UML statechart diagrams***	
SMP [111]	***An empirical study on using stereotypes to improve understanding of UML models***	
SMP [117]	***A Phased Highly Interactive Approach to Teaching UML-Based Software Development***	

Table 36 Studies with Highest Rigor Rating

- ***T. C. Lethbridge et al.*** SMP [41]:

This article shows how a technology called UMPLE, be used to improve teaching UML. The authors based on the experiences of using this UMPLE for two years on course and laboratory assignments suggest that performance of students has increased using this UMPLE [50].

- ***M. Esperanza Manso & J. Cruz-Lemus et al.*** SMP [45]:

This article investigates the dependences between structural complexities and size of UML class diagrams, as well as the dependence between cognitive complexities of UML class diagrams and their modifiability and comprehensibility [51].

- ***Chris Loftus et al.*** SMP [74]:

This article evaluates the results of a previous article “Can graduating students Design” [71]. An experiment was conducted in an academic setting which proves that many graduating students lack the ability of designing software systems [52].

- ***L. Kuzniarz et al.*** [SMP111]:

This article investigates the effect of structural complexity on the understandability of UML state chart diagrams [55]. A family of experiments was conducted in an academic setting to asses this influence.

- ***E. Astesiano & M. Cerioli, et al.*** [SMP 117]:

This article discusses an approach to introduce projects in software development within an under graduate software engineering course [56].

- ***Jose, Cruz-Lemus & Ann Maes et al.*** [SMP 109]:

This article discusses the results obtained from the empirical investigation on the effects of structural complexity on the understandability of UML state chart diagrams [54].

- ***G. Martin & Jay E. Aronson et al.*** [SMP 108]:

This article presents a survey conducted to find how the UML is adopted and used in the software development community. This survey was conducted based on the characteristics such as flexibility, understandability, training & ambiguity [53].

Most of the articles with high rigor rating [SMP 22, 37, 41, 45, 107, 108, 111, 117] ***discuss about usage UML to teach modeling in software engineering***. Table 36, presents the articles with high rigor ***Articles which had a poor description of context and study design, such as [SMP 5], [SMP 7], [SMP 9], [SMP 90] & [SMP 97] reported a very low rigor rating.*** Refer, Appendix 12.16 for the rigor ratings of each study.

7.1.2 Industrial Relevance

To select studies which show some intent on developing methods for industry rather than only academia, Industrial relevance was calculated. ***Most of the articles had students as it population for the experiments and are conducted in an academic setting which indicates very low levels of industrial relevance ratings.*** 57% of the articles reported zero industrial relevance. The average industrial relevance for the studies which have validated results was calculated at 0.62, ***which indicates that a lot research has to be carried out to teach modeling in the industrial setting***. Figure 44, shows the industrial relevance plotting of the articles.

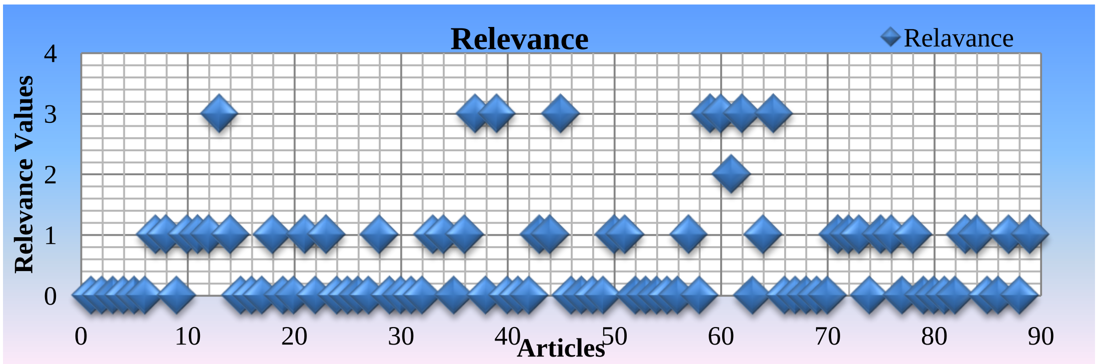


Figure 43 Industrial Relevance Rating

This calculation of Industrial relevance resulted in the selection of 8 articles which reported a relevance rating of 3. These studies are listed in the table 37,

- ***C. Damm et al.*** [SMP 20]:

This article attempts to examine the tool support for software development in industry as well as academics. Based on several observations of the existing tools, KNIGHT, a new tool is developed and several evaluations were made [47].

- ***J. Whittle & J. Hutchinson et al.*** [SMP 68]:

This article emphasizes on the mismatches between the industrial practice and teaching model driven software development. This study highlights the good practices and bad practices from the experiences collected from 17 companies [60].

- ***C. Damm & K. Hansen et al***. [SMP 71]:

This article is a ***companion paper*** of [SMP 20] [47]. Much emphasis is made on the design and software architecture of the KNIGHT tool rather than its evaluations [61].

ID	Title	Relevance
SMP [20]	***Tool support for cooperative object-oriented design: gesture based modelling on an electronic whiteboard***	**3**
SMP [68]	***Mismatches between Industry Practice and Teaching of Model-driven Software Development***	

SMP [71]	***Creative Object-Oriented Modelling: Support for Intuition, Flexibility, and Collaboration in CASE Tools***	
SMP [77]	***Toward Better Logical Models in UML***	
SMP [95]	***An E-whiteboard Application to Support Early Design-Stage Sketching of UML Diagrams***	
SMP [96]	***Pen-based Input of UML Activity Diagrams for. Business Process Modelling***	
SMP [98]	***SUMLOW: early design-stage sketching of UML diagrams on an E-whiteboard***	
SMP [101]	***Calico: A Tool for Early Software Design Sketching***	

Table 37 Articles with High Relevance Ratings

- ***P. V. Reddy et al***. [SMP 77]:

This article focuses on improving the logical models in UML. The author based on his industrial experience suggests that logical models can be made better by using hierarchical models, relational driven design over behavioral design and avoiding ambiguous interpretation of classes [62].

- ***Qi Chen et al.*** [SMP 95]:

This article presents SUMLOW, an UML sketching tool that uses E-whiteboard and pen based sketching interface to aid collaborative design [63].

- ***A.F. Donaldson & A. Williamson et al.*** [SMP 96]:

This article presents a prototype for pen based input systems designed based on KNIGHT [47] and SUMLOW [63, 65], supports modelling of UML activity diagrams and textual annotations of components [96].

- ***Qi Chen et al.*** [SMP 98]:

This article (a companion article to SUMLOW [SMP 95]) discusses the architecture design and implementation of SUMLOW tool in a more detailed way than its predecessor [63]. Also, more number of evaluators for the tool was considered including people from both academia and industry [65].

- ***M. Nicolas & B. Alex et al.*** [SMP 101]:

This article introduces Calico a sketching tool which aids software designed in editing, finding and producing software design at an early stage. This tool works using an electronic blackboard [66].

From the figure 45, we can observe that most of the articles can be seen in the lower right quadrant of the graph which shows that most of the articles in this research area had a substantial rigor but lack in industrial relevance.

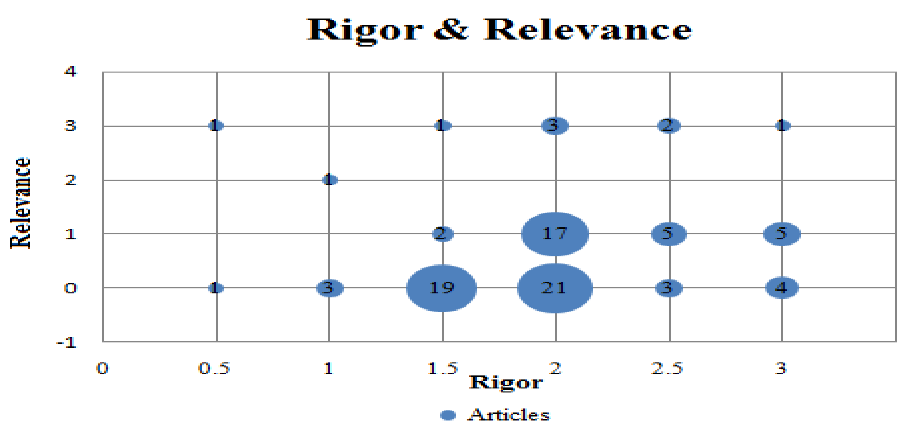


Figure 44 Rigor & Industrial relevance for the selected studies

7.1.3 Rigor, Industrial Relevance & Research Activity

From the figure 46, we can observe that average rigor of the articles did not have much improvement over the years and it remains at a rating of 2. From 7.1.1, we can observe that most of articles also had an average rigor rating of 2 which is mediocre. Based on these observations, ***we can infer that rigor of the articles over the years has maintained at a rating of 2 and there is scope for improvement in the overall rigor of the articles in this area.***

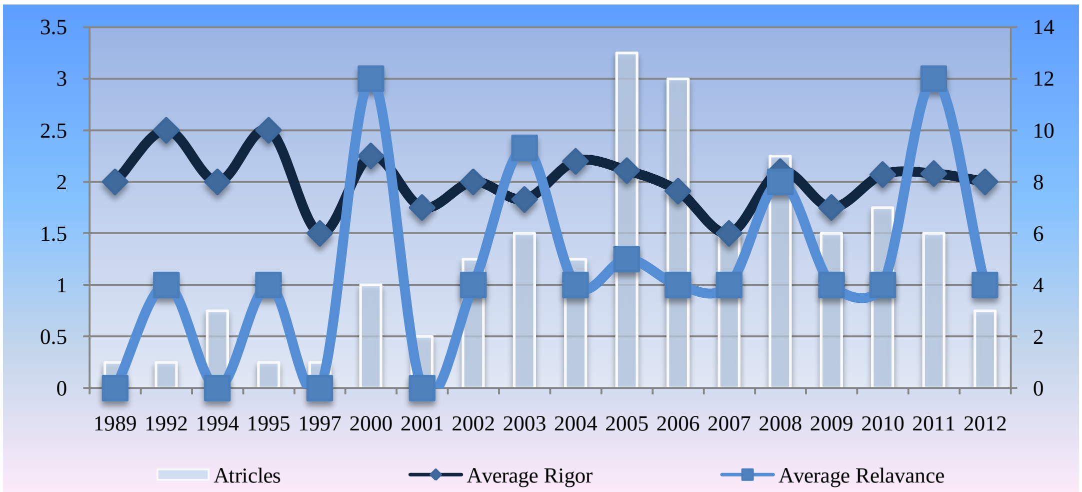


Figure 45 Average Rigor, Relevance and Research activity over the years

Though there is very less industrial relevance of articles in this research area, we can observe that from the year 2002 i.e., from the past decade, there has been an increase in the number of articles which have shown some intent on developing methods for industry. Also the average industrial relevance for these articles has improved over the past decade which shows that ***research activity for industrially relevant articles has been increasing over the past decade, which is a good phenomenon for the Software Engineering Industry and practitioners.***

From figures 47, ***articles from Journals have reported a higher rigor rating when compared with conferences or workshops articles***. Journals such as *Journal of Object Technology [36], Journal of Information and software Technology [79], L'Object [77] & Journal of Information Sciences [78]* have a high rigor in their publications. Table 38 lists the journals, conferences and workshops which had high rigor and relevance ratings.

High rigor/ relevance	Rigor	Industrial Relevance
Conferences	▪ Australian conference on software engineering [73] ▪ CHI [72] ▪ MODELS [37] ▪ Conference on Software Engineering Education & Training (CSEET) [75] ▪ Object Oriented Programming, Systems, Language & application (OOPSLA) [74]	▪ Human Centric Computing and Visualization (VL/ HCC) [82] ▪ Software Visualization (SoftVis) [81] ▪ European conference on Object oriented Programming (ECOOP) [80]
Workshops	➢ International workshop on Program comprehension (IWPC) [76]	➢ Models Educators symposium (EduSymp) workshop [17]
Journals	✓ ***Journal of Object Technology [36]*** ✓ ***Journal of Information and software***	✓ ***Journal of Object Technology [36]*** ✓ ***Software practices and Experience***

	Technology [79] ✓ *L'Object [77]* ✓ *Journal of Information Sciences [78]*	*Journal [83]*

Table 38 Rigor, Relevance & publication type

Articles from conferences such as *Australian conference on software engineering [73], CHI [72], MODELS [37], Conference on Software Engineering Education & Training (CSEET) [75]* & *Object Oriented Programming, Systems, Language & application (OOPSLA) [74]* & workshops such as *International workshop on Program comprehension (IWPC) [76]* has reported a high rigor rating.

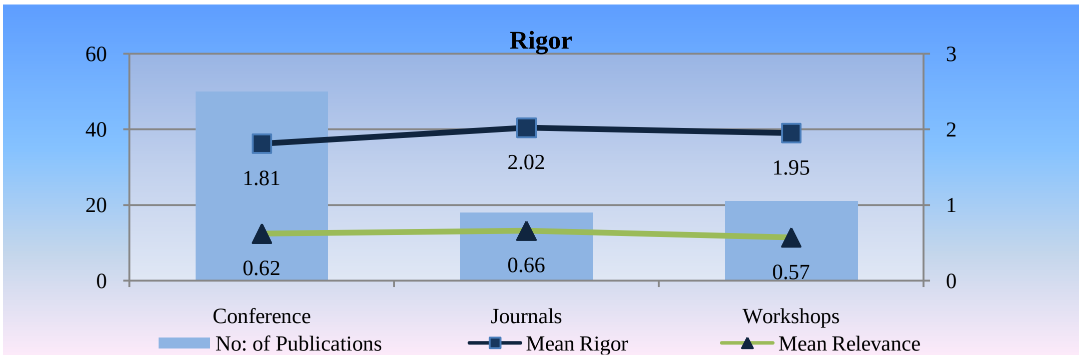


Figure 46 Rigor, Relevance & Publication type

From figures 47, ***articles from journals have reported a higher Industrial relevance rating when compared with conferences or workshops***. Journals such as *Journal of Object Technology [36] & software practices and Experience Journal* [83] had articles with high industrial relevance.

Conferences such as *Human Centric Computing and Visualization (VL/ HCC)* [82], *Software Visualization (SoftVis)* [81], *European conference on Object oriented Programming (ECOOP)* [80] and Workshops *such as Models Educators symposium (EduSymp) workshop* [17] and had articles with high industrial relevance.

7.1.4 Rigor, Industrial Relevance & Manual Classification

From figure 48***, Articles which discuss about teaching modeling languages have a high Industrial relevance and Rigor ratings***. Also, most of the articles i.e., 8 out of 10 articles with highest rigor ratings from Table 36, [SMP 22, 37, 41, 45, 107, 108, 111, 117] had UML as a de-facto language to teach modeling in software engineering in academia.

50% of articles with high relevance rating from Table 37, [SMP 71, 95, 97, 98] discusses about tools to draw diagrams of Unified Modeling Language, UML and [SMP 77] discusses ways to improve logical models in UML.

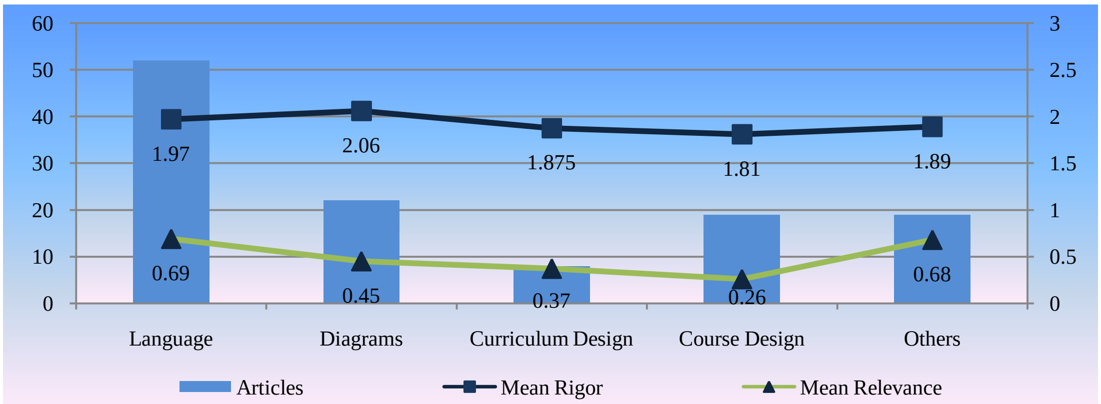


Figure 47 Rigor, Relevance & Manual Classification

This shows that *UML has a very high industrial relevance and used widely to teach modeling in academic as well as industrial settings*, though there exits other languages such as OCL and OVAL. The classifications, course and curriculum design reported low on Industrial relevance and rigor ratings. **This shows *that much research needs to be carried out on providing courses and curriculum design to teach modeling in an industrial setting*.**

7.1.5 Rigor, Industrial Relevance & Classification Facets

Classification facets such as Research type, audience type, study setting, research method, and contribution type described earlier in chapter 6 were considered for rigor and relevance study. The rigor and relevance ratings of the classification facets are described in the following section.

- **Study setting:**

Rigor and relevance study is conducted on articles classified under this classification facet, as to know which environment/setting has more industrial relevance and has yielded articles with utmost rigor. ***Most of the articles with high rigor rating such as SMP [22, 37, 41, 74, 45, 53, 109, 111, and 117] were conducted in an academic setting***. Whereas, only *one article SMP [20]* which examines the tool support for software development in industry as well as academics was *conducted in a mixed setting i.e., with software engineers from the industry and teachers from the academia* [47]. From figure 49, we can observe that though the mean rigor of articles which have industrial setting as their environment was slightly higher there was only one article. Hence, from the above observations, ***we can say that articles from academic setting had a better overall rigor rating when compared with articles from a mixed setting or industrial setting***.

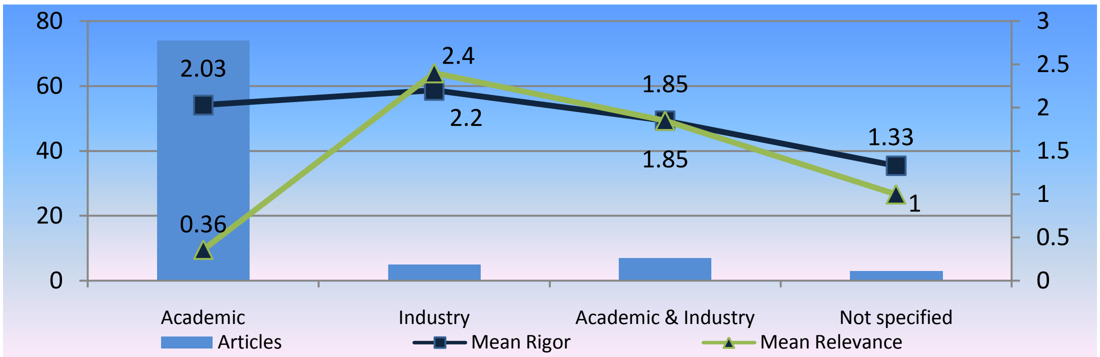


Figure 48 Rigor, Relevance and Study setting

There are only three articles, carried out in an industrial setting which show some industrial relevance. All these articles, SMP [77, 95, and 96] had an industrial relevance rating of 3. Also, Five out of six articles SMP [20, 68, 71, 98, and 101] from the mixed setting had a high industrial relevance rating of 3. From figure 49 & 50, we can observe that ***though articles with industrial setting as their environment are less in number, they had a high industrial relevance rating***.

- **Audience Type:**

Rigor and industrial relevance among articles classified on the type of audience are inversely proportional. Considering the type of audience involved, though articles with software engineers as their audience had more rigor when compared to the others they are very less in number. Only four articles have software engineers as their audience out of which only one article, which discusses a newly developed and yet to be validated state of art Object oriented metrics which can be used to measure the complexity of UML class diagrams [SMP 113] reported a rigor of 2.5, the other articles had a rigor 2 respectively. An important observation here is that ***most of the articles which had students as it audience had a high rigor***; articles such as [SMP 22, 37, 41, 45, 74, 109, 111, and 117] reported a rigor rating of 3. ***This suggests that most of the articles which had students as its audience did not compromise on rigor.***

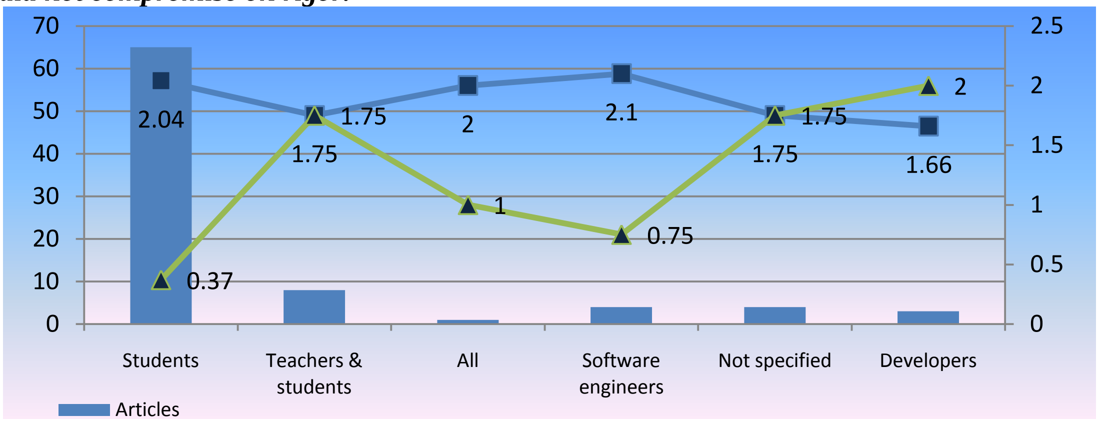


Figure 49 Rigor, Relevance rating and Audience Type

Articles with software developers as it audience had a higher rigor rating compared to the others. Two of its three articles which discuss pen based input systems [SMP 95 and 96] reported a rigor a 3. Article [SMP 77] which had Software engineers as it audience, suggests that logical models can be made better by using hierarchical models reported a high industrial relevance rating of 3. Surprisingly***, most of the articles which had both students and teachers as their audience also reported a high industrial relevance***. Articles such as [SMP 20, 68, 71 and 101] which had both students and teachers as their audience to develop tools for designing, teaching and sketching models in software engineering paradigms reported an industrial relevance rating of 3. The articles which had only students had reported a very low industrial relevance whereas articles which had only teachers as its audience did not have any industrial relevance. From figure 50, and the above observations, ***we can say that articles which had industrial SE practitioners as their audience had a better industrial relevance.***

- **Research Type:**

From Figure 51, we can observe that industrial relevance is proportional to rigor among the articles classified based on type of research and ***articles which had evaluations or validations in their studies reported a higher rigor and industrial relevance than other research types***. 3 of 9 articles from table 35, [SMP 22], [SMP 74], [SMP 109] which had validations in their studies reported a highest rigor of 3, while 4 articles out of 9 with high rigor such as [SMP 37], [SMP 45], [SMP 108], [SMP 111], which had evaluations in their studies had a high rigor of 3.

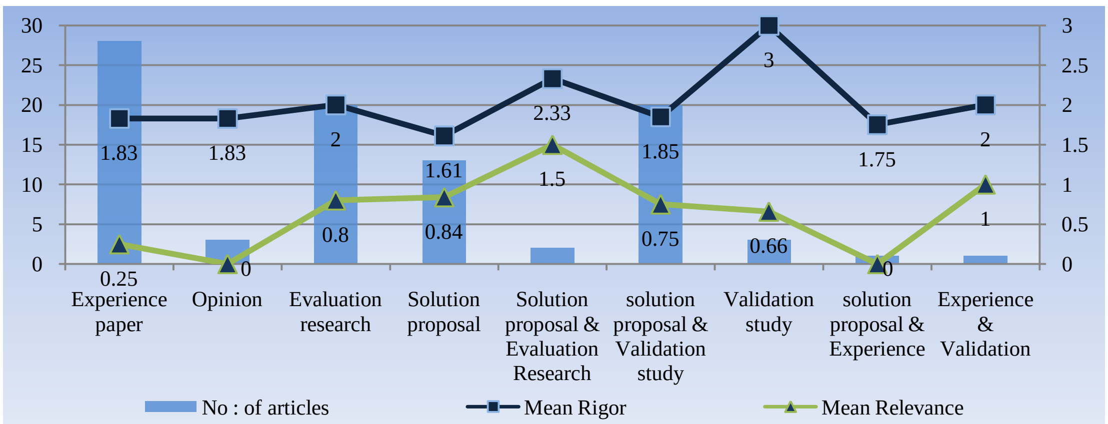


Figure 50 Rigor, Relevance & Research Type

Articles such as [SMP 77], [SMP 95], [SMP 96] which are solution proposals reported a relevance of 3. Solution proposals and validation studies such as [SMP 71], [SMP 98], [SMP 101] and solution proposal & Evaluation research studies such [SMP 20] reported a high relevance rating of 3. ***This shows that solution proposals with validated results have more relevance to the software engineering industry when compared to the others.***

- **Research method**

Articles which are based on quantitative research methods such as Surveys and Experiments had a better rigor compared to the others. Articles such as [SMP 108 & 109], which reported a high rigor rating, conducted surveys to analyze the usage adoptability of UML, as well as to measure the effect of structural complexity on understandability of UML. Articles such as [SMP 111], which reported a high rigor rating conducted experiments to know the usage of stereotype to improve the understandability of UML. Apart from surveys and experiments, case studies also recorded a moderate overall rigor around 2.

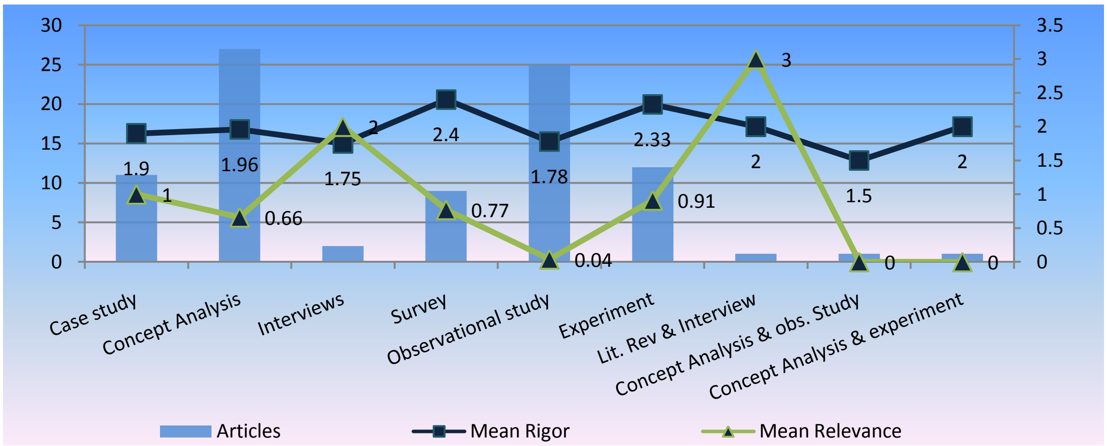


Figure 51 Rigor, Relevance and Research Method

Interviews and case studies which reported a moderate overall rigor had a high industrial relevance when compared to the others. Calico a sketching tool which reported high relevance rating used interviews as a research method for its study [SMP 101].

- **Contribution Type:**

Articles which contributed to measurement and method reported a higher rigor ratings followed by tools. Articles such as [SMP 113 & 130] which discuss about metrics for the measurement and evaluation of UML class diagrams reported a rigor rating of 3. Also, articles such as [SMP 37 & 41] which discuss how methods like UMPLE and composite sites can improve the understandability of Unified Modeling language (UML), also reported a rigor rating of 3.

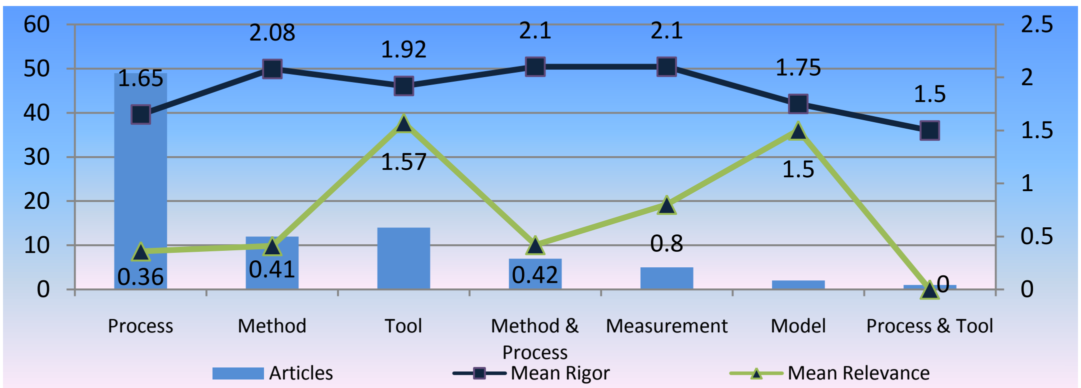


Figure 52 Rigor, Relevance and contribution type

Articles which discussed about the usage of Tools to improve the teaching of modeling in software engineering had more industrial relevance compared to the others. Also, most of the articles on tools, discussed about the usage of Interactive Whiteboards for designing and teaching modeling. Articles which discuss on tools and have industrial relevance are listed below in table 39.

Though there are articles discussing tools such as *UMLet* [SMP 5], *KNIGHT* [SMP 20], *Web based e-Learning Tool for UML class Diagrams* [SMP 58], *MinimUML* [SMP 65], *StudentUML* [SMP 86], *UMLGrader* [SMP 87], *e-Whiteboard* [SMP 95], *Pen-Based Input* [SMP 96], *Digital Pen & Paper* [SMP 97], *SUMLOW* [SMP 98], *Interactive Whiteboards* [SMP 100], *CALICO* [SMP 101],) only 10 of those articles had industrial relevance.

- ***UMLet*** [SMP 5]:

UMLet is a freely available, flyweight modeling tool based on Java which can be used to teach, share and create UML sketches. The major advantage this tool has over the others is its application size which is 5 MB [87].

- ***KNIGHT*** [SMP 20, 71]:

Knight is an electronic whiteboard tool, based on gesture based input recognition, which can be used for object oriented design. This tool has the support for collaborative design and integrates both formal and informal drawing elements [47].

- ***UML class Diagrams Tool*** [SMP 58]

This web based tool supports teaching and learning of UML class diagrams by automatically correcting the diagrams and immediately providing feedback to student on the exercises done [88].

- ***MinimUML*** [SMP 65]:

MinimUML is a tool to draw UML diagrams which has the features of error avoidance, abstract designs, code generation, exploratory learning which tools such as Violet [91], UMLet [87], Dia [92], ArgoUML [93], and QuickUML [90] (these tools were considered for evaluation and comparison by the author in the article) do not support [89].

- ***StudentUML*** [SMP 86]:

StudentUML is an educational tool which aids the learning, construction and development of consistent and valid UML diagrams. It has limited and unnecessary features yet effective to meet the needs of students [94].

ID	Tool	Relevance
[SMP 5]	UMLet	0
[SMP 20, 71]	✓ **KNIGHT**	**3,3**
[SMP 58]	UML class Diagrams Tool	0
[SMP 65]	MinimUML	1
[SMP 86]	StudentUML	1
[SMP 87]	UMLGrader	0
[SMP 95, 98]	✓ **SUMLOW**	**3,3**
[SMP 96]	✓ **Pen-Based Input**	**3**
[SMP 97]	Digital Pen & Paper	2
[SMP 100]	Interactive Whiteboards	1
[SMP 101]	✓ **CALICO**	**3**

Table 39 Tools with Industrial relevance

➢ ***UMLGrader*** [SMP 87]:
UMLGrader is a tool which provides automated feedback to the students on UML class diagrams. When a student draws a class diagram, this tool compares it with a standard solution and provides feedback on errors and missing elements, thus evaluating the diagrams [95].

➢ ***SUMLOW*** [SMP 95, 98]:
SUMLOW is a sketch based UML design tool using e-whiteboard. It is similar to the KNIGHT tool [47] which only offers gesture recognition, and the text has to be entered using a keyboard, whereas SUMLOW offers sketch based recognition, also preserving the hand drawn shapes [63, 65] .

➢ ***Pen-Based Input*** [SMP 96]:
A prototype for pen based input systems designed based on KNIGHT [47] and SUMLOW [63, 65], supports modelling of UML activity diagrams and textual annotations of components [96].

➢ ***Digital Pen & Paper*** [SMP 97]:
The possible improvements to sketch based UML diagram tools by using pen and paper technologies. The authors also discuss the usage of UML sketch books and UML paper palettes [64].

➢ ***Interactive Whiteboards*** [SMP 100]:
The possible uses of interactive whiteboard technology are discussed, in creating, learning, and understanding, modeling or designing a system representation [97].

➢ ***CALICO*** [SMP 101]:
CALICO is yet another sketching tool which makes use of interactive white boards for early stage designing. The main distinguishing feature of this tool is it does not have language barriers and offers support for informal languages and shapes [66].

Out of these 10 articles, 4 tools such as ***KNIGHT*** [47], ***SUMLOW*** [65], ***Pen - Based Input*** [64], and ***CALICO*** [66] had a high industrial relevance rating of 3.From Figure 58, we can observe that 6 out 8 articles i.e., ***75% of articles with high industrial relevance discussed about tools, this marks the importance of developing tools*** which aid teaching modeling in software engineering.

This relevance and rigor study is followed by a citation ranking analysis which is followed by a comparison of our classification with the initial classification [33].

7.2 Ranking Articles Based on citations

Citation study or ranking articles based on citation count was considered to identify the importance of the articles to the researchers whereas rigor and relevance were considered to evaluate the articles from qualitatively. This citation ranking assessment was also conducted on articles under different classes, as to know which classes or categories have more importance in the view of researchers. The articles with top 5 citation ranks are shown below in table 40.

➢ ***K. Beck & W. Cunningham et al.*** [SMP 81]:
This article introduces new techniques to teach object oriented design, called the CRC card technique. CRC stands for Class, Responsibility and collaboration. The authors suggest that this technique is beneficial to teach OOD concepts to novice programmers and helps experienced programmers to solve complicated existing designs [98].

➢ ***Brian Dobing & Jeffrey Parsons et al.*** [SMP107]:

This article reports the results of survey on how and why UML diagrams are used. Members of the Object management Group (OMG) were considered as participants for the survey. The results of the survey indicate that highest level of usage was found with USE case and Class diagrams whereas Collaboration diagrams reported the least usage among the participants. The results of the survey also indicate that the complexity of the UML is a concern, the author suggests that more emphasis must be carried out on teaching and learning UML effectively [99].

Article ID	Article Title	Number of Citations	**Rank**
[SMP 81]	A Laboratory For Teaching Object-Oriented Thinking	636	**1**
[SMP 107]	How UML IS USED	221	**2**
[SMP 20]	Tool Support for Cooperative Object-Oriented Design: Gesture Based Modeling on an Electronic Whiteboard	138	**3**
[SMP 113]	Early measures for UML class diagrams	85	**4**
[SMP 95]	An E-whiteboard Application to Support Early Design-Stage Sketching of UML Diagrams	65	**5**

Table 40 Articles with top 5 citation ranks

➢ ***Christian Heide Damm et al.*** [SMP 20]:

This article attempts to examine the tool support for software development in industry as well as academics. Based on several observations of the existing tools, KNIGHT, a new tool is developed and several evaluations were made [47]. Knight is an electronic whiteboard tool, based on gesture based input recognition, which can be used for object oriented design. This tool has the support for collaborative design and integrates both formal and informal drawing elements [47].

➢ ***Genero M et al.*** [SMP 113]:

This article discusses a newly developed and yet to be validated state of art Object oriented metrics which can be used to measure the complexity of UML class diagrams at an early design stage in the Object oriented development lifecycle [100].

➢ ***Qi Chen et al.*** [SMP 95]:

This article presents SUMLOW, an UML sketching tool that uses E-whiteboard and pen based sketching interface to aid collaborative design [63]. It is similar to the KNIGHT tool [47] which only offers gesture recognition, and the text has to be entered using a keyboard, whereas SUMLOW offers sketch based recognition, also preserving the hand drawn shapes [63, 65].

7.2.1 Citation Rank & Research Activity

Article [SMP 81], published in 1989, which introduces techniques such as CRC cards to teach modeling in software engineering to novices and the experienced, reported highest number of citations. This affirms that though it was published nearly two decades earlier, it is not obsolete and its importance has not diminished over the years. Figure 54 shows the citation ranks and the publication years.

Five years, 2001 to 2006 reported a better citation rank compared to others, with the year 2001 having more number of citation and better overall rank while the year 2005 reported the highest number of publications.

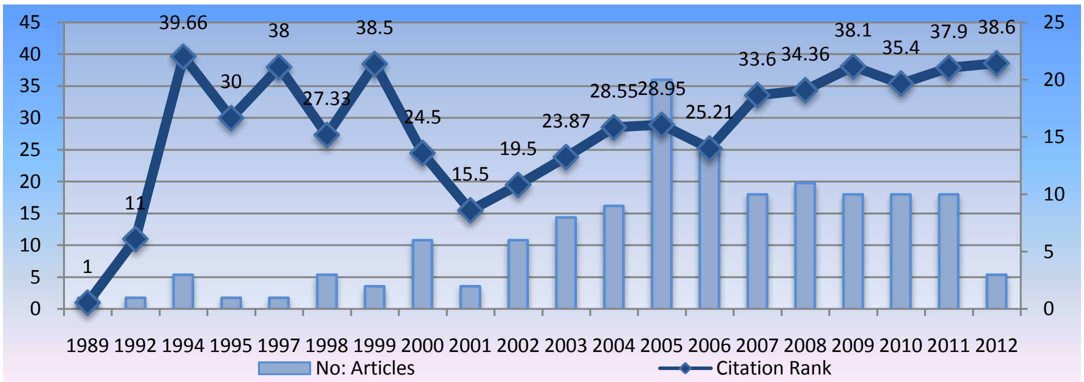


Figure 53 citation Rank and Publication years

Journals reported a better citation rank, followed by conferences and workshops. Journals such as ***ACM communications [103], L'object [77], IJCSCL [102]*** had a better citation ranks compared to the others. Conferences such as ***OOPSLA [74], MODELS [37]***, had a better citation rank among conferences.

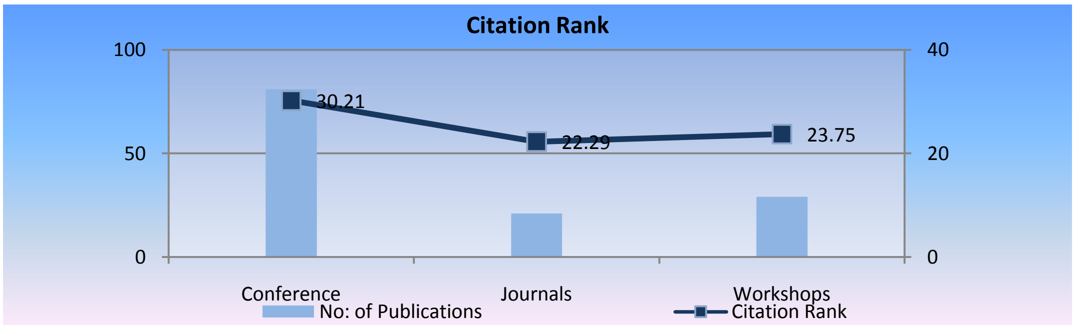


Figure 54 citation Rank and Publication type

Similarly, workshops such as ***Dastguhl Seminar on Soft Vis conference [100]*** reported a better citation rank among the other workshops. Mean citation ranks of conferences, journals and workshops are shown in figure 55.

7.2.2 Citation Rank & Manual Classification

The class of articles under Diagrams reported a better citation rank compared to the other classes. ***The reason for this is that most of the articles which discussed about diagrams are tools, which had better citation ranks***. The average citation ranks of classes obtained through Manual classification are shown in figure 56.

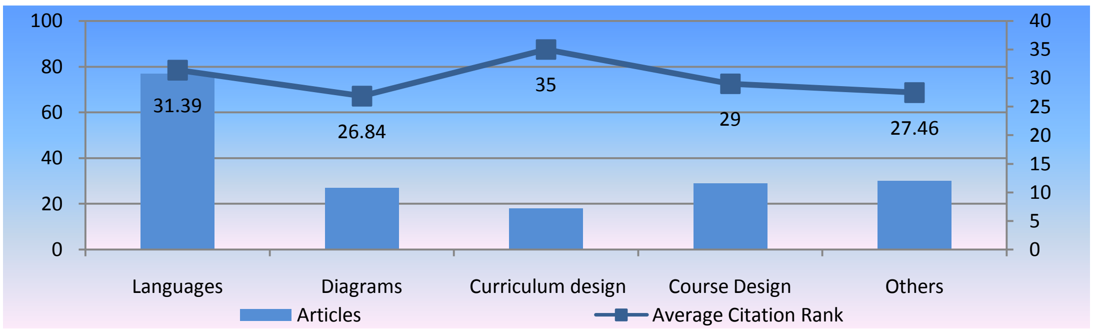


Figure 55 Citation rank and Manual classification

Articles which discuss diagrams such as [SMP 130] which suggests set of metrics to evaluate the UML class diagrams, also suggesting changes to UML class diagram notations to improve the readability based on two dimensions [104]. Articles [SMP 107, 113, 95] which had a better citation rank, discussed earlier in section7.2, discuss about the usage of diagrams to teach modeling in software engineering.

7.2.3 Citation Rank & Classification Facets

Classification facets such as Research type, audience type, study setting, research method, and contribution type which were considered earlier for rigor and relevance study, again were considered for the citation study.

- **Research Type:**

Articles with highest citations are observed from the solution proposal under solution proposal & evaluation research. Articles such as ***[SMP 20]*** which discusses the development of KNIGHT [47] an electronic white board tool discusses the solution to existing problems and evaluates it. Figure 57, shows research types and their citation ranks.

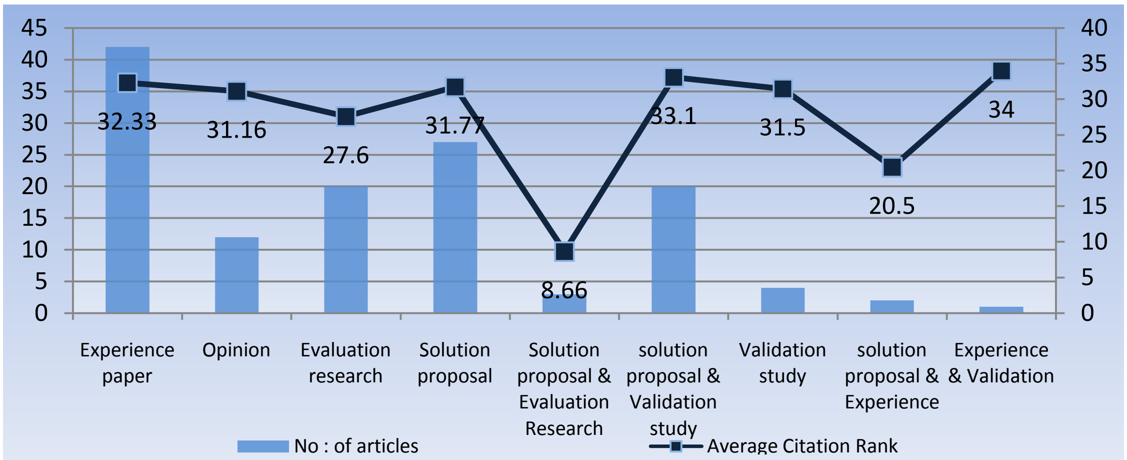


Figure 56 Citation Rank and Research type

Also, articles such as ***[SMP 113]*** proposes a solution to existing problems and develops new object oriented metrics which are developed based on author's previous experiences using these metrics.

- **Research Method:**

The group of articles which had experiments as their research method had a better citation rank compared with the others. We can observe from figure 58, that articles grouped under the category concept analysis and experiment had a mean citation rank of 19 whereas articles which had used only experiments as a research method had a mean citation rank of 27.5

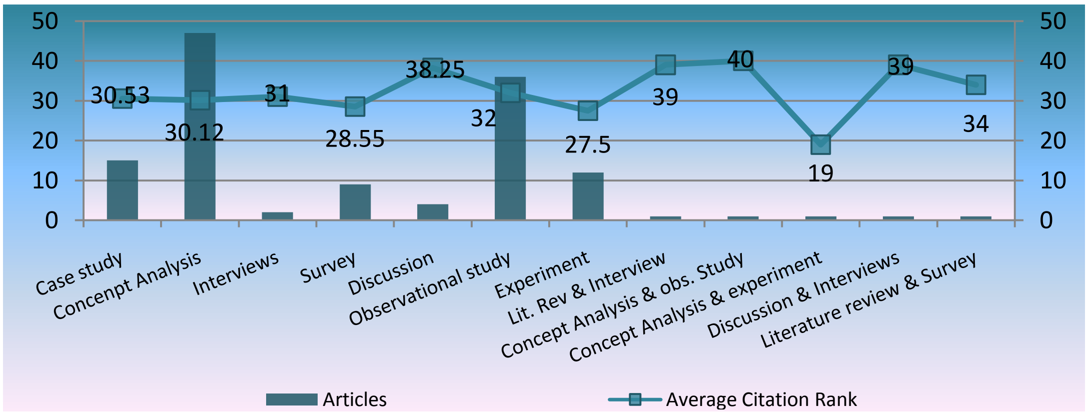


Figure 57 Citation Rank and Research Method

Article [SMP 111] is one such example which reports the results of a family of experiments conducted in an academic setting to assess the effect of structural complexity on the understandability of UML state chart diagrams [55].

- **Study setting:**

  Articles from the industry had a better citation rank compared to the articles from the academia, can be seen in figure 59. Articles such as [SMP 20, 95 and 113], discuss tools to teach, design, create models, developed in an industrial setting have a high citation rank compared to the others.

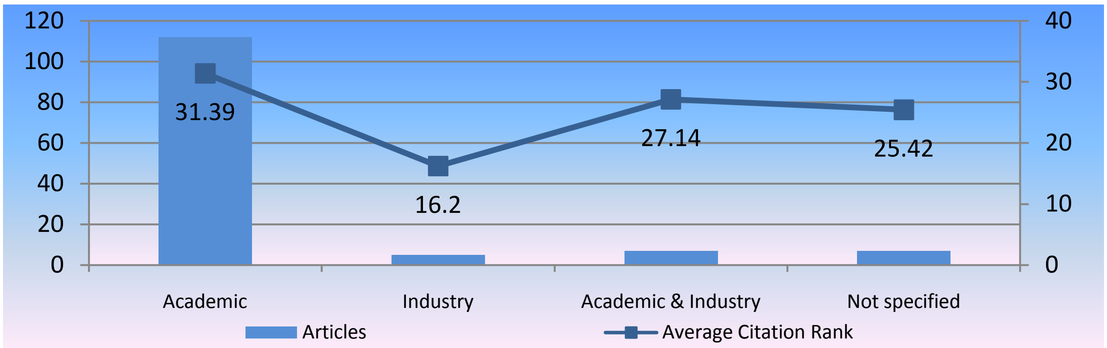


Figure 58 Citation Rank and Study setting

- **Audience Type:**

  From figure 60, we can observe that category which includes all the audience such as, teachers, students, and professionals from the industry, has a better citation rank over the others. But, we cannot generalize and make statement that articles which had all the above said audience in their studies had a better citation rank as there is only one article in that category, [SMP 75] which discusses how effectively graduating students can design.

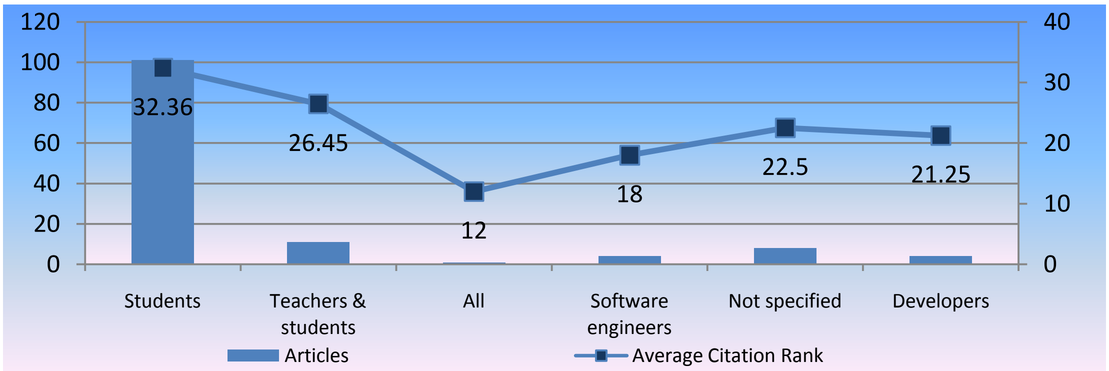


Figure 59 Citation rank and Audience Type

But, we can observe that, the right part of the graph which included professionals from industry such as software engineers and developers had a better citation rank than the audience from academia. Also, articles such as [SMP 81, 113 and 95] which had high citation ranks have audience from the industry. ***Hence, we can say that articles which considered audience from the software engineering Industry had a better citation rank over the others.***

- **Contribution type:**

  Articles which contributed to Measurements, Tools & Methods had a better mean citation rank compared to the others. Articles discussed earlier such as [SMP 130], which proposes metrics to evaluate UML class diagrams, had a better citation rank among articles classified under category Measurements. Similarly, articles [SMP 20 & 95] which discussed on tools which can use in modeling paradigms such SUMLOW & KNIGHT had better citation rank among the articles classified under this category. The mean citation ranks of categories under contribution type are shown in figure 61.

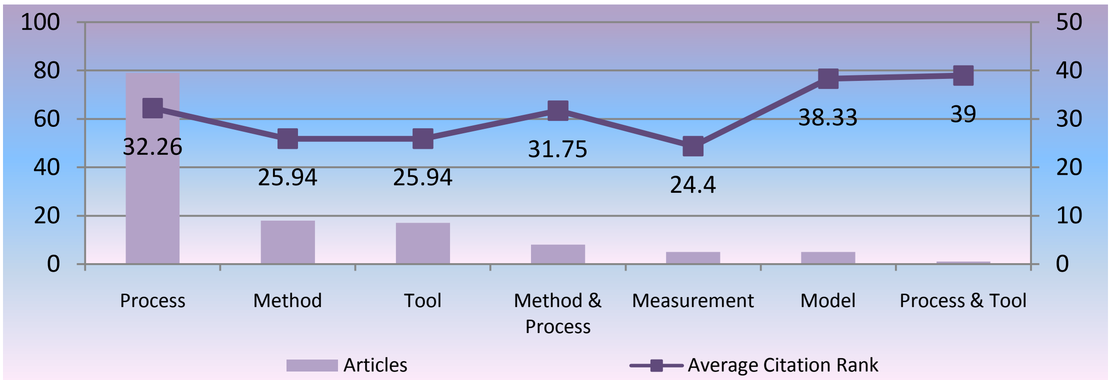


Figure 60 Citation rank and Contribution Type

Also, articles classified under the category Methods, such as [SMP 81], which discussed about the usage CRC cards to teach object oriented design reported the highest number of citations. ***Though there are a large number of articles published contributing to the process of teaching modeling, they reported a low overall citation rank.***
The following section discusses the overall ranking of the articles based on the citation rank rigor and industrial relevance.

7.3 Overall Ranking of articles

An overall ranking of the articles was calculated to assess the importance and identify highly rated articles based on rigor relevance and citation ranking. To compute this ranking we have used the following formula.

$$\boldsymbol{Overall\ Rating\ Ro = Ri + Re + (Cn * 0.05)}$$

Where, R_i is the rigor rating of that article,
R_e is the industrial relevance,
C_n is the number of citations.

Here, the values of rigor are in the range of 0-3, and the values of industrial relevance are in the range of 0-4, whereas the values of citations are in the range of 0-636, to normalize the values of citations between 3 and 4, the number of citations of articles were multiplied with a normalization factor of 0.05 (Refer Appendix 12.21 for the calculation of overall rating of each article). The articles with top 10 overall ranks are shown below in table 41.

Article ID	Description	Overall Rank
C. Damm et al. [SMP 20]	This article attempts to examine the tool support for software development in industry as well as academics. Based on several observations of the existing tools, KNIGHT, a new tool is developed and several evaluations were made [47].	**1**
C. Damm & K. Hansen et al. [SMP 71]	This article is a ***companion paper*** of [SMP 20] [47]. Much emphasis is made on the design and software architecture of the KNIGHT tool rather than its evaluations [61].	**2**
Qi Chen et al. [SMP 98]	This article (a companion article to SUMLOW [SMP 95]) discusses the architecture design and implementation of SUMLOW tool in a more detailed way than its predecessor [63]. Also, more number of evaluators for the tool was considered including people from both academia and industry [65].	**3**

Qi Chen et al. [SMP 95]	This article presents SUMLOW, an UML sketching tool that uses E-whiteboard and pen based sketching interface to aid collaborative design [63].	**4**
K. Beck & W. Cunningham et al. [SMP 81]	This article introduces new techniques to teach object oriented design, called the CRC card technique. CRC stands for Class, Responsibility and collaboration. The authors suggest that this technique is beneficial to teach OOD concepts to novice programmers and helps experienced programmers to solve complicated existing designs [98].	**5**
J. Whittle & J. Hutchinson et al. [SMP 68]	This article emphasizes on the mismatches between the industrial practice and teaching model driven software development. This study highlights the good practices and bad practices from the experiences collected from 17 companies [60].	**6**
P. V. Reddy et al. [SMP 77]	This article focuses on improving the logical models in UML. The author based on his industrial experience suggests that logical models can be made better by using hierarchical models, relational driven design over behavioral design and avoiding ambiguous interpretation of classes [62].	**7**
M. Nicolas & B. Alex et al. [SMP 101]	This article introduces Calico a sketching tool which aids software designed in editing, finding and producing software design at an early stage. This tool works using an electronic blackboard [66].	**8**
A.F. Donaldson & A. Williamson et al. [SMP 96]	This article presents a prototype for pen based input systems designed based on KNIGHT [47] and SUMLOW [63, 65], supports modeling of UML activity diagrams and textual annotations of components [96].	**9**
L. Kuzniarz et al. [SMP111]	This article investigates the effect of structural complexity on the understandability of UML state chart diagrams [55]. A family of experiments was conducted in an academic setting to asses this influence.	**10**

Table 41 Top 10 articles with overall ranking

Seven out of ten articles from the table 41 are tools. This marks the importance of tools to teaching modeling in software engineering. From the above table 41, we can observe that most of the articles [SMP 20, 71, 95, 96, 98, 101, and 111] with high overall ranking were articles with and industrial relevance rating of 3. Only two articles [SMP 20 and 77], with a rigor rating of 3 and one article, [SMP 81] from citations got a place in the top 10 articles with high overall ranking.

The following chapter presents the analysis of the results followed by discussion and conclusion.

8 ANALYSIS

In this chapter, a thematic analysis is carried out on the results to analyze the importance of classes and identify the research gaps in this area. Thematic analysis described in chapter 4 was reused for the systematic mapping study. A thematic study was used as our results are already classified, and need to be converted into themes to be analyzed suit this research than other analysis methods such as narrative synthesis [42] or content analysis [44]. An apriori list [24, 25] of codes was considered from the categories obtained from classification (using semi manual & classification facets). These codes were translated into themes which were again translated to higher order themes to give an overview of the research area. The overview of this analysis from classes to research gaps is shown in Figure 62. The translation of codes to themes is given in Appendix 12.22.

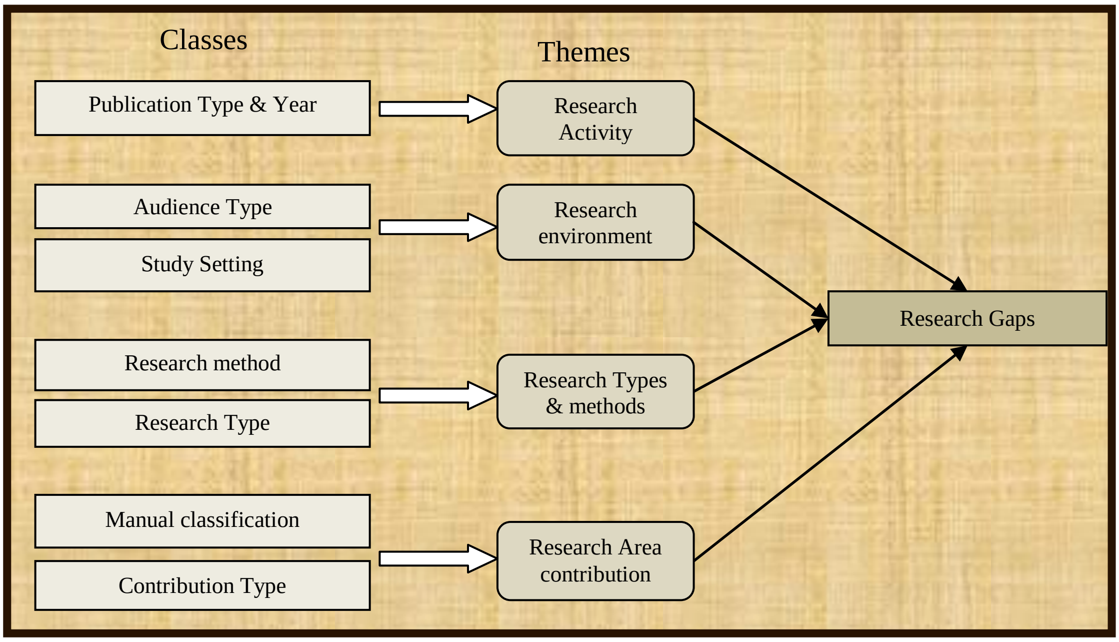


Figure 61 Inferences from the analysis of classes using thematic analysis

To analyze the importance of the identified classes, the highest and lowest ratings of the classes observed under number of publications, rigor, industrial relevance, and citation ranking are shown in table 42.

8.1.1 Research Activity:

Results obtained from systematic mapping indicate that there is an increase in the research activity on teaching modeling in software engineering in the last decade. From the table 43, we can observe that though a majority of the publications is from conferences, they had the lowest mean rigor. This shows that most of the conferences in this area do not contribute to the quality aspect of the publications.

8.1.2 Research environment:

Research environment consists of the type of the audience involved and the study setting. The analysis of these classes is discussed below.

- **Audience type:**

Articles whose ***audiences are from the industry had a relatively high rigor industrial relevance and citation rank*** when compared to those articles whose audiences are from the academia. This suggests that more importance is given to articles which had its audience from the industry.

- **Study Setting:**

Though the articles with **industrial study setting are less in number,** ***they had more number of citations, industrial relevance and rigor*** when compared with the publication from academic study setting. This marks the ***importance research publications carried out in an industrial setting*** in the area.

	Number of Publications	***Rigor***	***Citation Rank***	***Relevance***
Audience Type	Students	Software Engineers	All	Developers
	All	Developers	Students	Students
Study Setting	Academic	Industry		
	Industry	Not specified	Academic	Academic
Research Method	Concept Analysis	Survey	*Concept Analysis & Experiment	*Literature Reviews & Interviews
	Combinations of research methods	*Concept Analysis & Experiment	*Concept Analysis & Observational study	*Concept Analysis & Observational study, *Concept Analysis & Experiment, Experiment
Research Type	Experience Paper	Validation study	*Solution Proposal & Evaluation Research	
	*Experience Paper & validation study	*Solution Proposal & Experience paper	*Experience paper & Validation Study	Opinion paper, Solution Proposal & Validation Study
Contribution Type	Process	Measurement		Tools
	*Process & Tool			
Manual Classification	Languages	Diagrams		Language
	Curriculum	Course		Course, Curriculum
Publication Type	Conferences	Journals		
	Journals	Conferences	Workshops	Workshops

Highest rating   Least rating

Table 42 High's and low's of rigor, relevance & citation rank with respect to classes

8.1.3 Research Type & Method:

This theme consists of the type of the research conducted and the type of research method used to conduct the study.

- **Research Type:**

  Articles which proposed solutions to the existing problems and showed validated results by either validation or evaluation research , though are less in number had a overall high rigor, relevance and citation ranking which shows the importance of solution proposals in the area of teaching modeling.

- **Research Method:**

Though most of the articles used concept analysis as a research method, they did not have empirical findings which resulted in a poor rigor, industrial relevance and citation ranking. Articles with quantitative research methods such as interviews, surveys and experiments had a better overall citation ranking, rigor and industrial relevance compared to the other articles. This suggests the need for usage of quantitative research methods in this area of teaching modeling.

8.1.4 Research Area Contributions:

The classes obtained from manual classification more or the less discuss about the type of contributions such as languages, diagrams, course and curriculum design. This classification is joined along with contribution type facet, to analyze the results which contribute to the area of teaching modeling.

- **Manual Classification:**

Most of the publications with high rigor, industrial relevance and citation ranking focused on teaching languages and UML diagrams, left a vacuum in the areas of course design and curriculum design. There are no articles on curriculum design and course design to teach modeling in and industrial environment and also the articles which discuss curriculum and course design in an industrial setting had a low rigor and citation ranking.

- **Contribution type:**

Articles which contributed to measurement, tools and methods had a high rigor, industrial relevance and citations. Almost all of the articles with high industrial relevance are tools. Though the number of publication on articles which contributed to the process of teaching is high they do not have any industrial relevance. ***Hence, more focus should be made to improve the process of teaching modeling in an industrial setting***.

8.1.5 Inference

Analyzing the citation ranking, rigor and industrial relevance suggests that a researcher looking for articles with high rigor and citations and industrial relevance needs to be confined to journals. Also, we can observe that though articles which are carried out in industrial setting with audience from the industry have more importance, they are very less in number which suggests that more research should be emphasized on developing practices to teach modeling in an industrial setting.

Analyzing the Manual classification and contribution type, articles which discussed about the design of course and curriculum had a low number of publications, rigor, citation rank and Industrial relevance. This shows that there lies a research gap and more emphasis has to be made on the design of course and curriculum for teaching modeling in software engineering. Also, articles which contribute to measurements or metrics to assess the students performance though have a high citation rank and rigor, are very less in number, more attention should be put on developing metrics for measuring the software modeling abilities of students.

The discussion and conclusions of this research are presented in the following chapters.

9 DISCUSSION

The analysis and results obtained from systematic mapping indicate that there is an increase in the research activity on teaching modeling in software engineering in the last decade. Journals had a better quality compared to conferences or workshops. Journals such as ***L'object*** [77] had a better citation rank and rigor, whereas ***Journal of Object Technology*** **[36]** had a better Industrial relevance and rigor compared to the other journal. Conferences contributed to a large number of research articles, ***MODELS*** [36] conference topped the list of conferences in this area with higher number of articles, average citation ranking and rigor.

Also, Most of the research publications discussed the use of languages to teach modeling using concept analysis as a research method for their articles, followed by observational studies and experiments. But, surveys and experiments had a better overall rigor, industrial relevance and citation ranking. Many research articles are aimed at students, and are carried out in academic setting which indicates a gap for research in industry setting. Through the analysis of themes we have identified several research gaps and also important articles which contributed to the area of teaching modeling in software engineering.

Table, 43 shows the articles with a rigor rating of 3, and a citation rank below 5 and an industrial relevance rating of 3. "X" represents that no article exists with a high rating in that category.

Contribution Type & Reflections	Rigor	Relevance	Citation Rank
Process	[SMP 22,45,74,108,109,117]	[SMP 68]	[SMP 107]
Tool	[SMP 20/71, 98]	[SMP 20/ 71, 95/ 98, 96, 101]	[SMP 20, 95]
Measurement	[SMP 113, 130]	X	SMP [130]
Method	[SMP 37, 40]	X	SMP [81]
Model	X	[SMP 77]	X

Table 43 Important articles and their contributions to the research area.

Apart from this, a comparison of our classification with an existing classification is presented along with discussion on the threats to validity of this study, in the following section.

9.1 Comparison with existing classification

The classification obtained from systematic mapping reflects an existing classification on ways to teach modeling in software engineering [33]. Hence, a comparison is made on the results of this study with the existing classification.

Though no classification exits based on the published literature on teaching modeling in software engineering, there exists a classification developed by L. Kuzniarz and J. Borstler [33] based on interviews and discussions with people from academia present at Educators symposium (EduSymp 2011) [17]. This classification discusses different perspectives on teaching modeling in software engineering. According to the authors, there are five perspectives to teach modeling, such as why, how, what, where and when. Table 44 shows their perceptions and the categories from the initial classification [33].

The initial classification was compared with the classifications obtained from our mapping study to observe the relationship between the state of art classifications based on surveys and state of practice classifications based on published research.

Perceptions	Definition	categories
Why	Why should modeling be included in curriculum	• Way of thinking, • problem solving, • successful research, • successful development, • being up to date, • Being competitive.
What	What to include in the modeling curriculum	• Creating models, • using models, • informal models, • formal models, • integration of models, • transformation, • code generation, • languages, tools, • best practices , • consistency
How	How modeling should be taught in software engineering	• Examples, • Exercise, • Projects, • Industrial practices, • Industry lectures, • Communication, • Presentations, • Discussions , • Teaching methods
When	In which context does the study take place such as university or job	• University, • job training etc.
Where	In which study period or semester or years of the course period should modeling be taught	• Not mentioned.

Table 44 Perceptions and categories

Though, categories chosen for our systematic study have different class names and were seen in a different perspective, there are some categories in common with the initial classification [33] such as Tools, languages, models, methods and process. Table 45 shows the comparison.

Initial Classification [33]		**Categories from our classification strategy**		**Articles found under this category**
Perspectives	**Categories**	**Matching classes or categories**	**Classification types**	**No : of articles**
What	**Models**	**Models**	Contribution type Facet	3
	Languages	**Languages**	Semi-Manual classification scheme	74
	---	**Diagrams**	Semi-Manual classification scheme	27
	Tools	**Tools**	Contribution type Facet	17
Where	**University**	**Academic**	study setting Facet	105

	Job training	**Industry**		8
When	**---**	**Course design**	Semi-Manual classification scheme	29
		Curriculum design	Semi-Manual Classification scheme	18
How	**Teaching methods**	**Process**	Contribution type Facet	79
		Metrics		5
		Methods		19

Table 45 comparison of categorization strategies

From the above table we can observe that categories under ‘what’ perspective were similar to the categories in contribution type facet. Categories under ‘where’ perspective, Universities and jobs were synonymous to the categories in study setting such Academic and industry setting. Languages category under ‘where’ perspective is similar to language class obtained from semi-manual classification scheme.

Tools, a category under ‘what’ perspective is same as tools a category in contribution type facet. The perspective ‘where’ resembles with study setting class with academic and industry setting as its categories. ‘When’, a perspective considered from the initial classification [33] resembles course and curriculum design obtained from semi-manual classification scheme. Categories in the perspective ‘how’ such as teaching methods resemble categories in contribution type such as process, metrics and methods.

The comparison of our classification with the initial classification [33] indicates that our classification presents wider view on the different ways available to teach modeling in software engineering. Apart from providing reflections on the results, we performed a qualitative evaluation of the obtained results based on rigor and industrial relevance [67].

9.2 Validity threats

As this research is a qualitative study, Construct validity internal validity threat and threat to reliability were identified as threats to this study. These identified threats were documented and strategies that were used in order to mitigate these threats are discussed.

9.2.1 Construct validity:

Construct validity refers to the extent to which the operational measures are planned for conducting the study [113]. Threats and mitigation strategies related to construction validity are discussed below:

- **Article Coverage:**

  While conducting systematic literature review & systematic mapping, there might be a threat of missing out on a few articles which are related to this study. To mitigate this threat and to ensure that all articles were covered, apart from the automated search, a manual search on electronic databases and journals and conferences related to the area of teaching modeling was carried out. To further ensure that no articles have been missed out, snowball sampling was conducted on the articles obtained from the automated and manual searches.

- **‘No suitable’ Class:**

  When classifying articles in systematic mapping, there is a chance of researcher finding no suitable class to classify a particular article. To mitigate this threat we have we have devised a class “OTHERS” in semi manual classification (semi manual classification is obtained through the process of keyword identification) to classify articles which do not fall under any of the obtained classes such as Languages, Diagrams, Curriculum design or Course Design.

9.2.2 Internal Validity threat:

Internal validity refers to the extent to which the systematic error (also known as bias) can be prevented based on the design and conduct of the study [112]. Addressing issues related to internal validity, helps in improving, the generalisability (refers to the applicability of the results outside the scope of a study) of the results [112].

- **Selection Bias:**

  Selection bias is the bias observed due to the differences between the authors with respect to the treatment of a particular article [112]. When there are two different persons working on articles there might be a chance for difference in opinions and decisions. Particularly, while conducting systematic mapping and systematic literature review, we have encountered a huge number of articles and conducting the literature review and mapping of these articles within a stipulated time of 20 weeks was a daunting task.

  Hence we divided the number of articles into two parts and conduct the literature review. To ensure that both of us had similar opinions and to assess the strength of our decisions, we calculated kappa coefficient on a random sample of 20 articles. A substantial agreement was observed, which suggests that we had similar opinions, based on this result; we carried further with our decisions.

- **Classification Bias:**

  Classification Bias is observed when there is a difference between the authors on the classification of articles in classes and categories. While, conducting the classification of articles in systematic mapping, situations might arise such as, a difference of opinion in the classification of articles between the two authors. To avoid those situations of classification bias, we both, read the article, discussed on the class or categories it should belong to and only then classified that article. This process is repeated until all the articles have been classified. After this classification is finished, we both, now independently, read the articles and their classification and discussed again if had differences and made modifications to the classifications. Thus, we have avoided classification bias from the study.

- **Attrition bias:**

  Attrition Bias (Also, known as exclusion bias) is said to be the bias observed due to the differences between the authors on the withdrawals or exclusion of articles from the study [112].While conducting a systematic literature review or mapping studies, there might be a chance for researcher bias in the inclusion and exclusion of articles. To avoid this bias, we have developed a rigorous inclusion and exclusion criteria and also documented the reasons for excluding the articles based on the criteria. (Refer sections 4.1.2, 4.2.3 & 6.2.2, 6.3.3).

  Similarly, while conducting the systematic literature review, we have excluded some articles based on quality assessment, as there were no empirical findings for those studies (Refer Appendix 12.5). Some researchers might find it interesting to include those 10 articles, including these articles shall not affect the results of SLR as they do not discuss new classifications, tools or guidelines to conduct systematic mapping. Also, we have documented the reason for the exclusion of these 10 articles to avoid the attrition bias in the study.

9.2.3 Reliability threat:

Reliability (also known as conclusion validity) refers to the ability of repeating the study and drawing same conclusions or findings [38] [41]. This is a major threat to validity while conducting systematic mapping studies [40].

- **Keyword Identification**

  While conducting systematic mapping study and choosing keywords in semantic analysis, there is a possibility of researchers not identifying the exact keywords as we identified. To mitigate this threat, we have documented the identification of keywords clearly (refer Appendix 12.13 & 12.14) and each step of classification scheme is explained properly, as to guide others researchers.

Conclusions drawn from the study and future work for this study are presented in the following chapter.

10 CONCLUSION

The goal of this research was to provide a systematic mapping on the state of published articles on teaching modeling in software engineering. There exist many ways of conducting systematic mapping studies, Hence a systematic literature review was carried out to investigate the proper way of conducting systematic mapping in software engineering and choose a method which suits our research. Through our literature review we found out that there exist no mapping guidelines which suit exactly our research. So, proper guidelines were developed in this regard. Though these guidelines were developed only to suit our research, they can also be used by researchers conducting systematic mapping in software engineering. These developed guidelines were employed to conduct systematic mapping on teaching modeling. Table 35 presents the research questions and their results.

RQ #)	Research Questions	Findings
RQ 1)	**How is systematic mapping carried out in software engineering?**	Using PICOC for keyword formulation, using automated search following, adopting one of the six guidelines and using six visualization diagrams.
RQ 1.1)	What guidelines were suggested for conduct systematic mapping in software engineering?	There exist 7 guidelines to conduct systematic mapping in software engineering such as, Petersen [2], Bailey [39], Aarskey[29], Durham's [28], Kitchenhamn[21], Jorgensen [26], Biolchini[27]. Refer section 4.3.1 for further details on these guidelines.
RQ 1.2)	What classification and categorization schemes are used to cluster the research articles?	There exists one classification scheme, six classification facets to cluster the articles. Refer section 4.3.1.
RQ 1.3)	What methods/tools are used to carry out the classification of research publications?	There exists only one tool developed by Felizardo et al [32].
RQ 2)	**Which systematic mapping guidelines are appropriate to be employed in our research context?**	New guidelines were developed combining aspects from Petersen [2], Kitchenhamn [21] and Aarskey [29]. Refer Chapter 5 for guidelines.
RQ 3)	**What research has been carried so far on teaching modeling in software engineering and how can it be classified?**	131 articles, published from 1989-2012 were considered for the study. Articles were classified using classification schemes and classification facets mentioned in section 6.2.4
RQ 3.1)	What is the state of research activity on teaching modeling in software engineering?	There was an increase in the research on teaching modeling in the past decade, with UML being an area with vast number of publications. Refer section 6.4
RQ 3.2)	What categories or groups can be identified through these publications?	Four classes were identified from the publications such as, Languages, Diagrams, Course Design and Curriculum Design. Refer section 6.3.2.1
RQ 3.3)	What are the contents of the groups identified?	Refer section 6.4 and 12.11 & 12.12 under APPENDIX, for the contents of the identified groups.
RQ 3.4)	What relations can be drawn between the identified groups?	Bubble charts were drawn to observe the relationships between the groups. Relationships were observed between the classes obtained from semi-manual

		classification scheme and classification facets. Refer section 6.4 for bubble charts.
RQ 4)	**What reflections can be made on the obtained mappings?**	A qualitative evaluation of the results was conducted, based on rigor, industrial relevance and citations ranking which resulted in the extraction of 8 processes, 4 tools, 3 methods, 2 measurement-metrics and 1 model best suited to teach modeling in software engineering. See table 43 and also, Refer Chapter 7 for the reflections.

Table 46 Summary of findings

Results of this systematic mapping study indicate that there is an increase in the research activity on teaching modeling in software engineering, with Unified modeling Language being the widely research area. Much research is emphasized on teaching modeling to students from academia which indicates a research gap in developing methods, models, tools and processes to teach modeling to students/practitioners from the industry. Also, considering the citation ranking, industrial relevance and rigor of the articles, areas such as course and curriculum development are highly neglected, suggesting the need for more research focus.

10.1 Future Work

Though we have indentified tools, process, methods, models, and measurement-metrics and evaluated them based on rigor, industrial relevance and citation ranking, this is only an investigation of the published research (state of art). Hence, a survey to know the state of practice techniques used in teaching modeling in software engineering would add as a future work to this research.

Also, no method is available for assessing the strength of classifications made in systematic mapping process. Developing a method to assess classification strength can add reliability to the process of classification. These two problems can be considered as future work succeeding this study. While conducting systematic mapping and plotting bubble charts, we have observed that there was no proper tool to draw bubble charts based on the results of systematic mapping. A proper tool should be developed for drawing bubble charts in systematic mapping.

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http://sites.computer.org/ccse/SE2004Volume.pdf

12 APPENDIX

12.1 Search Strings and Databases for SLR

Database	Search String
IEEE	**(((((“Systematic mapping” or “systematic map” or “systematic mapping study” or “systematic mapping studies” or “systematic maps”) and (“Methods” or “framework” or “model” or “practice”) or (“tools” or “tool” or “techniques”) or (“categorization” or “classification” or “grouping”) or (“guidelines” or “rules”)))) AND "software engineering")**
ACM	**(("systematic mapping" or "systematic map" or "systematic mapping study" or "systematic mapping studies") and software engineering)**
SCOPUS	**("Systematic mapping" OR "systematic map" OR "systematic mapping study" OR "systematic mapping studies" OR "systematic maps") AND ("software engineering") OR (model OR method OR approach OR tools ORtool OR techniques OR framework OR practice OR classification OR categorization OR process OR guidelines OR rules OR strategy OR way))**
INSPEC / COMPENDEX (Engineering village)	**((((Systematic mapping or systematic map or systematic mapping study or systematic mapping studies or systematic maps) WN All fields) AND (((Methods or framework or model or practice) or (tools or tool or techniques) or (categorization or classification or grouping) or (guidelines or rules)) WN All fields)) AND ((software engineering) WN All fields))**

Table 47 Search Strings for SLR

12.2 Search Strings and databases for SMP

Database	Search string
IEEE	((teaching modeling) AND (software engineering))
ACM	(teaching modeling)
SCOPUS	ALL(teaching modeling AND software engineering)
INSPEC &COMPENDEX (Engineering village)	(((teaching modeling) WN All fields) AND ((software engineering) WN All fields))

Table 48 Search string for systematic mapping process

12.3 Snowball sampling for SLR and SMP

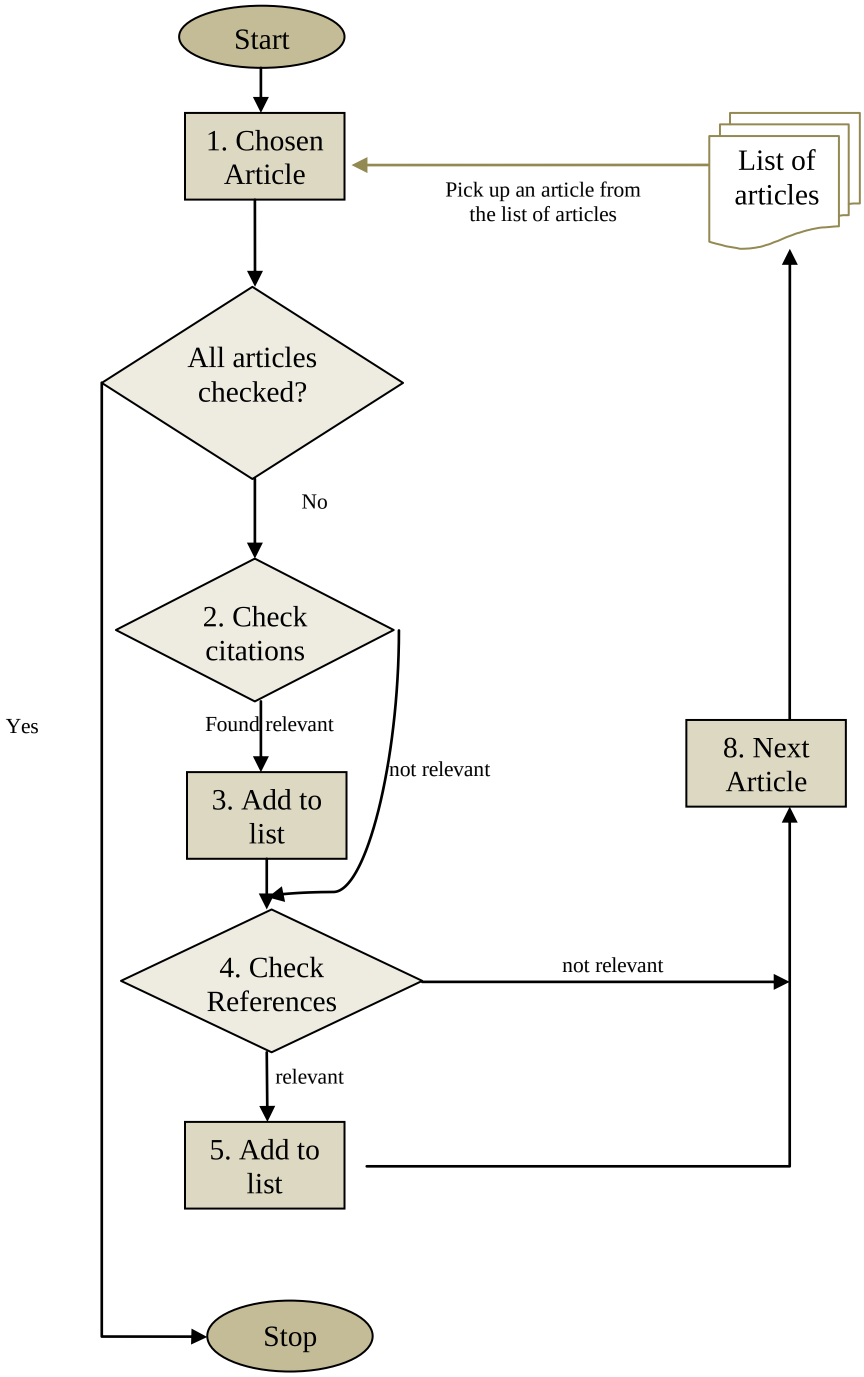

Figure 62 Snowball sampling process for SLR and SM

12.4 SLR Selected studies before Quality assesment

SID	Article
~[SLR-1]	Afzal, W.; Torkar, R.; Feldt, R.; , *"A systematic mapping study on non-functional search-based software testing," , in SEKE 2008. The 20th International Conference on Software Engineering & Knowledge Engineering, 1-3 July 2008. 2008. Skokie, IL, USA: Knowledge Systems Institute Graduate School.*
~[SLR-2]	Antonio, E.A.; Ferrari, F.C.; FerrazFabbri, S.C.P.; , "A Systematic Mapping of Architectures for Embedded Software," *Critical Embedded Systems (CBSEC), 2012 Second Brazilian Conference on , vol., no., pp.18-23, 20-25 May 2012,doi: 10.1109/CBSEC.2012.22.*
~[SLR-3]	Bailey, J.; Budgen, D.; Turner, M.; Kitchenham, B.; Brereton, P.; Linkman, S.; , "Evidence relating to Object-Oriented software design: A survey," *Empirical Software Engineering and Measurement, 2007. ESEM 2007. First International Symposium on , vol., no., pp.482-484, 20-21 Sept. 2007,doi: 10.1109/ESEM.2007.58.*
~[SLR-4]	Acuna, Silvia T.; Castro, John W.; Dieste, Oscar; Juristo, Natalia; , "A systematic mapping study on the open source software development process," *Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.42-46, 14-15 May 2012,doi: 10.1049/ic.2012.0005.*
~[SLR-5]	Arshad, Ali; Usman, Muhammad; , "Security at software architecture level: A systematic mapping study," *Evaluation & Assessment in Software Engineering (EASE 2011), 15th Annual Conference on , vol., no., pp.164-168, 11-12 April 2011,doi: 10.1049/ic.2011.0020.*
~[SLR-6]	Barmi, Z.A.; Ebrahimi, A.H.; Feldt, R.; , "Alignment of Requirements Specification and Testing: A Systematic Mapping Study," *Software Testing, Verification and Validation Workshops (ICSTW), 2011 IEEE Fourth International Conference on , vol., no., pp.476-485, 21-25 March 2011,doi: 10.1109/ICSTW.2011.58.*
~[SLR-7]	Barney, S.;et al.; , "Software quality trade-offs: A systematic map*," in Information and Software Technology, 2012. 54(7): p. 651-662.*
~[SLR-8]	Barreiros, E.; Almeida, A.; Saraiva, J.; Soares, S.; , "A Systematic Mapping Study on Software Engineering Testbeds," *Empirical Software Engineering and Measurement (ESEM), 2011 International Symposium on , vol., no., pp.107-116, 22-23 Sept. 2011,doi: 10.1109/ESEM.2011.19.*
~[SLR-9]	*Bastos, Jonatas Ferreira; da MotaSilveiraNeto, Paulo Anselmo; de Almeida, Eduardo Santana; de LemosMeira, Silvio Romero; , "Adopting software product lines: A systematic mapping study," Evaluation & Assessment in Software Engineering (EASE 2011), 15th Annual Conference on , vol., no., pp.11-20, 11-12 April 2011 doi: 10.1049/ic.2011.0002.*
~[SLR-10]	Catal, C.; Mishra, D. ; , "Test case prioritization: a systematic mapping study," *Software Quality Journal, 2012: p. 1-34.*
~[SLR-11]	Condori-Fernandez, N.; Daneva, M.; Sikkel, K.; Wieringa, R.; Dieste, O.; Pastor, O.; , "A systematic mapping study on empirical evaluation of software requirements specifications techniques," *Empirical Software Engineering and Measurement, 2009. ESEM 3rd International Symposium on , vol., no., pp.502-505, 15-16 Oct. 2009,doi: 10.1109/ESEM.2009.5314232.*
~[SLR-12]	Cruzes, D.S.; Dyba, T. ; , "Research Synthesis in Software Engineering: A tertiary Study," *Information and software Technology,2011, 53(5):440-445.*
~[SLR-13]	da MotaSilveiraNeto, P. A. : I. d. Carmo Machado, ; et al. "A systematic mapping study of software product lines testing," *Information and software Technology,2011, 53(5):407-423.*
~[SLR-14]	Da Silva, F.Q.B.;, et al.; , "Six years of systematic literature reviews in software engineering: An updated tertiary study*," Information and Software Technology, 2011. 53(9): p. 899-913.*
~[SLR-15]	da Silva, F.Q.B.; Suassuna, M.; Lopes, R.F.; Gouveia, T.B.; Franca, A.C.A.; de Oliveira, J.P.N.; de Oliveira, L.F.M.; Santos, A.L.M.; , "Replication of Empirical Studies in Software Engineering: Preliminary Findings from a Systematic Mapping Study," *Replication in Empirical Software Engineering Research (RESER), 2011 Second International Workshop , vol., no., pp.61-70, 21-21*
~[SLR-16]	Freitas da Silva, I. ; , "Agile Software Product Lines: a Systematic Mapping Study," *Software Practice and Experience, Article first published online: 3 May 2011.*
~[SLR-17]	Durelli, V.H.S.; Araujo, R.F.; Silva, M.A.G.; Oliveira, R.A.P.; Maldonado, J.C.; Delamaro, M.E.; , "What a Long, Strange Trip It's Been: Past, Present, and Future Perspectives on Software Testing Research,*" Software Engineering (SBES), 2011 25th Brazilian Symposium on , vol., no., pp.30-39, 28-30*

	Sept. 2011, doi: 10.1109/SBES.2011.17.
~[SLR-18]	Elberzhager, F.; Münch, J.; V.T.N. Nha ; , "A systematic mapping study on the combination of static and dynamic quality assurance techniques*," Information and Software Technology, 2012. 54(1): p. 1-15.*
~[SLR-19]	Elberzhager, F. ; et al.; , "Reducing test effort: A systematic mapping study on existing approaches,"*Information and Software Technology, 2012. 54(10): p. 1092-1106.*
~[SLR-20]	Engstrom, E. ;Runeson, P. ; , "Software product line testing – A systematic mapping study," *Information and Software Technology, 2011. 54(1): p. 2-13.*
~[SLR-21]	Fauzi, S.S.M.; Bannerman, P.L.; Staples, M.; , "Software Configuration Management in Global Software Development: A Systematic Map," *Software Engineering Conference (APSEC), 2010 17th Asia Pacific , vol., no., pp.404-413, Nov. 30 2010-Dec. 3 2010,doi: 10.1109/APSEC.2010.53.*
~[SLR-22]	Feitosa, D.; et al.; , "Software Engineering in the Embedded Software and Mobile Robot Software Development: A Systematic Mapping," *in 22nd International Conference on Software Engineering & Knowledge Engineering (SEKE 2010), 1-3 July 2010. 2010. Skokie, IL, USA: Knowledge Systems Institute Graduate School.*
~[SLR-23]	Felizardo, K.R.; et al.; ,"A systematic mapping on the use of visual data mining to support the conduct of systematic literature reviews," *Journal of Software, 2012. 7(2): p. 450-461.*
~[SLR-24]	Fernandez, A.; E. Insfran,; S. Abrahão,;, "Usability evaluation methods for the web: A systematic mapping study,"*Information and Software Technology, 2011. 53(8): p. 789-817.*
~[SLR-25]	Jalali, S.; Wohlin, C.; , "Agile Practices in Global Software Engineering - A Systematic Map," *Global Software Engineering (ICGSE), 2010 5th IEEE International Conference on , vol., no., pp.45-54, 23-26 Aug. 2010, doi: 10.1109/ICGSE.2010.14.*
~[SLR-26]	João, Lemos, ; Carina, A. ; Leticia, D. ; Genaina, N.R.;, " A systematic mapping study on creativity in requirements engineering," *In* Proceedings of the 27th Annual ACM Symposium on Applied Computing *(SAC '12)2012. ACM, New York, NY, USA, 1083-1088. DOI=10.1145/2245276.2231945.*
~[SLR-27]	Kitchenham, B.; , "What's up with software metrics? - A preliminary mapping study,"*J. Syst. Softw., 2010.* ***83****(1): p. 37-51.*
~[SLR-28]	Kitchenham, B.; P. Brereton,; D. Budgen,; , "The Educational Value of Mapping Studies of Software Engineering Literature," *in Proceedings of the 32nd ACM/IEEE International Conference on Software Engineering - Volume 12010, ACM: Cape Town, South Africa. p. 589-598.*
~[SLR-29]	Kitchenham, B.; P. Brereton,; D. Budgen,; , "Mapping study completeness and reliability - a case study," *in Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on. 2012.*
~[SLR-30]	Kitchenham, B.A.; D. Budgen,; O.P. Brereton,; , "The value of mapping studies: a participantobserver case study," *in Proceedings of the 14th international conference on Evaluation and Assessment in Software Engineering2010, British Computer Society: UK. p. 25-33.*
~[SLR-31]	Kitchenham, B.A.; D. Budgen,; O. Pearl Brereton,; , "Using mapping studies as the basis for further research - A participant-observer case study,"*Information and Software Technology, 2011.* ***53****(6): p. 638-651.*
~[SLR-32]	Kusumo, Dana S.; Staples, Mark; Zhu, Liming; He Zhang; Jeffery, Ross; , "Risks of off-the-shelf-based software acquisition and development: A systematic mapping study and a survey," *Evaluation & Assessment in Software Engineering (EASE 2012), vol., no., pp.233-242, 14-15May 2012,*
~[SLR-33]	Laguna, M.A.; Y. Crespo,; , "A systematic mapping study on software product line evolution: From legacy system reengineering to product line refactoring," *Science of Computer Programming, 2012.*
~[SLR-34]	Maglyas, A.; Nikula, U.; Smolander, K.; , "What do we know about software product management? - a systematic mapping study," *Software Product Management (IWSPM), 2011 Fifth International Workshop on , vol., no., pp.26-35, 30-30 Aug. 2011,doi: 10.1109/IWSPM.2011.6046201.*
~[SLR-35]	Mohebzada, J.G.; Ruhe, G.; Eberlein, A.; , "Systematic mapping of recommendation systems for requirements engineering," *Software and System Process (ICSSP), 2012 International Conference on , vol., no., pp.200-209, 2-3 June 2012,doi: 10.1109/ICSSP.2012.6225965.*
~[SLR-36]	Mujtaba, S.; Petersen, K.; Feldt, R.; Mattsson, M.; , " Software Product Line Variability: A Systematic Mapping Study," *In: 15th Asia-Pacific Software Engineering Conference (APSEC 2008).*
~[SLR-37]	Elisa, Yumi, N.; Daniel F. ; Katia, R.F.; , " Using systematic mapping to explore software architecture knowledge," *In* Proceedings of the 2010 ICSE Workshop on Sharing and Reusing Architectural Knowledge *(SHARK '10). ACM, New York, NY, USA, 29-36.*

~[SLR-38]	Petersen, K.; , “Measuring and predicting software productivity: A systematic map and review,”*Information and Software Technology 53 (2011) 317–343.*
~[SLR-39]	Petersen, K.; N.B. Ali,; , “Identifying Strategies for Study Selection in Systematic Reviews and Maps,” *in Empirical Software Engineering and Measurement (ESEM), 2011 International Symposium on. 2011.*
~[SLR-40]	Petersen, K.; et al.; , “Systematic mapping studies in software engineering,” *in Proceedings of the 12th international conference on Evaluation and Assessment in Software Engineering2008, British Computer Society: Italy. p. 68-77.*
~[SLR-41]	Portillo-Rodríguez, J. ; et al.; , “Tools used in Global Software Engineering: A systematic mapping review,” *Information and Software Technology, 2012. 54(7): p. 663-685.*
~[SLR-42]	Qadir, M.M.; Usman, M.; , "Software Engineering Curriculum: A systematic mapping study," *Software Engineering (MySEC), 2011 5th Malaysian Conference in , vol., no., pp.269-274, 13-14 Dec. 2011*
~[SLR-43]	Shippey, Thomas; Bowes, David; Chrisianson, Bruce; Hall, Tracy; , "A mapping study of software code cloning," *Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.274-278, 14-15 May 2012,doi: 10.1049/ic.2012.0035.*
~[SLR-44]	Da Silva, I.F.; et al.; , “ Agile software product lines: A systematic mapping study,” *in Software - Practice and Experience, 2011. 41(8): p. 899-920.*
~[SLR-45]	Steinmacher, I. ; A.P. Chaves,; M.A. Gerosa,; , “ Awareness Support in Distributed Software Development: A Systematic Review and Mapping of the Literature,” *Computer Supported Cooperative Work: CSCW: An International Journal, 2012: p. 1-46.*
~[SLR-46]	Wendler, R.; , “The maturity of maturity model research: A systematic mapping study,” *Information and Software Technology, 2012.*
~[SLR-47]	Budgen, D.; Turner, M.; Brereton, P.; Kitchenham, B.; , “Using Mapping Studies in Software Engineering,” *in Proceedings of PPIG 2008’, Lancaster University, pp. 195–204,2008.*
~[SLR-48]	M. Guessi,; L. B. R. Oliveira, ; E. Y. Nakagawa,; , "Modeling Aspect-oriented Software Systems Using UML: A Systematic Mapping," in *Proceedings of the 36 Latin American Conference of Informatics (CLEI 2010), Asuncion, Paraguay, 2010, pp. 1-14.*
~[SLR-49]	Arksey, H.; O'Malley, L.; ,“Scoping studies: towards a methodological framework,” *International Journal of Social Research Methodology, page no 19-32.The International Journal of Social Research Methodology2005*
~[SLR-50]	Silva, F.B.; M. Suassuna,; et al.; “Replication of Empirical Studies in software engineering research: a systematic mapping study,” *in Empirical Software Engineering, pg 1-57,2012.*
~[SLR-51]	Wieringa, R.; Maiden, N.; Mead, N; Rolland, C.; , “Requirements engineering paper classification and evaluation criteria:A proposal and a discussion,” *Requirements Engineering 2005; 11(1):102–7*
~[SLR-52]	Barbara K. ; O.P. Brereton,; David, B. ;, Mark, T.;, John, B.; Stephen, L.;, “Systematic literature reviews in software engineering - A systematic literature review,” *Information and Software Technology, v.51 n.1, p.7-15,* January, 2009 [doi>*10.1016/j.infsof.2008.09.009]* .
~[SLR-53]	Lobato, Luanna Lopes; do Carmo Machado, Ivan; da MotaSilveiraNeto, Paulo Anselmo; de Almeida, Eduardo Santana; de LemosMeira, Silvio Romero; , "Risk Management in software engineering: A scoping study,"*Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.243-252, 14-15 May 2012,doi: 10.1049/ic.2012.0032.*
~[SLR-54]	Milena, G.; Lucas BuenoRuas, Oliveira; Elisa Y.N.; , “Extensions of UML to Model Aspect-oriented Software Systems ,”*CLEI electronic journal volume 14 number 1 paper 3 april 2011.*
~[SLR-55]	Sharma, A.; Hellmann, T.D.; Maurer, F.; , "Testing of web services - A systematic mapping," *Services (SERVICES), 2012 IEEE Eighth World Congress on , vol., no., pp.346-352, june*
~[SLR-56]	Hellmann, T.D.; Sharma, A.; Ferreira, J.; Maurer, F.; , "Agile Testing: Past, Present, and Future -- Charting a Systematic Map of Testing in Agile Software Development," *Agile Conference (AGILE), 2012 , vol., no., pp.55-63, 13-17 Aug. 2012,doi: 10.1109/Agile.2012.8.*
~[SLR-57]	Julio Menezes, Jr. ;Cristine, G.; Hermano, M.; , “Indicators and Metrics for Risk Assessment in Software Projects : A Mapping Study,” *in proceedings of ESELAW 2012.*

Table 49 Selected studies before quality assessment

12.5 Removed articles after Quality assessment in SLR

SID	Article
~[SLR-27]	Kitchenham, B.; , "What's up with software metrics? - A preliminary mapping study,"*J. Syst. Softw., 2010.* ***83****(1): p. 37-51.*
~[SLR-28]	Kitchenham, B.; P. Brereton,; D. Budgen,; , "The Educational Value of Mapping Studies of Software Engineering Literature," *in Proceedings of the 32nd ACM/IEEE International Conference on Software Engineering - Volume 12010, ACM: Cape Town, South Africa. p. 589-598.*
~[SLR-29]	Kitchenham, B.; P. Brereton,; D. Budgen,; , "Mapping study completeness and reliability - a case study," *in Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on. 2012.*
~[SLR-30]	Kitchenham, B.A.; D. Budgen,; O.P. Brereton,; , "The value of mapping studies: a participantobserver case study," *in Proceedings of the 14th international conference on Evaluation and Assessment in Software Engineering2010, British Computer Society: UK. p. 25-33.*
~[SLR-31]	Kitchenham, B.A.; D. Budgen,; O. Pearl Brereton,; , "Using mapping studies as the basis for further research - A participant-observer case study,"*Information and Software Technology, 2011.* ***53****(6): p. 638-651.*
~[SLR-39]	Petersen, K.; N.B. Ali,; , "Identifying Strategies for Study Selection in Systematic Reviews and Maps," *in Empirical Software Engineering and Measurement (ESEM), 2011 International Symposium on. 2011.*
~[SLR-40]	Petersen, K.; et al.; , "Systematic mapping studies in software engineering," *in Proceedings of the 12th international conference on Evaluation and Assessment in Software Engineering2008, British Computer Society: Italy. p. 68-77.*
~[SLR-47]	Budgen, D.; Turner, M.; Brereton, P.; Kitchenham, B.; , "Using Mapping Studies in Software Engineering," *in Proceedings of PPIG 2008', Lancaster University, pp. 195–204,2008.*
~[SLR-49]	Arksey, H.; O'Malley, L.; ,"Scoping studies: towards a methodological framework," *International Journal of Social Research Methodology, page no 19-32.The International Journal of Social Research Methodology2005.*
~[SLR-51]	Wieringa, R.; Maiden, N.; Mead, N; Rolland, C.; , "Requirements engineering paper classification and evaluation criteria:A proposal and a discussion," *Requirements Engineering 2005; 11(1):102–107.*

Table 50 Removed articles after Quality assessment

12.6 Removed articles after full text reading

SID	Article
1	Anjum, M.; D. Budgen,; ,“A mapping study of the definitions for service oriented architecture,” *in 16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012), 14-15 May 2012. 2012. Stevenage, UK: IET.*
2	Bjrnson, F.O.; T. Dingsyr,;, “Knowledge management in software engineering: A systematic review of studied concepts,” *findings and research methods used. Information and Software Technology, 2008.* ***50****(11): p. 1055-1068.*
3	Cavalcanti, T.R.; F.Q.B.d. Silva,; , “Historical, Conceptual, and Methodological Aspects of the Publications of the Brazilian Symposium on Software Engineering: A Systematic Mapping Study,” *in Proceedings of the 2011 25th Brazilian Symposium on Software Engineering2011, IEEE Computer Society. p. 14-23.*
4	Da Silva, F.Q.B.; et al.,; , “An evidence-based model of distributed software development project management: Results from a systematic mapping study,”*Journal of Software Maintenance and Evolution, 2011.*
5	Durelli, V.H.S.; K.R. Felizardo,; M.E. Delamaro,; , “Systematic mapping study on high-level language virtual machines,” *in Virtual Machines and Intermediate Languages2010, ACM: Reno, Nevada. p. 1-6.*
6	Felizardo, K.R.; et al.,;, “An approach based on visual text mining to support categorization and classification in the systematic mapping,” *in Proceedings of the 14th international conference on Evaluation and Assessment in Software Engineering2010, British Computer Society: UK. p. 34-43.*
7	Fortaleza, L.L.; et al.,; ,“Towards a GSE international teaching network: Mapping Global Software Engineering courses,” *in Collaborative Teaching of Globally Distributed Software Development Workshop (CTGDSD), 2012. 2012.*
8	Kerzazi, N.; et al.,; ,“Mapping Knowledge into Software Process,” *in Computing in the Global Information Technology (ICCGI), 2010 Fifth International Multi-Conference on. 2010.*
9	Mufioz, L.; J.N. Mazon,; J. Trujillo,; , “ETL Process Modeling Conceptual for Data Warehouses: A Systematic Mapping Study,”*Latin America Transactions, IEEE (Revista IEEE America Latina), 2011.* ***9****(3): p. 358-363.*
10	Murugesupillai, E.; B. Mohabbati,; D. Gaevic,; , “A preliminary mapping study of approaches bridging software product lines and service-oriented architectures,” *in 15th International Software Product Line Conference, SPLC'11, August 21, 2011 - August 26, 2011. 2011. Munich, Germany: Association for Computing Machinery.*
11	Neto, P.A.d.M.S.; et al.,; , “Corrigendum: Corrigendum to: "A systematic mapping study of software product lines testing",” *Inf. Softw. Technol. 53 (5) (2011) 407-423. Inf. Softw. Technol., 2012.* ***54****(7): p. 802.*
12	Nik Daud, N.M.; W.M.N.W. Kadir,; , “Systematic mapping study of quality attributes measurement in service oriented architecture,” *in Information Science and Digital Content Technology (ICIDT), 2012 8th International Conference on. 2012.*
13	Palacios, M.; et al.,; , “Testing in Service Oriented Architectures with dynamic binding: A mapping study,”*Inf. Softw. Technol., 2011.* ***53****(3): p. 171-189.*
14	Pretorius, R.; D. Budgen,; , “A mapping study on empirical evidence related to the models and forms used in the UML,” *in 2nd International Symposium on Empirical Software Engineering and Measurement, ESEM 2008, October 9, 2008 - October 10, 2008. 2008. Kaiserslautern, Germany: Association for Computing Machinery.*
15	Saraiva, J.; et al.,; , “Aspect-oriented software maintenance metrics: A systematic mapping study,” *in Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on. 2012.*
16	Silva, F.Q.B.d.; et al.,; , “Six years of systematic literature reviews in software engineering: An updated tertiary study,” *Inf. Softw. Technol., 2011.* ***53****(9): p. 899-913.*
17	Ueda, E.T.; W.V. Ruggiero,; , “A systematic mapping on the role-permission relationship in role based access control models,”*IEEE Latin America Transactions, 2012.* ***10****(1): p. 1243-1250.*

Table 51 Removed Articles after full text reading

12.7 Articles from Snowball sampling in SLR

SID	Article
~[SLR-47]	Budgen, D.; Turner, M.; Brereton, P.; Kitchenham, B.; , "Using Mapping Studies in Software Engineering," in *Proceedings of PPIG 2008', Lancaster University, pp. 195–204,2008*
~[SLR-48]	M. Guessi,; L. B. R. Oliveira, ; E. Y. Nakagawa,; , "Modeling Aspect-oriented Software Systems Using UML: A Systematic Mapping," *in Proceedings of the 36 Latin American Conference of Informatics (CLEI 2010), Asuncion, Paraguay, 2010, pp. 1-14.*
~[SLR-49]	Arksey, H.; O'Malley, L.; , "Scoping studies: towards a methodological framework," International Journal of Social Research Methodology*, page no 19-32.*The *International Journal of Social Research Methodology2005.*
~[SLR-50]	Silva, F.B.; M. Suassuna,; et al.;, "Replication of Empirical Studies in software engineering research: a systematic mapping study," *in Empirical Software Engineering, pg 1-57,2012.*
~[SLR-51]	Wieringa, R.; Maiden, N.; Mead, N.; Rolland, C.; , "Requirements engineering paper classification and evaluation criteria:A proposal and a discussion," *Requirements Engineering 2005; 11(1):102–107.*
~[SLR-52]	Barbara K. ; O.P. Brereton,; David, B. ;, Mark, T.;, John, B.; Stephen, L.;, "Systematic literature reviews in software engineering - A systematic literature review," *Information and Software Technology, v.51 n.1, p.7-15,* January, 2009 [doi>*10.1016/j.infsof.2008.09.009]* .
~[SLR-53]	Lobato, Luanna Lopes; do Carmo Machado, Ivan; da MotaSilveiraNeto, Paulo Anselmo; de Almeida, Eduardo Santana; de LemosMeira, Silvio Romero; , "Risk Management in software engineering: A scoping study,"*Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.243-252, 14-15 May 2012,doi: 10.1049/ic.2012.0032.*
~[SLR-54]	Milena, G.; Lucas BuenoRuas, Oliveira; Elisa Y.N.; , "Extensions of UML to Model Aspect-oriented Software Systems ,"*CLEI electronic journal volume 14 number 1 paper 3 april 2011.*
~[SLR-55]	Sharma, A.; Hellmann, T.D.; Maurer, F.; , "Testing of web services - A systematic mapping," *Services (SERVICES), 2012 IEEE Eighth World Congress on , vol., no., pp.346-352, 24-29 June 2012,doi: 10.1109/SERVICES.2012.21.*
~[SLR-56]	Hellmann, T.D.; Sharma, A.; Ferreira, J.; Maurer, F.; , "Agile Testing: Past, Present, and Future -- Charting a Systematic Map of Testing in Agile Software Development," *Agile Conference (AGILE), 2012 , vol., no., pp.55-63, 13-17 Aug. 2012,doi: 10.1109/Agile.2012.8.*
~[SLR-57]	Julio Menezes, Jr. ;Cristine, G.; Hermano, M.; , "Indicators and Metrics for Risk Assessment in Software Projects : A Mapping Study," *in proceedings of ESELAW 2012.*

Table 52 Articles From snowball sampling SLR

12.8 SLR Selected Studies

SID	Article
[SLR 1]	Afzal, W.; Torkar, R.; Feldt, R.; , "A systematic mapping study on non-functional search-based software testing," , *in SEKE 2008. The 20th International Conference on Software Engineering & Knowledge Engineering, 1-3 July 2008. 2008. Skokie, IL, USA: Knowledge Systems Institute Graduate School.*
[SLR 2]	Antonio, E.A.; Ferrari, F.C.; FerrazFabbri, S.C.P.; , "A Systematic Mapping of Architectures for Embedded Software," *Critical Embedded Systems (CBSEC), 2012 Second Brazilian Conference on , vol., no., pp.18-23, 20-25 May 2012,doi: 10.1109/CBSEC.2012.22.*
[SLR 3]	Bailey, J.; Budgen, D.; Turner, M.; Kitchenham, B.; Brereton, P.; Linkman, S.; , "Evidence relating to Object-Oriented software design: A survey," *Empirical Software Engineering and Measurement, 2007. ESEM 2007. First International Symposium on , vol., no., pp.482-484, 20-21 Sept. 2007,doi: 10.1109/ESEM.2007.58.*
[SLR 4]	Acuna, Silvia T.; Castro, John W.; Dieste, Oscar; Juristo, Natalia; , "A systematic mapping study on the open source software development process," *Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.42-46, 14-15 May 2012,doi: 10.1049/ic.2012.0005.*
[SLR 5]	Arshad, Ali; Usman, Muhammad; , "Security at software architecture level: A systematic mapping study," *Evaluation & Assessment in Software Engineering (EASE 2011), 15th Annual Conference on , vol., no., pp.164-168, 11-12 April 2011,doi: 10.1049/ic.2011.0020.*
[SLR 6]	Barmi, Z.A.; Ebrahimi, A.H.; Feldt, R.; , "Alignment of Requirements Specification and Testing: A Systematic Mapping Study," *Software Testing, Verification and Validation Workshops (ICSTW), 2011 IEEE Fourth International Conference on , vol., no., pp.476-485, 21-25 March 2011,doi: 10.1109/ICSTW.2011.58.*
[SLR 7]	Barney, S.;et al.; , "Software quality trade-offs: A systematic map*," in Information and Software Technology, 2012. 54(7): p. 651-662.*
[SLR 8]	Barreiros, E.; Almeida, A.; Saraiva, J.; Soares, S.; , "A Systematic Mapping Study on Software Engineering Testbeds," *Empirical Software Engineering and Measurement (ESEM), 2011 International Symposium on , vol., no., pp.107-116, 22-23 Sept. 2011,doi: 10.1109/ESEM.2011.19.*
[SLR 9]	*Bastos, Jonatas Ferreira; da MotaSilveiraNeto, Paulo Anselmo; de Almeida, Eduardo Santana; de LemosMeira, Silvio Romero; , "Adopting software product lines: A systematic mapping study," Evaluation & Assessment in Software Engineering (EASE 2011), 15th Annual Conference on , vol., no., pp.11-20, 11-12 April 2011 doi: 10.1049/ic.2011.0002.*
[SLR 10]	Catal, C.; Mishra, D. ; , "Test case prioritization: a systematic mapping study," *Software Quality Journal, 2012: p. 1-34.*
[SLR 11]	Condori-Fernandez, N.; Daneva, M.; Sikkel, K.; Wieringa, R.; Dieste, O.; Pastor, O.; , "A systematic mapping study on empirical evaluation of software requirements specifications techniques," *Empirical Software Engineering and Measurement, 2009. ESEM 2009. 3rd International Symposium on , vol., no., pp.502-505, 15-16 Oct. 2009,doi: 10.1109/ESEM.2009.5314232.*
[SLR 12]	Cruzes, D.S.; Dyba, T. ; , "Research Synthesis in Software Engineering: A tertiary Study," *Information and software Technology,2011, 53(5):440-445.*
[SLR 13]	da MotaSilveiraNeto, P. A. : I. d. Carmo Machado, ; et al. "A systematic mapping study of software product lines testing," *Information and software Technology,2011, 53(5):407-423.*
[SLR 14]	Da Silva, F.Q.B.;, et al.; , "Six years of systematic literature reviews in software engineering: An updated tertiary study*," Information and Software Technology, 2011. 53(9): p. 899-913.*
[SLR 15]	da Silva, F.Q.B.; Suassuna, M.; Lopes, R.F.; Gouveia, T.B.; Franca, A.C.A.; de Oliveira, J.P.N.; de Oliveira, L.F.M.; Santos, A.L.M.; , "Replication of Empirical Studies in Software Engineering: Preliminary Findings from a Systematic Mapping Study," *Replication in Empirical Software Engineering Research (RESER), 2011 Second International Workshop on , vol., no., pp.61-70, 21-21 Sept. 2011,doi: 10.1109/RESER.2011.14.*
[SLR 16]	Freitas da Silva, I. ; , "Agile Software Product Lines: a Systematic Mapping Study," *Software Practice and Experience, Article first published online: 3 May 2011.*
[SLR 17]	Durelli, V.H.S.; Araujo, R.F.; Silva, M.A.G.; Oliveira, R.A.P.; Maldonado, J.C.; Delamaro, M.E.; , "What a Long, Strange Trip It's Been: Past, Present, and Future Perspectives on Software Testing Research,*" Software Engineering (SBES), 2011 25th Brazilian Symposium on , vol., no., pp.30-39, 28-30 Sept. 2011, doi: 10.1109/SBES.2011.17.*
[SLR 18]	Elberzhager, F.; Münch, J.; V.T.N. Nha, ; , "A systematic mapping study on the combination of static and dynamic quality assurance techniques*," Information and Software Technology, 2012. 54(1): p. 1-15.*

[SLR 19]	Elberzhager, F. ; et al.; , "Reducing test effort: A systematic mapping study on existing approaches,"*Information and Software Technology, 2012. 54(10): p. 1092-1106.*
[SLR 20]	Engstrom, E. ;Runeson, P. ; , "Software product line testing – A systematic mapping study," *Information and Software Technology, 2011. 54(1): p. 2-13.*
[SLR 21]	Fauzi, S.S.M.; Bannerman, P.L.; Staples, M.; , "Software Configuration Management in Global Software Development: A Systematic Map," *Software Engineering Conference (APSEC), 2010 17th Asia Pacific , vol., no., pp.404-413, Nov. 30 2010-Dec. 3 2010,doi: 10.1109/APSEC.2010.53.*
[SLR 22]	Feitosa, D.; et al.; , "Software Engineering in the Embedded Software and Mobile Robot Software Development: A Systematic Mapping," *in 22nd International Conference on Software Engineering & Knowledge Engineering (SEKE 2010), 1-3 July 2010. 2010. Skokie, IL, USA: Knowledge Systems Institute Graduate School.*
[SLR 23]	Felizardo, K.R.; et al.; ,"A systematic mapping on the use of visual data mining to support the conduct of systematic literature reviews," *Journal of Software, 2012. 7(2): p. 450-461.*
[SLR 24]	Fernandez, A.; E. Insfran,; S. Abrahão,;, "Usability evaluation methods for the web: A systematic mapping study,"*Information and Software Technology, 2011. 53(8): p. 789-817.*
[SLR 25]	Jalali, S.; Wohlin, C.; , "Agile Practices in Global Software Engineering - A Systematic Map," *Global Software Engineering (ICGSE), 2010 5th IEEE International Conference on , vol., no., pp.45-54, 23-26 Aug. 2010, doi: 10.1109/ICGSE.2010.14.*
[SLR 26]	João, Lemos, ; Carina, A. ; Leticia, D. ; Genaina, N.R.;, " A systematic mapping study on creativity in requirements engineering," *In* Proceedings of the 27th Annual ACM Symposium on Applied Computing *(SAC '12)2012. ACM, New York, NY, USA, 1083-1088. DOI=10.1145/2245276.2231945.*
[SLR 27]	Kusumo, Dana S.; Staples, Mark; Zhu, Liming; He Zhang; Jeffery, Ross; , "Risks of off-the-shelf-based software acquisition and development: A systematic mapping study and a survey," *Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.233-242, 14-15May 2012,*
[SLR 28]	Laguna, M.A.; Y. Crespo,; , "A systematic mapping study on software product line evolution: From legacy system reengineering to product line refactoring," *Science of Computer Programming, 2012.*
[SLR 29]	Maglyas, A.; Nikula, U.; Smolander, K.; , "What do we know about software product management? - a systematic mapping study," *Software Product Management (IWSPM), 2011 Fifth International Workshop on , vol., no., pp.26-35, 30-30 Aug. 2011,doi: 10.1109/IWSPM.2011.6046201.*
[SLR 30]	Mohebzada, J.G.; Ruhe, G.; Eberlein, A.; , "Systematic mapping of recommendation systems for requirements engineering," *Software and System Process (ICSSP), 2012 International Conference on , vol., no., pp.200-209, 2-3 June 2012,doi: 10.1109/ICSSP.2012.6225965.*
[SLR 31]	Mujtaba, S.; Petersen, K.; Feldt, R.; Mattsson, M.; , " Software Product Line Variability: A Systematic Mapping Study," *In: 15th Asia-Pacific Software Engineering Conference (APSEC 2008).*
[SLR 32]	Elisa, Yumi, N.; Daniel F. ; Katia, R.F.; , " Using systematic mapping to explore software architecture knowledge," *In* Proceedings of the 2010 ICSE Workshop on Sharing and Reusing Architectural Knowledge *(SHARK '10). ACM, New York, NY, USA, 29-36.*
[SLR 33]	Petersen, K.; , "Measuring and predicting software productivity: A systematic map and review,"*Information and Software Technology 53 (2011) 317–343.*
[SLR 34]	Portillo-Rodríguez, J. ; et al.; , "Tools used in Global Software Engineering: A systematic mapping review," *Information and Software Technology, 2012. 54(7): p. 663-685.*
[SLR 35]	Qadir, M.M.; Usman, M.; , "Software Engineering Curriculum: A systematic mapping study," *Software Engineering (MySEC), 2011 5th Malaysian Conference in , vol., no., pp.269-274, 13-14 Dec. 2011*
[SLR 36]	Shippey, Thomas; Bowes, David; Chrisianson, Bruce; Hall, Tracy; , "A mapping study of software code cloning," *Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.274-278, 14-15 May 2012,doi: 10.1049/ic.2012.0035.*
[SLR 37]	Da Silva, I.F.; et al.; , " Agile software product lines: A systematic mapping study," *in Software - Practice and Experience, 2011. 41(8): p. 899-920.*
[SLR 38]	Steinmacher, I. ; A.P. Chaves,; M.A. Gerosa,; , " Awareness Support in Distributed Software Development: A Systematic Review and Mapping of the Literature," *Computer Supported Cooperative Work: CSCW: An International Journal, 2012: p. 1-46.*
[SLR 39]	Wendler, R.; , "The maturity of maturity model research: A systematic mapping study," *Information and*

	Software Technology, 2012.
[SLR 40]	M. Guessi,; L. B. R. Oliveira, ; E. Y. Nakagawa,; , "Modeling Aspect-oriented Software Systems Using UML: A Systematic Mapping," *in Proceedings of the 36 Latin American Conference of Informatics (CLEI 2010), Asuncion, Paraguay, 2010, pp. 1-14.*
[SLR 41]	Silva, F.B.; M. Suassuna,; et al.; "Replication of Empirical Studies in software engineering research: a systematic mapping study," *in Empirical Software Engineering, pg 1-57,2012.*
[SLR 42]	Barbara K. ; O.P. Brereton,; David, B. ;, Mark, T.;, John, B.; Stephen, L.;, "Systematic literature reviews in software engineering - A systematic literature review," *Information and Software Technology, v.51 n.1, p.7-15,* January, 2009 [doi>*10.1016/j.infsof.2008.09.009]* .
[SLR 43]	Lobato, Luanna Lopes; do Carmo Machado, Ivan; da MotaSilveiraNeto, Paulo Anselmo; de Almeida, Eduardo Santana; de LemosMeira, Silvio Romero; , "Risk Management in software engineering: A scoping study,"*Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on , vol., no., pp.243-252, 14-15 May 2012,doi: 10.1049/ic.2012.0032.*
[SLR 44]	Milena, G.; Lucas BuenoRuas, Oliveira; Elisa Y.N.; , "Extensions of UML to Model Aspect-oriented Software Systems ,"*CLEI electronic journal volume 14 number 1 paper 3 april 2011.*
[SLR 45]	Sharma, A.; Hellmann, T.D.; Maurer, F.; , "Testing of web services - A systematic mapping," *Services (SERVICES), 2012 IEEE Eighth World Congress on , vol., no., pp.346-352, 24-29 June 2012,doi: 10.1109/SERVICES.2012.21.*
[SLR 46]	Hellmann, T.D.; Sharma, A.; Ferreira, J.; Maurer, F.; , "Agile Testing: Past, Present, and Future -- Charting a Systematic Map of Testing in Agile Software Development," *Agile Conference (AGILE), 2012 , vol., no., pp.55-63, 13-17 Aug. 2012,doi: 10.1109/Agile.2012.8.*
[SLR 47]	Julio Menezes, Jr. ;Cristine, G.; Hermano, M.; , "Indicators and Metrics for Risk Assessment in Software Projects : A Mapping Study," *in proceedings of ESELAW 2012.*

12.9 SLR Results overview

ID	Categories	Articles	Total No. of Articles
1.	Publication Year		
	2007	[SLR 3]	1
	2008	[SLR 1],[SLR 31]	2
	2010	[SLR 21],[SLR 22],[SLR 25],[SLR 32],[SLR 40], [SLR 42]	6
	2011	[SLR 5],[SLR 6],[SLR 8], [SLR 9], [SLR 11], [SLR 12] [SLR 13],[SLR 14],[SLR 15],[SLR 16],[SLR 17], [SLR 20],[SLR 24],[SLR 29],[SLR 33],[SLR 35], [SLR 37],[SLR 41],[SLR 44],	19
	2012	[SLR 2],[SLR 4],[SLR 7],[SLR 10],[SLR 18],[SLR 19], [SLR 23],[SLR 26],[SLR 27],[SLR 28],[SLR 30], [SLR 34],[SLR 36],[SLR 38],[SLR 39],[SLR 43], [SLR 45] ,[SLR 46] ,[SLR 47]	19
2.	Systematic mapping guidelines		
	Adhoc	[SLR 1],[SLR 5],[SLR 11],[SLR 12],[SLR 14], [SLR 15], [SLR 21], [SLR 23], [SLR 24], [SLR 35]	10
	Petersen	[SLR 2], [SLR 6], [SLR 7],[SLR 13], [SLR 17],[SLR 18], [SLR 20],[SLR 22],[SLR 28],[SLR 30],[SLR 31], [SLR 32],[SLR 33],[SLR 34],[SLR 40],[SLR 44], [SLR 45],[SLR 46],	18
	Kitchenhamn	[SLR 4],[SLR 8],[SLR 10],[SLR 29],[SLR 38], [SLR 42]	7
	Both	[SLR 9],[SLR 16],[SLR 19],[SLR 25],[SLR 26],[SLR 37], [SLR 39]	7
	Bailey	[SLR 3]	1
	durham template	[SLR 27]	1
	Jorgenson	[SLR 36]	1
	aarskey	[SLR 41],[SLR 43]	2
	biolchini	[SLR 47]	1
3.	search strategy		
	Picoc	[SLR 1],[SLR 2],[SLR 3],[SLR 6],[SLR 7],[SLR 9], [SLR 11],[SLR 18],[SLR 23],[SLR 26],[SLR 27], [SLR 32],[SLR 33],[SLR 37],[SLR 38],[SLR 42], [SLR 47]	17
	Own	[SLR 4],[SLR 5],[SLR 8],[SLR 10],[SLR 12],[SLR 13], [SLR 14],[SLR 15],[SLR 16],[SLR 17],[SLR 19], [SLR 20],[SLR 21],[SLR 22],[SLR 24],[SLR 25], [SLR 28],[SLR 29],[SLR 30],[SLR 31],[SLR 34], [SLR 35],[SLR 36],[SLR 39],[SLR 40],[SLR 41], [SLR 43],[SLR 44],[SLR 45],[SLR 46]	30
4	search type		
	Both	[SLR 1],[SLR 8],[SLR 9],[SLR 13],[SLR 14],[SLR 15], [SLR 16],[SLR 21],[SLR 24],[SLR 26],[SLR 31], [SLR 37],[SLR 41],[SLR 42],[SLR 43]	15
	Automated	[SLR 2],[SLR 3],[SLR 4],[SLR 5],[SLR 6],[SLR 7], [SLR 10],[SLR 11],[SLR 12],[SLR 17],[SLR 18], [SLR 19],[SLR 20],[SLR 22],[SLR 23],[SLR 25], [SLR 27],[SLR 28],[SLR 29],[SLR 30],[SLR 32], [SLR 33],[SLR 34],[SLR 35],[SLR 36],[SLR 38], [SLR 39],[SLR 40],[SLR 44],[SLR 45],[SLR 46], [SLR 47]	32
5	Snowball		
	Yes	[SLR 1],[SLR 9],[SLR 16],[SLR 20],[SLR 26], [SLR 33], [SLR 37]	7
	No	[SLR 8],[SLR 13],[SLR 14],[SLR 15],[SLR 21], [SLR 24], [SLR 31],[SLR 41],[SLR 42],[SLR 43], [SLR 2],[SLR 3],[SLR 4],[SLR 5],[SLR 6],[SLR 7], [SLR 10],[SLR 11], [SLR 12],[SLR 17],[SLR	40

		18], [SLR 19],[SLR 22],[SLR 23],[SLR 25],[SLR 27], [SLR 28],[SLR 29],[SLR 30],[SLR 32],[SLR 34], [SLR 35],[SLR 36],[SLR 38],[SLR 39],[SLR 40], [SLR 44],[SLR 45],[SLR 46],[SLR 47],	
6	Data Analysis technique		
	None	[SLR 1],[SLR 2],[SLR 3],[SLR 4],[SLR 5],[SLR 6], [SLR 7],[SLR 8],[SLR 10],[SLR 11],[SLR 13],[SLR 14] ,[SLR 15],[SLR 16],[SLR 17],[SLR 18],[SLR 19], [SLR 20],[SLR 21],[SLR 22],[SLR 23],[SLR 24], [SLR 25],[SLR 26],[SLR 27],[SLR 28],[SLR 29], [SLR 30],[SLR 31],[SLR 32],[SLR 33],[SLR 34], [SLR 35],[SLR 36],[SLR 37],[SLR 39],[SLR 40], [SLR 41],[SLR 42],[SLR 43],[SLR 44],[SLR 45], [SLR 46],[SLR 47]	44
	Narrative	[SLR 9],[SLR 12]	2
	Narrative and content analysis	[SLR 38]	1
7	Visualization type		
	None	[SLR 3],[SLR 8],[SLR 11],[SLR 14],[SLR 15],[SLR 27],[SLR 28],[SLR 29],[SLR 36],[SLR 42]	10
	Venn	[SLR 38],[SLR 30],[SLR 45]	3
	Line	[SLR 4],[SLR 16]	
	Bar	[SLR 5],[SLR 6],[SLR 7],[SLR 9],[SLR 10],[SLR 12],[SLR 13],[SLR 17],[SLR 18],[SLR 19],[SLR 21],[SLR 24],[SLR 25],[SLR 30],[SLR 33],[SLR 38],[SLR 39],[SLR 41],[SLR 45],[SLR26]	20
	Pie	[SLR 5],[SLR 10],[SLR 17],[SLR 20],[SLR 34],[SLR 35],[SLR 38],[SLR 39],[SLR 44],[SLR 46],[SLR 47]	11
	Bubble	[SLR 1],[SLR 2],[SLR 4],[SLR 6],[SLR 7],[SLR 9],[SLR 16],[SLR 17],[SLR 18],[SLR 19],[SLR 20],[SLR 22],[SLR 24],[SLR 25],[SLR 26],[SLR 30],[SLR 31],[SLR 32],[SLR 33],[SLR 37],[SLR 39],[SLR 40],[SLR 41],[SLR 43],[SLR 44],[SLR 45],[SLR 46]	27
8	Classifications		
	Keywording	[SLR 44],[SLR 40],[SLR 33],[SLR 32],[SLR 22],[SLR 19],[SLR 18]	7
	Research Type	[SLR 5],[SLR 6],[SLR 7],[SLR 8],[SLR 9],[SLR 10],[SLR 13],[SLR 16],[SLR 17],[SLR 20],[SLR 22],[SLR 24],[SLR 26],[SLR 27],[SLR 28],[SLR 31],[SLR 37],[SLR 45],[SLR 46]	19
	Research Method	[SLR 3],[SLR 11],[SLR 8],[SLR 14],[SLR 15],[SLR 19],[SLR 21],[SLR 39]	8
	Research questions	[SLR 9],[SLR 13],[SLR 24]	3
	Study focus	[SLR 11],[SLR 21],[SLR 7]	3
	Contribution type	[SLR 2],[SLR 19],[SLR 20],[SLR 22],[SLR 25],[SLR 31],[SLR 37],[SLR 7]	8
	Publication information	[SLR 1],[SLR 3],[SLR 4],[SLR 5],[SLR 6],[SLR 7],[SLR 10],[SLR 12],[SLR 13],[SLR 14],[SLR 15],[SLR 16],[SLR 17],[SLR 21],[SLR 23],[SLR 24],[SLR 25],[SLR 29],[SLR 30],[SLR 32],[SLR 34],[SLR 36],[SLR 37],[SLR 38],[SLR 39],[SLR 40],[SLR 41],[SLR 42],[SLR 44],[SLR 45],[SLR 46],[SLR 47]	32

Table 53 Overview of SLR results

12.10 Selected studies for SMP

Automated search	
SID	Article
[SMP 1]	Jürgen Börstler ; ,"Improving CRC-card role-play with role-play diagrams," In *Companion to the 20th annual ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications* (OOPSLA '05)2005. ACM, New York, NY, USA, 356-364. DOI=10.1145/1094855.1094973.
[SMP 2]	Albar, A.; Abu Hashish, F.; , "Using of object oriented approach design models learning in information software engineering," *Engineering Education (ICEED), 2011 3rd International Congress on , vol., no., pp.152-154,7-8Dec.2011doi:10.1109/ICEED.2011.6235379.*
[SMP 3]	Alfert, K.; Pleumann, J.; Schroder, J.; , "Software engineering education needs adequate modeling tools," *Software Engineering Education and Training, 2004. Proceedings. 17th Conference on , vol., no., pp. 72-77,1-3,March,2004.doi: 10.1109/CSEE.2004.1276513.*
[SMP4]	Ali, Z.; Bolinger, J.; Herold, M.; Lynch, T.; Ramanathan, J.; Ramnath, R.; , "Teaching object-oriented software design within the context of software frameworks," *Frontiers in Education Conference (FIE), 2011 , vol., no., pp.S3G-1-S3G-5,12-15Oct.2011doi: 10.1109/FIE.2011.6142889.*
[SMP 5]	Auer, M.; Tschurtschenthaler, T.; Biffl, S.; ,"A flyweight UML modelling tool for software development in heterogeneous environments," *Euromicro Conference, 2003. Proceedings.29th , vol., no., pp. 267- 272, 1-6 Sept.2003doi: 10.1109/EURMIC.2003.1231600.*
[SMP 6]	Baghaei, N;,&Mitrovic, A.; , "A constraint-based collaborative environment for learning UML class diagrams,". *In M. Ikeda, K. Ashley & T. W. Chan (eds.) Proc. ITS 2006 (pp. 176–186).*
[SMP 7]	Berndtsson, M.; ,"Analyzing course configurations for teaching object-oriented modeling and design," *Education, IEEE Transactions on , vol.48, no.2, pp. 337- 339, May 2005 doi: 10.1109/TE.2004.842891.*
[SMP 8]	Bezivin, J.,; R. France,;.et al. "Teaching Modeling: Why, When, What?," *MODELS 2009 Workshops, LNCS 6002, pp. 55–62, 2010.Springer-Verlag Berlin Heidelberg 2010*
[SMP9]	Boberic-krsticev, D;, &Tesendic, D;, "Teaching Object-Oriented Modelling Using UML," *Numerical Analysis and Applied Mathematics ICNAAM 2011,AIP Conf. Proc. 1389, 810-812 (2011); doi: 10.1063/1.3636856.*
[SMP 10]	Brandsteidl, M,; Wieland, k,; and Huemer, c,;. "Novel Communication Channels in Software Modeling Education," *In MODELS'10 Proceedings of the 2010 international conference on Models in software engineering, pages 40-54. Springer, 2010.*
[SMP 11]	Jeffrey Brewer and Leslie Lorenz.,;,"Using UML and agile development methodologies to teach object-oriented analysis & design tools and techniques". *In Proceedings of the 4th conference on Information technology curriculum (CITC4 '03). ACM, New York, NY, USA, 54-57. DOI=10.1145/947121.947133.*
[SMP12]	Bernd Bruegge, Jim Blythe, Jeffrey Jackson, and Jeff Shufelt.;."Object-oriented system modeling with OMT",. *SIGPLAN Not. 27, 10 (October 1992), 359-376. DOI=10.1145/141937.141966.*
[SMP13]	Paolo Bucci;, Timothy J.; Long,; and Bruce W.; Weide,;." Do we really teach abstraction?".*InProceedings of the thirty-second SIGCSE technical symposium on Computer Science Education(SIGCSE '01). ACM, New York, NY, USA, 26-30. DOI=10.1145/364447.364531.*
[SMP14]	Chiorean, D;, Petraşcu,V,; et al.,"Using Constraints in Teaching software modeling,"*MODELS 2011 Workshops, LNCS 7167, pp. 25–39, 2012.Springer-Verlag Berlin Heidelberg 2012.*
[SMP15]	Paolo Ciancarini.;." On the education of future software engineers,".*In Proceedings of the 27th international conference on Software engineering (ICSE '05). ACM, New York, NY, USA, 649-650. DOI=10.1145/1062455.1062584.*
[SMP16]	Charles T,;. Cook, Svetlana Drachova;,et al.. ,"A systematic approach to teaching abstraction and mathematical modeling".*In Proceedings of the 17th ACM annual conference on Innovation and technology in computer science education (ITiCSE '12). ACM, New York, NY, USA, 357-362. DOI=10.1145/2325296.2325378.*
[SMP17]	*Costal, D.;, Gómez;, c.;, et al.*"Facilitating the Definition ofGeneral Constraints in UML*".MoDELS 2006, LNCS 4199, pp. 260–274, 2006.Springer-Verlag Berlin Heidelberg 2006.*
[SMP18]	Coyne, R.;, Bruegge B,;, et al. "Teaching More Comprehensive Model-Based Software Engineering:

	Experience With Objectory's Use Case Approach,”.Software Engineering Education.R.ibrahim,springer Berlin Heidelberg.vol 895,pg 339-374.
[SMP 19]	Dagdeviren, H.; Juric, R.; Lees, P.; , "Experiences of teaching UML within the information systems curriculum," *Information Technology Interfaces, 2004. 26th International Conference on , vol., no., pp.381-386 Vol.1, 7-10 June 2004.*
[SMP 20]	Christian HeideDamm, Klaus Marius Hansen, and Michael Thomsen.;”Tool support for cooperative object-oriented design: gesture based modelling on an electronic whiteboard*.”.In*Proceedings of the SIGCHI conference on Human Factors in Computing Systems *(CHI '00). ACM, New York, NY, USA, 518-525. DOI=10.1145/332040.332488.*
[SMP 21]	Michae L,; Davis ,;”A new approach to teaching object-oriented concepts and methodology to information technology students,”, *Journal of Computing in Small Colleges, v 15, n 1, p 133-8, Nov. 1999.*
[SMP 22]	Debuse, J.C.W.; Stiller, T.; , "Technologies and Strategies for Integrating Object-Oriented Analysis and Design Education with Programming,*" Software Engineering, 2008. ASWEC 2008. 19th Australian Conference on , vol., no., pp.97-103, 26-28 March 2008.doi: 10.1109/ASWEC.2008.4483197.*
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[SMP 128]	Wrycza, S.; Marcinkowski, B.; "UML 2 teaching at postgraduate studies – Prerequisites and practice,", *Proceedings of ISECON 2005, 22, New Orleans. AITP Foundation for Information Technology Education.*
[SMP 129]	Cruz-Lemus, J.A.; Genero, M.; Piattini, M.; " Using Controlled Experiments for Validating UML Statechart Diagrams Measures," *In: Cuadrado-Gallego, J.J.; Braungarten, R.; et al.; editor, IWSM-Mensura 2007. LNCS, vol. 4895, pp. 129–138. Springer, Heidelberg (2008).*
[SMP 130]	Eichelberger, H.; " Nice class diagrams admit good design?"*In Proceedings of the 2003 ACM symposium on Software visualization (SoftVis '03).ACM, New York, NY, USA, 159-ff. DOI=10.1145/774833.774857.*
***Snowball* 3**	
[SMP 131]	Schulte, C;." Dynamic object structures as a conceptual framework for teaching object-oriented concepts to novices," *In Proceedings of 5th Annual Finnish/Baltic Sea Conference on Computer Science Education (Koli, Finland, November 17-20).*

Table 54 Selected studies for systematic mapping

12.11 Overview of SMP results

ID	Categories	Articles	No. of articles
1	Language		
	OCL	[SMP 14],[SMP 17]	2
	OVAL	[SMP 53]	1
	UML	[SMP 2],[SMP 5],[SMP 6],[SMP 9],[SMP 10], [SMP 11],[SMP 15],[SMP 17],[SMP 22],[SMP 23], [SMP 26],[SMP 28],[SMP 29],[SMP 31],[SMP 32], [SMP 33],[SMP 35],[SMP 37],[SMP 38],[SMP 39], [SMP 40],[SMP 41],[SMP 42],[SMP 43],[SMP 45],[SMP 48], [SMP 50],[SMP 51],[SMP 55],[SMP 56], [SMP 58],[SMP 59], [SMP 61],[SMP 62],[SMP 65],[SMP 71],[SMP 73], [SMP 74],[SMP 77],[SMP 78],[SMP 79],[SMP 84],[SMP 85], [SMP 86],[SMP 87],[SMP 88],[SMP 90],[SMP 91], [SMP 92],[SMP 94],[SMP 95],[SMP 96],[SMP 97], [SMP 98],[SMP 105],[SMP 107],[SMP 108],[SMP 109], [SMP 110],[SMP 111],[SMP 112],[SMP 113], [SMP 114] , [SMP 115],[SMP 116],[SMP 117], [SMP 118],[SMP 119],[SMP 124],[SMP 127], [SMP 128],[SMP 129],[SMP 130],[SMP 131]	74
2	Diagrams		
	ALL	[SMP 40],[SMP 65],[SMP 78],[SMP 107],[SMP 110], [SMP 116], [SMP 127]	7
	Class diagrams	[SMP 6],[SMP 36],[SMP 45],[SMP 47],[SMP 58], [SMP 87],[SMP 89],[SMP 113],[SMP 122],[SMP 124], [SMP 130]	11
	State chart diagrams	[SMP 37],[SMP 109],[SMP 129]	3
	Sequence diagrams , collaboration diagrams and state chart diagrams	[SMP 84]	1
	Sequence diagrams and collaboration diagrams	[SMP 32]	1
	Sequence diagrams	[SMP 51]	1
	Activity diagrams	[SMP 96]	1
	Role play	[SMP 1]	1
	Use case diagram	[SMP 54]	1
3	Curriculum		
		[SMP 4],[SMP 19],[SMP 21],[SMP 23],[SMP 24], [SMP 27],[SMP 30],[SMP 42],[SMP 43],[SMP 44], [SMP 46],[SMP 49],[SMP 52],[SMP 55], [SMP 62], [SMP 76],[SMP 119],[SMP 127]	18
4	Course		
		[SMP 7],[SMP 9],[SMP 10],[SMP 23],[SMP 24], [SMP 26],[SMP 27],[SMP 30],[SMP 31], [SMP 38] , [SMP 40],[SMP 48],[SMP 55],[SMP 62],[SMP 63], [SMP 70],[SMP 80],[SMP 83],[SMP 92],[SMP 93], [SMP 94],[SMP 104],[SMP 105],[SMP 112],[SMP 116], [SMP 117],[SMP 118],[SMP 119],[SMP 120]	29
5	Others		
		[SMP 3],[SMP 8],[SMP 12],[SMP 13],[SMP 16], [SMP 18],[SMP 20],[SMP 25],[SMP 34],[SMP 57], [SMP 60],[SMP 64],[SMP 66],[SMP 67],[SMP 68], [SMP 69],[SMP 72],[SMP 75],[SMP 81], [SMP 82],[SMP 99][SMP 100],[SMP 101],[SMP 102],[SMP 103], [SMP 106],[SMP 121],[SMP 123],[SMP 125], [SMP 126]	30

Table 55 Overview of systematic study results on teaching modeling

12.12 SMP Results using Classification facets

ID	Attributes	Articles	Total No. of articles
1.	Years		
	1989	[SMP 81]	1
	1992	[SMP 12]	1
	1994	[SMP 34],[SMP 46],[SMP 103]	3
	1995	[SMP 18]	1
	1997	[SMP 102]	1
	1998	[SMP 67],[SMP 124],[SMP 125]	3
	1999	[SMP 21], [SMP 25]	2
	2000	[SMP 20],[SMP 40],[SMP 53],[SMP 71],[SMP 99], [SMP 104]	6
	2001	[SMP 13],[SMP 36]	2
	2002	[SMP 33],[SMP 72],[SMP 80],[SMP 82],[SMP 84], [SMP 116]	6
	2003	[SMP 5],[SMP 11],[SMP 76],[SMP 77],[SMP 95],[SMP 105],[SMP 110], [SMP 130]	8
	2004	[SMP 3],[SMP 19],[SMP 27],[SMP 28],[SMP 30], [SMP 47],[SMP 62], [SMP 78],[SMP 111]	9
	2005	[SMP 1],[SMP 7],[SMP 15],[SMP 26],[SMP 37],[SMP 38],[SMP 50], [SMP 60],[SMP 64],[SMP 79], [SMP 96],[SMP 106],[SMP 108],[SMP 114], [SMP 118],[SMP 123],[SMP 127],[SMP 128],[SMP 129],[SMP 131]	20
	2006	[SMP 6],[SMP 17],[SMP 29],[SMP 61],[SMP 65], [SMP 66],[SMP 75], [SMP 88],[SMP 107],[SMP 113], [SMP 115],[SMP 119],[SMP 120], [SMP 121]	14
	2007	[SMP 31],[SMP 49],[SMP 51],[SMP 59],[SMP 85], [SMP 86],[SMP 90], [SMP 91],[SMP 117],[SMP 126]	10
	2008	[SMP 22],[SMP 39],[SMP 42],[SMP 45],[SMP 52], [SMP 57],[SMP 94], [SMP 97],[SMP 98],[SMP 101], [SMP 112]	11
	2009	[SMP 8],[SMP 23],[SMP 32],[SMP 48],[SMP 63], [SMP 69],[SMP 70], [SMP 73],[SMP 89],[SMP 100]	10
	2010	[SMP 10],[SMP 24],[SMP 35],[SMP 43],[SMP 44], [SMP 54],[SMP 55], [SMP 56],[SMP 58],[SMP 109]	10
	2011	[SMP 2],[SMP 4],[SMP 9],[SMP 14],[SMP 41],[SMP 68],[SMP 74], [SMP 87],[SMP 122],[SMP 83]	10
	2012	[SMP 16],[SMP 92],[SMP 93]	3
2	Audience		
	Students	[SMP 1],[SMP 2],[SMP 3],[SMP 4],[SMP 6],[SMP 7], [SMP 9],[SMP 10], [SMP 11],[SMP 12],[SMP 13],[SMP 14],[SMP 15],[SMP 16],[SMP 18], [SMP 19],[SMP 21],[SMP 22],[SMP 23],[SMP 24],[SMP 25],[SMP 26], [SMP 27],[SMP 28],[SMP 29],[SMP 30],[SMP 31],[SMP 32],[SMP 33], [SMP 34],[SMP 35], [SMP 36],[SMP 37],[SMP 38],[SMP 39],[SMP 40], [SMP 41],[SMP 42],[SMP 43],[SMP 45],[SMP 46],[SMP 48],[SMP 49], [SMP 51],[SMP 52],[SMP 53], [SMP 54],[SMP 55],[SMP 56],[SMP 58],[SMP 59], [SMP 60],[SMP 61],[SMP 62],[SMP 63],[SMP 64],[SMP 65],[SMP 66], [SMP 69],[SMP 70],[SMP 72],[SMP 73],[SMP 74],[SMP 76],[SMP 78], [SMP 80],[SMP 84],[SMP 85],[SMP 86],[SMP 87],[SMP 88],[SMP 89], [SMP 90],[SMP 91],[SMP 92],[SMP 93],[SMP 94],[SMP 100],[SMP 102], [SMP 103],[SMP 104],[SMP 105],[SMP 106],[SMP 109],[SMP 110], [SMP 111],[SMP 112],[SMP 114],[SMP 117],[SMP 118],[SMP 119], [SMP 120],[SMP 121],[SMP 122],[SMP 123],[SMP 126],[SMP 127], [SMP 128],[SMP	101

		129],[SMP 131],[SMP 83]	
	Both	[SMP 5],[SMP 8],[SMP 17],[SMP 20],[SMP 47],[SMP 50], [SMP 67],[SMP 68],[SMP 71],[SMP 82],[SMP 101]	11
	Teachers	[SMP 44],[SMP 57]	2
	All	[SMP 75]	1
	Software engineers	[SMP 77],[SMP 81],[SMP 99],[SMP 113]	4
	Not specified	[SMP 79],[SMP 97],[SMP 98],[SMP 107],[SMP 108],[SMP 116],[SMP 125], [SMP 130]	8
	Developers	[SMP 95],[SMP 96],[SMP 124],[SMP 115]	4
3	Research Type		
	Experience paper	[SMP 1],[SMP 7],[SMP 10],[SMP 11],[SMP 16],[SMP 18],[SMP 19], [SMP 26],[SMP 30],[SMP 32],[SMP 34],[SMP 38],[SMP 39],[SMP 41], [SMP 43],[SMP 44],[SMP 48],[SMP 52],[SMP 55],[SMP 56],[SMP 57], [SMP 59],[SMP 62],[SMP 63],[SMP 66],[SMP 72],[SMP 73],[SMP 76], [SMP 78],[SMP 80],[SMP 82],[SMP 92],[SMP 93],[SMP 94], [SMP 110],[SMP 117],[SMP 118],[SMP 119],[SMP 121],[SMP 123], [SMP 124], [SMP 128]	42
	Opinion	[SMP 2],[SMP 8],[SMP 14],[SMP 15],[SMP 31],[SMP 36],[SMP 40], [SMP 64],[SMP 67],[SMP 105],[SMP 106],[SMP 116]	12
	Evaluation research	[SMP 3],[SMP 9],[SMP 12],[SMP 37],[SMP 45],[SMP 49],[SMP 68], [SMP 75],[SMP 84],[SMP 86],[SMP 89],[SMP 90],[SMP 100],[SMP 107], [SMP 108],[SMP 111],[SMP 112],[SMP 120],[SMP 127],[SMP 129]	20
	Solution proposal	[SMP 4],[SMP 5],[SMP 13],[SMP 21],[SMP 23],[SMP 25],[SMP 42], [SMP 46],[SMP 47],[SMP 53],[SMP 69],[SMP 77],[SMP 79],[SMP 85], [SMP 87],[SMP 88],[SMP 91],[SMP 95],[SMP 96],[SMP 97],[SMP 102], [SMP 103],[SMP 104],[SMP 125],[SMP 130],[SMP 131],[SMP 83]	27
	Solution proposal and evaluation research	[SMP 6],[SMP 20],[SMP 113]	3
	Solution proposal and validation study	[SMP 17],[SMP 54], [SMP 28],[SMP 29],[SMP 101],[SMP 24], [SMP 33],[SMP 35],[SMP 51],[SMP 58],[SMP 60],[SMP 65],[SMP 70], [SMP 71],[SMP 98],[SMP 99],[SMP 115],[SMP 122],[SMP 50],[SMP 114]	20
	Validation Study	[SMP 22],[SMP 27],[SMP 74],[SMP 109],	4
	Solution proposal and experience	[SMP 81] [SMP 126]	2
	Experience paper and validation study	[SMP 61]	1
4	Research method		
	Discussion and interviews	[SMP 83]	1
	Literature review and interviews	[SMP 68]	1
	Concept analysis and survey	[SMP 41]	1
	Concept analysis and observational study	[SMP 126]	1
	Concept analysis and experiment	[SMP 6]	1
	Concept analysis and case study	[SMP 125]	1
	Case study	[SMP 2],[SMP 9],[SMP 12],[SMP 14],[SMP 16],[SMP 17],[SMP 27], [SMP 30],[SMP 34],[SMP 35],[SMP 60],[SMP 61],[SMP 76],[SMP 95],[SMP 128]	15

	Concept analysis	[SMP 1],[SMP 4],[SMP 5],[SMP 13],[SMP 20],[SMP 21],[SMP 23],[SMP 25] [SMP 29],[SMP 33],[SMP 36],[SMP 39],[SMP 42],[SMP 43],[SMP 46], [SMP 47],[SMP 51],[SMP 53],[SMP 54],[SMP 56],[SMP 58],[SMP 65], [SMP 67],[SMP 69],[SMP 70],[SMP 71], [SMP 72], [SMP 77],[SMP 79], [SMP 81], [SMP 85],[SMP 87], [SMP 88], [SMP 91],[SMP 96],[SMP 97], [SMP 98],[SMP 99],[SMP 102],[SMP 103],[SMP 104],[SMP 105],[SMP 113], [SMP 115],[SMP 123],[SMP 130],[SMP 131]	47
	Interviews	[SMP 100],[SMP 101]	2
	Survey	[SMP 10],[SMP 22],[SMP 44],[SMP 93],[SMP 107],[SMP 108],[SMP 109],[SMP 122], [SMP 127],	9
	Discussion	[SMP 8],[SMP 31],[SMP 64],[SMP 116]	4
	Observational Study	[SMP 3],[SMP 7],[SMP 11],[SMP 15],[SMP 19],[SMP 24],[SMP 26], [SMP 28],[SMP 32],[SMP 38],[SMP 40],[SMP 48],[SMP 49],[SMP 52], [SMP 55],[SMP 57],[SMP 59],[SMP 62],[SMP 63],[SMP 66],[SMP 73], [SMP 74],[SMP 78],[SMP 80],[SMP 82],[SMP 89],[SMP 90],[SMP 92], [SMP 94],[SMP 106],[SMP 110],[SMP 117],[SMP 118],[SMP 119], [SMP 121],[SMP 124],	36
	Experiment	[SMP 18],[SMP 37],[SMP 45],[SMP 50],[SMP 75],[SMP 84], [SMP 86] ,[SMP 111],[SMP 112],[SMP 114],[SMP 120], [SMP 129]	12
5	Contribution type		
	Process	[SMP 2],[SMP 3],[SMP 7],[SMP 9],[SMP 10],[SMP 11],[SMP 13],[SMP 14], [SMP 15],[SMP 16],[SMP 19],[SMP 21],[SMP 22],[SMP 23],[SMP 24], [SMP 25],[SMP 26],[SMP 27],[SMP 28],[SMP 29],[SMP 30],[SMP 31], [SMP 34],[SMP 35],[SMP 36],[SMP 38],[SMP 39],[SMP 40],[SMP 42], [SMP 43], [SMP 45],[SMP 46],[SMP 48],[SMP 52],[SMP 55],[SMP 56], [SMP 59],[SMP 60],[SMP 61],[SMP 62],[SMP 63],[SMP 64],[SMP 66], [SMP 70],[SMP 72],[SMP 73],[SMP 74],[SMP 76],[SMP 80],[SMP 86], [SMP 89],[SMP 90],[SMP 92],[SMP 94],[SMP 104],[SMP 105],[SMP 106], [SMP 109],[SMP 110],[SMP 112],[SMP 117],[SMP 118],[SMP 119], [SMP 121],[SMP 122],[SMP 123],[SMP 128],[SMP 83],[SMP 8],[SMP 67], [SMP 68],[SMP 82],[SMP 44],[SMP 57],[SMP 75],[SMP 107],[SMP 108], [SMP 124],[SMP 115]	79
	Method	[SMP 4],[SMP 17],[SMP 18],[SMP 32],[SMP 33],[SMP 37],[SMP 47], [SMP 53],[SMP 54],[SMP 78],[SMP 79],[SMP 81],[SMP 84],[SMP 91], [SMP 114],[SMP 116],[SMP 125],[SMP 130]	18
	Tool	[SMP 5],[SMP 6],[SMP 20],[SMP 51],[SMP 58],[SMP 65],[SMP 71], [SMP 85],[SMP 87],[SMP 88],[SMP 95],[SMP 96],[SMP 97],[SMP 98], [SMP 99],[SMP 100],[SMP 101]	17
	Method and Process	[SMP 1],[SMP 12],[SMP 41],[SMP 49],[SMP 50],[SMP 93],[SMP 126], [SMP 131]	8
	Measurement	[SMP 111],[SMP 113],[SMP 120],[SMP 127],[SMP 129]	5
	Model	[SMP 69],[SMP 77],[SMP 102]	3
	Process and tool	[SMP 103]	1
6	Study setting		
	Academic	[SMP 1],[SMP 2],[SMP 3],[SMP 4],[SMP 6],[SMP 7],[SMP 9],[SMP 10], [SMP 11],[SMP 12],[SMP 13],[SMP 14],[SMP 15],[SMP 16],[SMP 18], [SMP 19],[SMP 21],[SMP 22],[SMP 23],[SMP 24],[SMP 25],[SMP 26], [SMP 27],[SMP 28],[SMP 29],[SMP 30],[SMP 31],[SMP 32],[SMP 33], [SMP 34],[SMP 35],[SMP 36],[SMP 37],[SMP 39],[SMP 40],[SMP 41], [SMP 42],[SMP 43],[SMP 45],[SMP 46],[SMP 48],[SMP 49],[SMP 51], [SMP 52],[SMP 54],[SMP 55],[SMP 56],[SMP 58],[SMP 59],[SMP 60], [SMP 61],[SMP 62],[SMP 63],[SMP 64],[SMP	112

		65],[SMP 66],[SMP 69], [SMP 70],[SMP 72],[SMP 73],[SMP 74],[SMP 76],[SMP 78],[SMP 80], [SMP 84],[SMP 85],[SMP 86],[SMP 87],[SMP 88],[SMP 89],[SMP 90], [SMP 91],[SMP 92],[SMP 93],[SMP 94],[SMP 99],[SMP 100],[SMP 102],[SMP 103], [SMP 104],[SMP 105],[SMP 106],[SMP 109],[SMP 110],[SMP 111], [SMP 112],[SMP 114],[SMP 117],[SMP 118],[SMP 119],[SMP 120], [SMP 121],[SMP 122],[SMP 123],[SMP 124], [SMP 126],[SMP 127],[SMP 128], [SMP 129],[SMP 131],[SMP 83],[SMP 8],[SMP 47],[SMP 50],[SMP 67], [SMP 44],[SMP 75],[SMP 38],[SMP 57],[SMP 81],[SMP 82], [SMP 108]	
	Industry	[SMP 20],[SMP 77],[SMP 95],[SMP 96],[SMP 113]	5
	Academic and Industry	[SMP 5],[SMP 17],[SMP 53],[SMP 68],[SMP 71],[SMP 98],[SMP 101]	7
	Not Specified	[SMP 79],[SMP 97],[SMP 107], [SMP 115], [SMP 116],[SMP 125],[SMP 130]	7
7	Academic Setting focus		
	Not specified	[SMP 1],[SMP 6],[SMP 7],[SMP 8],[SMP 14],[SMP 15],[SMP 17],[SMP 29], [SMP 32],[SMP 34],[SMP 35],[SMP 36],[SMP 41],[SMP 43],[SMP 45], [SMP 47],[SMP 50],[SMP 51],[SMP 53],[SMP 55],[SMP 57],[SMP 58], [SMP 62],[SMP 64],[SMP 65],[SMP 67],[SMP 68],[SMP 69],[SMP 70], [SMP 71],[SMP 78],[SMP 79],[SMP 80],[SMP 81],[SMP 82],[SMP 87], [SMP 89],[SMP 90],[SMP 94],[SMP 97],[SMP 99],[SMP 101],[SMP 102],[SMP 104], [SMP 105],[SMP 106],[SMP 107],[SMP 110],[SMP 111],[SMP 114], [SMP 116],[SMP 120],[SMP 124],[SMP 125],[SMP 126],[SMP 129],[SMP 130], [SMP 131]	58
	Undergraduate	[SMP 2],[SMP 5],[SMP 9],[SMP 10],[SMP 12],[SMP 13],[SMP 16],[SMP 18],[SMP 19],[SMP 22],[SMP 24],[SMP 25],[SMP 26],[SMP 31],[SMP 33],[SMP 40],[SMP 42],[SMP 46],[SMP 49],[SMP 54],[SMP 56],[SMP 60],[SMP 66],[SMP 73],[SMP 76],[SMP 84],[SMP 86],[SMP 92],[SMP 93],[SMP 109],[SMP 112],[SMP 117],[SMP 118],[SMP 122],[SMP 127]	35
	Undergraduate and graduate	[SMP 3],[SMP 23],[SMP 28],[SMP 30],[SMP 37],[SMP 38],[SMP 39],[SMP 74],[SMP 75],	9
	Undergraduate and post graduate	[SMP 85],[SMP 88],[SMP 100],[SMP 103],[SMP 121],[SMP 83],	6
	Undergraduate, graduate, post graduate, high school and secondary	[SMP 108]	1
	Upper secondary and undergraduate	[SMP 123]	1
	Post graduate	[SMP 21],[SMP 91],[SMP 98],[SMP 128]	4
	Secondary school	[SMP 44],[SMP 72]	2
	High school	[SMP 59],	1
	Graduate	[SMP 4],[SMP 11],[SMP 27],[SMP 48],[SMP 52],[SMP 61],[SMP 119]	7
8	Industry setting focus		
	All	[SMP 17],[SMP 20]	2
	Designers and developers	[SMP 67]	1
	Not specified	[SMP 5],[SMP 58],[SMP 63],[SMP 71],[SMP 77],[SMP 97],[SMP 101],[SMP 102],[SMP 104],[SMP 125],[SMP 126]	11
	engineers	[SMP 81],[SMP 82]	2
	Developers	[SMP 95],[SMP 96],[SMP 98],[SMP 115]	4
	Designers	[SMP 113]	1
9	Validation		
	Yes	[SMP 1],[SMP 3],[SMP 6],[SMP 7],[SMP 9],[SMP 10],[SMP 12],[SMP 13], [SMP 16],[SMP 18],[SMP 22],[SMP 24],[SMP 28],[SMP 29],[SMP 30], [SMP 32],[SMP 33],[SMP 35],[SMP 37],[SMP 39],[SMP 41],[SMP	89

		45], [SMP 49],[SMP 52],[SMP 54],[SMP 55],[SMP 58],[SMP 60],[SMP 61], [SMP 63],[SMP 65],[SMP 70],[SMP 71][SMP 72],[SMP 73],[SMP 74],[SMP75], [SMP 76], [SMP 77], [SMP 78],[SMP 80],[SMP 81], [SMP 82], [SMP 84],[SMP 86],[SMP 87],[SMP 89],[SMP 90], [SMP 91],[SMP 92],[SMP 93],[SMP 94],[SMP 100],[SMP 102],[SMP 103],[SMP 104],[SMP 105], [SMP 106],[SMP 109], [SMP 110],[SMP 111],[SMP 112],[SMP 114],[SMP 117],[SMP 118], [SMP 119],[SMP 120],[SMP 121],[SMP 122],[SMP 126],[SMP 127], [SMP 128],[SMP 129],[SMP 17],[SMP 20],[SMP 50],[SMP 68],[SMP 101],[SMP 99],[SMP 113], [SMP 98],[SMP 107],[SMP 108],[SMP 95],[SMP 96],[SMP 115]	
	No	[SMP 2],[SMP 4],[SMP 8],[SMP 11],[SMP 14],[SMP 15], [SMP 19],[SMP 21],[SMP 23],[SMP 25],[SMP 26],[SMP 27],[SMP 31], [SMP 34],[SMP 38],[SMP 40],[SMP 42],[SMP 43],[SMP 44], [SMP 46],[SMP 48],[SMP 47],[SMP 51],[SMP 53] [SMP 56],[SMP 57], [SMP 59],[SMP 62],[SMP 64],[SMP 66],[SMP 67],[SMP 69],[SMP 79], [SMP 85],[SMP 88], [SMP 116],[SMP 123],[SMP 124],[SMP 125],[SMP 130],[SMP 131], [SMP 83]	42

Table 56 SMP results overview using classification facet

12.13 Keywords showing Frequencies using Tagcrowd

Figure 63 Snippet from Tag crowd showing all keywords and their frequencies

12.14 Keywords obtained from selected studies of SMP

ID	Title	Keywords
1	Improving CRC Card Role Play with Role Play Diagrams	collaborative, object oriented design, problems, novices, CRC card, role play, new diagram, professionals
2	Using Of Object Oriented Approach Design Models Learning In Information Software Engineering	object oriented, UML, literature review, approach, importance KAU
3	Software Engineering Education Needs Adequate Modeling Tools	tools, graphical modeling language, teaching experience
4	Teaching Object-Oriented Software Design within the Context of Software Frameworks	OODS, curriculum, novice s/w developers, graduates , methodology, software framework
5	A Flyweight UML Modelling Tool for Software Development in Heterogeneous Environments	flyweight, tool, software development, free, heterogeneous environment, UML sketches
6	A Constraint-Based Collaborative Environment for Learning UML Class Diagrams	CSCL, constraint based ITS automated teaching tool, object oriented modeling, UML class diagrams, collect UML, environment
7	Analyzing Course Configurations for Teaching Object-Oriented Modeling and Design	teaching strategies, students, OOP, course configuration, object oriented modeling and design
8	Teaching Modeling: Why, When, What?	purpose, need, discussion
9	Teaching Object-Oriented Modelling Using UML	course, evaluation, OOAD, problems, teaching modeling UML, students with or without OOP knowledge
10	Novel Communication Channels in Software Modeling Education	object oriented modeling, UML, course, teaching media
11	Using UML and Agile Development Methodologies to Teach Object-Oriented Analysis & Design Tools and Techniques	using UML and agile, teach, OOAD, tools, techniques ,models, examples
12	Object-Oriented System Modeling with OMT	unfamiliar, using, methodology, OMT, project, undergraduate
13	Do We Really Teach Abstraction?	abstraction, cs1, cs2, undergraduates, reason, software behavior
14	Using Constraints in Teaching Software Modeling	OCL, course design, constraints, advantages, rigorous models
15	On the Education of Future Software Engineers	UML, Rup, business oriented, issues
16	A Systematic Approach to Teaching Abstraction and Mathematical Modeling	undergraduate, curriculum, CS, systematic approach, abstraction, experimentation
17	Facilitating the Definition of General Constraints in UML	real life application, UML, UCL , constraints, specifications
18	Teaching More Comprehensive Model-Based Software Engineering: Experience With Objectory's Use Case Approach	experience report, experiment, software project, model based methodology, tool, issues
19	Experiences of Teaching UML within the Information Systems Curriculum	experience , curriculum, information systems, is, undergraduate
20	Tool Support for Cooperative Object-Oriented Design:Gesture Based Modeling on an Electronic Whiteboard	gesture based modeling , OOD, tool support, e whiteboard
21	A new approach to teaching object oriented concepts and methodlogy to informatiopn techonology students	information technology curriculum, it, object oriented modeling, data modeling approach, difficulties
22	Technologies and Strategies for Integrating Object-Oriented Analysis and Design Education with Programming	teaching strategies, students, OOP, UML, object oriented programming and design
23	The Two States of the Mind to Teach UML	humanities curricula, course development, UML, undergraduate and graduate
24	Modeling with Plato: The Unified Modeling Language in a Cultural Context	humanistic informatics, course development, curriculum, implementation and results , experience

25	Learning object-oriented software design at a distance	distance learning, CRC, role play, computer based simulation approach
26	Teaching UML Is Teaching Software Engineering Is Teaching Abstraction	abstraction, course design, UML ,CS
27	If I had a Model, I'd Model in the Mornin'	management information systems MIS, curriculum, course MDA
28	Executable/Translatable UML in Computing Education	UML, problems, executable UML, case studies, benefits
29	Interactive Exercises To Support Effective Learning of UML Structural Modeling	UML structural models, exercises, student learning
30	Software Modeling Techniques for a First Course in Software Engineering: A Workshop-Based Approach	CS curriculum, problems, workshop based approach, course development, curriculum development
31	UML Tools: What is their Role in Undergraduate Computer Science Courses?	course design, UML tools, computer science
32	The Role of Collaboration Diagrams in OO Software Engineering Student Projects	student projects, comparison, sequence diagram, collaboration diagram, UML diagrams
33	tool support for Collaborative teaching and learning of Object-Oriented Modeling	tool, ideogram UML, gesture based collaborative modeling, UML, project assignments
34	An Information Modelling Approach to Teaching Object-oriented Analysis	information modeling, tools, modeling notation, case studies
35	Fostering UML Modeling Skills and Social Skills through Programming Education	UML modeling , template, class based design skills, PBL, Lego mind storms
36	object oriented real world modeling revisited	modeling, real world, pseudo world, class diagrams
37	Evaluating the Effect of Composite States on the Understandability of UML State chart Diagrams	UML, state charts, diagrams, understandability, evaluation, composite states
38	Best Practices for Teaching UML Based Software Development	UML, experiences, course design, teaching,
39	The UML Is More Than Boxes and Lines	UML ,laboratory material, well-formedness, semantics, teaching
40	UML for undergraduate software engineering	UML, undergraduate, course design, diagrams & components
41	Teaching UML Using Umple: Applying Model-Oriented Programming in the Classroom	UMPLE, web based code generation, teaching method,
42	A Method of Elicitation Teaching for Object-Oriented Analysis and Design Curriculum	UML, curriculum design, OOAD, elicitation teaching, SE
43	Applying Case Method Approach to a Unified Modeling Language Curriculum	UML, case method, curriculum design, se,
44	Exploring Teachers' Attitudes Towards Object Oriented Modelling and Programming in Secondary Schools	teacher attitude, secondary school, curriculum, CS
45	Empirical Validation of Measures for UML Class Diagrams: A Meta-Analysis Study	UML, class diagram, complexity, meta analysis study, experiment
46	An Introduction to Class Based Domain Modelling	guideline, framework curriculum, software engineering, class based model
47	Teaching Object Oriented Concepts with Eclipse	story diagrams, eclipse ,class diagrams
48	Teaching Object-Oriented Modeling and UML to Various Audiences	UML, CS, experience, course design, limitations,
49	Applying Pantomime and Reverse Engineering Techniques in Software Engineering Education	speechless modeling, pantomime, reverse semantic traceability, curriculum, CS, SE
50	Using Pantomime in Teaching OOA&OOD with UML	UML, speechless modeling, software development problems
51	The EasyCRC Tool	easy CRC, tool, UML, sequence diagrams, CRC cards
52	Evolving an Integrated Curriculum for Object-Oriented Analysis and Design	OOAD, experience ,case studies, curriculum, CS

53	Teaching Object-Orientation with the Object Visualization and Annotation Language (OVAL)	oval, graphical language
54	Teaching Undergraduate Students to Model Use Cases Using Tree Diagram Concepts	Use case diagrams, description, tree diagram, software engineering, undergraduate
55	Experiences in Threading UML Throughout a Computer Science Program	UML, curriculum, CS, experience, course design
56	Teaching Consistency of UML Specifications	Teaching material, consistency issues, UML, specifications
57	Current Issues in Teaching Software Modeling: Educators Symposium at MODELS 2008	summary, issues, teaching modeling
58	A web-based e-learning tool for UML class diagrams	UML, class diagram, e learning, teaching, tool
59	Teaching UML Modeling Before Programming at the High School Level	uml, teaching experience
60	Concept Identification in Object-Oriented Domain Analysis: Why Some Students Just Don't Get It	difficulties OOAD, classification of difficulties
61	Teaching Software Modeling in a Simulated Project Environment	difficulties, teaching tools, teaching UML, simulated environment
62	Implementation of Object-Orientation Using UML in Entry Level Software Development Courses	UML, course design, curriculum design, CS
63	Design for Object-Oriented Modeling Course Blending Individual and Collaborative Learning Activities	experience, collaborative, individual, OOM, course design, undergraduates
64	How to Teach Software Modeling	ways to teach , technique
65	Minim UML: A Minimalist Approach to UML Diagramming for Early Computer Science Education	tool, UML, diagrams, CS
66	If You're Not Modeling, You're Just Programming: Modeling Throughout an Undergraduate Software Engineering Program	techniques, pedagogy, teaching undergraduate, SE
67	Teaching Novice Conceptual Data Modellers to Become Experts	difficulites, problems, novice, techniques
68	Mismatches between Industry Practice and Teaching of Model-Driven Software Development	model driven software development, issues, problems, industry, academic
69	Teaching Software Design Using a Case Study on Model Transformation	model transformation, case study example
70	The Theory and Practice of Bilingual Teaching in "Object-Oriented Software Engineering"	bilingual teaching, advantages, OOSE, course design
71	Creative Object-Oriented Modelling: Support for Intuition, Flexibility, and Collaboration in CASE Tools	collaborative, whiteboard, intuitive, flexibility, tool, UML, gesture based
72	Thinking in Object Structures: Teaching Modelling in Secondary Schools	secondary school, teaching, methods, pedagogy
73	Teaching Models @ BIG: On Efficiently Assessing Modeling Concepts	UML, experiences, examples, exercises, tests, assessing, modeling knowledge
74	Can Graduating Students Design: Revisited	validating, experiment results, pedagogic recommendations
75	Can Graduating Students Design Software Systems?	experiment, student performance
76	Modelling: A Neglected Feature in the Software Engineering Curriculum	curriculum design, SE, modeling issues
77	Toward Better Logical Models in UML	UML, hierarchical, class representation, logical models
78	On the Contribution of UML Diagrams to Software System Comprehension	uml, diagrams, understandability, comprehension
79	Formalism, technique and rigor in Use Case Modeling	UML, use case, rigor, formal
80	Role Playing in an Object-Oriented World	course design, role playing, exercise, OOD, CS
81	A Laboratory For Teaching Object-Oriented Thinking	CRC, teaching pedagogy, exercise
82	Reflections on CRC Cards for OO Design	CRC, reflection cards, strengths weakness, observation

83	Initial classification of related issues: teaching modeling	teaching, course design, discussion, classification
84	An Initial Experimental Assessment of the Dynamic Modelling in UML	UML, diagram, sequence, comprehension, dynamic modeling, collaboration state chart
85	Student UML: An Educational Tool Supporting Object-Oriented Analysis and Design	UML, tool,OOAD
86	Evaluation of Student UML: an Educational Tool for Consistent Modelling with UML	UML, tool, evaluation, students
87	UML grader: An Automated Class Diagram Grader	UML grader, class diagrams, tool
88	A Constraint-Based Tutor for Learning Object-Oriented Analysis and Design using UML	tool, uml, constraint based modeling intelligent tutoring system,
89	An Evaluation of Pedagogical Feedbacks in DIAGRAM, a Learning Environment for Object-Oriented Modeling	evaluation , learning environment, class diagrams,
90	Evaluating a Collaborative Constraint-based Tutor for UML Class Diagrams	evaluation, collect UML,
91	Supporting collaborative learning and problem-solving in a constraint-based CSCL environment for UML class diagrams	implementation, design, collect UML, UML
92	How Should Teaching Modeling and Programming Intertwine?	experience, OOM, UML course design, SE
93	Teaching Models @ BIG: Replacing Traditional Classroom Lectures with Lecture Videos – An Experience Report	course design, lecture videos, survey
94	Teaching Models @ BIG: How to Give 1000 Students an Understanding of the UML	experiences, course design, UML
95	An E-whiteboard Application to Support Early Design-Stage Sketching of UML Diagrams	tool, sketches, UML, collaborative, e whiteboard pen based
96	Pen-based Input of UML Activity Diagrams for Business Process Modelling	Tool, UML, sketch activity diagram, pen based input
97	Enhancing UML Sketch Tools with Digital Pens and Paper	tool, UML, sketches, pen paper
98	SUMLOW: Early Design-Stage Sketching of UML Diagrams on an E-whiteboard	tool, sketches, UML, collaborative, e whiteboard pen based
99	Supporting Several Levels of Restriction in the UML	tool, collaborative, gesture recognition, e white board, sketches
100	How Interactive Whiteboards Can be Used to Support Collaborative Modeling	whiteboard, collaborative, interviews
101	Calico: A Tool for Early Software Design Sketching	sketches, collaborative, tool
102	Teaching Object-Oriented Analysis and Design: A cognitive approach.	Cognitive Models, Mental Models, Educational Theories, Object-Oriented Analysis and Design, Computer-Based Training Tools
103	Object oriented design: a teaching environment	tool, CRC based, teaching OOM
104	Teaching OOAD with active lectures and brainstorms	techniques, active e-learning, pedagogy, teaching , course design
105	Using UML To Facilitate The Teaching Of Object-Oriented Systems Analysis And Design	course design, UML
106	What is a Model?	undamentals, definitions,
107	How UML IS USED	UML, diagrams,usage, guidelines
108	Does UML make the grade? Insights from the software development community	valuation of UML, survey, effectiveness
109	The impact of structural complexity on the Understandability of UML state chart diagrams	UML State chart diagram Model quality Structural complexity Understandability Metrics Prediction Empirical validation Experiment
110	Inconsistencies in Student Designs	UML, diagrams, inconsistencies, didactic development process, student design

111	An Empirical Study on Using Stereotypes to Improve Understanding of UML Models	UML, stereotypes, comprehension, understanding, models
112	A Prophylactic Approach to Teaching UML in an Undergraduate Introduction to Software Engineering Course	UML, course design, cognitive theory, prophylactic approach, experiment
113	Early measures for UML class diagrams	UML, class diagram, metric, measurement
114	“The Babel Experiment”: An Advanced Pantomime-based Training in OOA&OOD with UM	UML, experiment, pantomime, game, speechless modeling
115	Teaching Object-Oriented Design with UML – A Blended Learning Approach	UML, blended learning, e-learning
116	Teaching object oriented software engineering with UML	UML, DIAGRAMS, objected oriented design, teaching SE, course design
117	A Phased Highly-Interactive Approach to Teaching UML-based Software Development	Undergraduate Software Engineering course, multi-phase course project, MDA, UML-based development method, Project community forum, Questionnaire
118	Teaching Experiences with UML at The University of Texas at Dallas	course design, UML, teaching experience
119	Integrating Visual Modeling throughout the Computer Science Curriculum	curriculum, UML, graphical/ visual modeling, course design
120	Using Experiments in Software Engineering as an Auxiliary Tool for Teaching – A Perspective of Students' Learning Process	experiments, course design, OOSD
121	Identifying Novice Difficulties in Object Oriented Design	design faults, class design,
122	Threshold Concepts in Object-Oriented Modelling	OO modelling, threshold concepts, Concept maps, Class diagram, Sequence, undergraduate
123	Teaching Object Oriented Modelling With CRC-Cards And Role playing Games	CRC cards, role playing games
124	37 Things that Don't Work in Object-Oriented Modelling with UML	UML, problems, developers, class diagram, use case, case tools
125	A Cooperation Model for Teaching/Learning Modeling Disciplines	collaborative, co-operative model, teaching and learning
126	CRC-Cards and Role play Diagrams Informal Tools to Teach OO Thinking	CRC, roleplay, experiences
127	Object Oriented Analysis and Design: Do We Need More UML in the Classroom?	survey, UML, it, curriculum, diagrams
128	UML 2 Teaching at Postgraduate Studies –Prerequisites and Practice	didactic, UML, postgraduate, problems, solutions, experience
129	Using Controlled Experiments for Validating UML Using Controlled Experiments for Validating UML State chart Diagrams Measures	UML, state charts, diagrams, understandability, measurement
130	Nice Class Diagrams Admit Good Design?	UML, class diagrams, framework, aesthetics, metrics, HCI, software engineering
131	Dynamic Object Structures as a Conceptual Framework for Teaching Object Oriented Concepts to Novices	object structures, conceptual framework, UML

Table 57 Keywords & Selected studies

12.15 SMP Results: Publication Fora

Name of the Conference/work shop/ journal	conference	Works shop/ journal	Total
Oopsla	[SMP 1],[SMP 12], [SMP 27],[SMP 81]	[SMP 47](w), [SMP 104] (w)	6
International congress on engineering education	[SMP 2]		1
Conference on software engineering education and training	[SMP 3],[SMP 32], [SMP 35],[SMP 76], [SMP 41],[SMP 50]		6
Frontiers in education conference	[SMP 4],[SMP 25], [SMP 29],[SMP 49]		4
EUROMICRO conference	[SMP 5]		1
ITS (conference)	[SMP 6],[SMP 88]		2
Transactions on education		[SMP 7](j),[SMP 30](j) ,[SMP 55](j)	3
Models Edusymp	[SMP 17],[SMP 38], [SMP 39],[SMP 37], [SMP 57],[SMP 83], [SMP 107]	[SMP 8](w), [SMP 10] (w),[SMP 14](w), [SMP 26] (w),[SMP 45] (w),[SMP 48](w), [SMP 61](w), [SMP 66] (w),[SMP 68](w), [SMP 92](w)[SMP 93](w),[SMP 94](w),[SMP 118](w), [SMP 122](w),[SMP 117](w),	22
Numerical Analysis and Applied Mathematics ICNAAM	[SMP 9]		1
CITC	[SMP 11]		1
Sigcse	[SMP 13],[SMP 31], [SMP 52],[SMP 74], [SMP 75], [SMP 80], [SMP 114]		7
ICSE	[SMP 15],[SMP 64]		2
ITICSE	[SMP 16],[SMP 23], [SMP 24],[SMP 33], [SMP 53],[SMP 121]		6
CSEE	[SMP 18]		1
Information Technology interface/TI	[SMP 19]		1
Chi	[SMP 20]		1
Ccsc	[SMP 21],[SMP 40], [SMP 87],[SMP 105]		4
Australian conference on software engineering	[SMP 22]		1
Australasian computing education conference(ACE)	[SMP 28]		1
Software education conference	[SMP 34],[SMP 46]		2
Journal of system and software		[SMP 36](j)	1
International conference for young computing scientists	[SMP 42]		1
International conference on education technology and computing (ICETC)	[SMP 43]		1
ICER	[SMP 44]		1
International conference on software engineering advances (ICSEA)	[SMP 51]		1
Wiley periodicals, inccomput APPI engedu		[SMP 54](j)	1
Requirements engineering education and training (REET)		[SMP 56](W)	1
Educon	[SMP 58]		1

International conference n advanced learning technologies (ICALT)	[SMP 59]		1
International conference on requirements engineering (RE)	[SMP 60]		1
SIGITE	[SMP 62]		1
International conference on computer in education	[SMP 63]		1
Journal of educational resources in computing		[SMP 65](j)	1
CSEEP	[SMP 67]		1
International conference on information technology: new generations	[SMP 69]		1
International conference on computing engineering and technology	[SMP 70]		1
ECOOP	[SMP 71]	[SMP 72](w)	2
Journal of object technology	[SMP 77],[SMP 78], [SMP 79]		3
CRPIT	[SMP 82]		1
Empirical software engineering		[SMP 84](j)	1
Panhellenic conference on informatics(PCI)	[SMP 85]		1
Informatics education Europe IEE11	[SMP 86]		1
AIED	[SMP 89],[SMP 90]		2
International journal of computer support collaborative learning (IJCSCL)		[SMP 91](j)	1
Human centric computing conference		[SMP 95](w)	1
HCI		[SMP 96](w)	1
SOFTVIS	[SMP 97]		1
SOFTWARE practice and experience		[SMP 98](j)	1
UML	[SMP 99]	[SMP 110](w)	2
Journal of universal computer science		[SMP 100](j)	1
VL/HCC workshop: Sketch tools for diagramming		[SMP 101](w)	1
World Multi-Conference on Systemics, Cybernetics and Informatics	[SMP 102]		1
Transactions on information and communications		[SMP 103](j)	1
Dagstuhl seminar		[SMP 106](seminar)	1
Communication of the acm		[SMP 107](j)	1
Information and software technology		[SMP 108](j)	1
Information sciences		[SMP 109](j)	1
International workshop on program comprehension (IWPC)		[SMP 111](w)	1
International conference on learning	[SMP 112]		1
L'object		[SMP 113](j)	1
Pedagogies and tools for learning object oriented concepts		[SMP 115](w)	1
EAEEIE (Annual conference on innovations in educations for electrical and information engineering	[SMP 116]		1
International journal of human and social sciences		[SMP 119](j)	1
SERPS		[SMP 120](w)	1
Wcce	[SMP 123]		1
Precise behavioural semantics		[SMP 124](w)	1
Internal workshop on groupware (CRIWG)		[SMP 125](w)	1
CETUSS workshop on computer science education		[SMP 126](w)	1
Information systems education journal(isedi)		[SMP 127](j)	1

ISECON	[SMP 128]		1
Software process and product measurement		[SMP 129](j)	1
Symposium on software visualization		[SMP 130](w)	1
Conference on computer science education	[SMP 131]		1

Table 58 SMP : Results Publication Fora

12.16 Relationship between Research Method type & Manual Classification

Relationship between Research Method type & Manual Classification			
ID	Relationship	Articles	Count
1	Language & Case study	[SMP 2] [SMP 9] [SMP 17] [SMP 35] [SMP 61] [SMP 95] [SMP 128]	7
	Language & Concept analysis	[SMP 5] [SMP 23] [SMP 29] [SMP 33] [SMP 39] [SMP 42] [SMP 43] [SMP 51] [SMP 53] [SMP 56] [SMP 58] [SMP 65] [SMP 71] [SMP 77] [SMP 79] [SMP 85] [SMP 87] [SMP 88] [SMP 91] [SMP 96] [SMP 97] [SMP 98] [SMP 105] [SMP 113] [SMP 115] [SMP 130] [SMP 131]	27
	Language & Interviews		
	Language & Survey	[SMP 10] [SMP 22] [SMP 107] [SMP 108] [SMP 109] [SMP 127]	6
	Language & Discussion	[SMP 31] [SMP 116]	2
	Language & Observational Study	[SMP 11] [SMP 15] [SMP 26] [SMP 28] [SMP 32] [SMP 38] [SMP 40] [SMP 48] [SMP 55] [SMP 59] [SMP 62] [SMP 73] [SMP 74] [SMP 78] [SMP 90] [SMP 92] [SMP 94] [SMP 110] [SMP 117] [SMP 118] [SMP 119] [SMP 124]	22
	Language & Experiment	[SMP 37] [SMP 45] [SMP 50] [SMP 84] [SMP 86] [SMP 111] [SMP 112] [SMP 114] [SMP 120] [SMP 129]	10
	Language & Concept analysis and case study		
	Language & Concept analysis and experiment	[SMP 6]	1
	Language & Concept analysis and observational study		
	Language & Concept analysis and survey	[SMP 41]	1
	Language & Literature review and interviews		
	Language & Discussion and interviews		
2	Diagrams & Case study		
	Diagrams & Concept analysis	[SMP 1] [SMP 36] [SMP 47] [SMP 51] [SMP 54] [SMP 58] [SMP 65] [SMP 87] [SMP 96] [SMP 113] [SMP 130]	11
	Diagrams & Interviews		
	Diagrams & Survey	[SMP 107] [SMP 109] [SMP 122] [SMP 127]	4
	Diagrams & Discussion	[SMP 116]	1
	Diagrams & Observational Study	[SMP 32] [SMP 40] [SMP 78] [SMP 89] [SMP 110] [SMP 124]	6
	Diagrams & Experiment	[SMP 37] [SMP 45] [SMP 84] [SMP 129]	4
	Diagrams & Concept analysis and case study		
	Diagrams & Concept analysis and experiment	[SMP 6]	1
	Diagrams & Concept analysis and observational study		
	Diagrams & Concept analysis and survey		
	Diagrams & Literature review and interviews		
	Diagrams & Discussion and interviews		
3	Curriculum & Case study	[SMP 27] [SMP 30] [SMP 76]	3
	Curriculum & Concept analysis	[SMP 4] [SMP 21] [SMP 23] [SMP 42] [SMP 43] [SMP 46] [SMP 70]	7

	Curriculum & Interviews		
	Curriculum & Survey	[SMP 44] [SMP 127]	2
	Curriculum & Discussion		
	Curriculum & Observational Study	[SMP 19] [SMP 49] [SMP 52] [SMP 55] [SMP 62] [SMP 63] [SMP 119]	7
	Curriculum & Experiment		
	Curriculum & Concept analysis and case study		
	Curriculum & Concept analysis and experiment		
	Curriculum & Concept analysis and observational study		
	Curriculum & Concept analysis and survey		
	Curriculum & Literature review and interviews		
	Curriculum & Discussion and interviews		
4	Course & Case study	[SMP 9] [SMP 27] [SMP 30]	3
	Course & Concept analysis	[SMP 23] [SMP 104] [SMP 105]	3
	Course & Interviews		
	Course & Survey	[SMP 10] [SMP 93]	2
	Course & Discussion	[SMP 31] [SMP 116]	2
	Course & Observational Study	[SMP 7] [SMP 26] [SMP 38] [SMP 40] [SMP 48] [SMP 55] [SMP 62] [SMP 80] [SMP 92] [SMP 94] [SMP 117] [SMP 118] [SMP 119]	13
	Course & Experiment	[SMP 112] [SMP 120]	2
	Course & Concept analysis and case study		
	Course & Concept analysis and experiment		
	Course & Concept analysis and observational study		
	Course & Concept analysis and survey		
	Course & Literature review and interviews		
	Course & Discussion and interviews	[SMP 83]	1
5	Others & Case study	[SMP 12] [SMP 14] [SMP 16] [SMP 34] [SMP 60]	5
	Others & Concept analysis	[SMP 13] [SMP 20] [SMP 67] [SMP 69] [SMP 72] [SMP 81] [SMP 99] [SMP 102] [SMP 103] [SMP 123]	10
	Others & Interviews	[SMP 100] [SMP 101]	2
	Others & Survey		
	Others & Discussion	[SMP 8] [SMP 64]	2
	Others & Observational Study	[SMP 3] [SMP 57] [SMP 66] [SMP 82] [SMP 106] [SMP 121]	6
	Others & Experiment	[SMP 18] [SMP 75]	2
	Others & Concept analysis and case study	[SMP 125]	1
	Others & Concept analysis and experiment		
	Others & Concept analysis and observational study	[SMP 126]	1
	Others & Concept analysis and survey		
	Others & Literature review and interviews	[SMP 68]	1
	Others & Discussion and interviews		

Table 59 Relationship between Research Method type & Manual Classification

12.17 Relationship between Research type & Manual Classification

Relationship between Research type & Manual Classification			
ID	Relationship	Articles	Count
1	Language & Experience paper	[SMP 10] [SMP 11] [SMP 26] [SMP 32] [SMP 38] [SMP 39] [SMP 41] [SMP 43] [SMP 48] [SMP 55] [SMP 56] [SMP 59] [SMP 62] [SMP 73] [SMP 78] [SMP 92] [SMP 94] [SMP 110] [SMP 117] [SMP 118] [SMP 119] [SMP 124] [SMP 128]	23
	Language & Opinion	[SMP 2] [SMP 14] [SMP 15] [SMP 31] [SMP 40] [SMP 105] [SMP 116]	7
	Language & Evaluation research	[SMP 9] [SMP 37] [SMP 45] [SMP 84] [SMP 86] [SMP 90] [SMP 107] [SMP 108] [SMP 111] [SMP 112] [SMP 127] [SMP 129]	12
	Language & Solution proposal	[SMP 5] [SMP 23] [SMP 42] [SMP 53] [SMP 77] [SMP 79] [SMP 85] [SMP 87] [SMP 88] [SMP 91] [SMP 95] [SMP 96] [SMP 97] [SMP 130] [SMP 131]	15
	Language & Solution proposal and evaluation research	[SMP 6] [SMP 113]	2
	Language & Solution proposal and validation study	[SMP 28] [SMP 29] [SMP 33] [SMP 35] [SMP 50] [SMP 51] [SMP 58] [SMP 65] [SMP 71] [SMP 98] [SMP 114] [SMP 115]	12
	Language & Validation Study	[SMP 22] [SMP 74] [SMP 109]	3
	Language & Solution proposal and experience		0
	Language & Experience paper and validation study	[SMP 17] [SMP 61]	2
2	Diagrams & Experience paper	[SMP 1] [SMP 32] [SMP 78] [SMP 110] [SMP 124]	5
	Diagrams & Opinion	[SMP 36] [SMP 40] [SMP 116]	3
	Diagrams &Evaluation research	[SMP 37] [SMP 45] [SMP 84] [SMP 89] [SMP 107] [SMP 127] [SMP 129]	7
	Diagrams &Solution proposal	[SMP 47] [SMP 87] [SMP 96] [SMP 130]	4
	Diagrams &Solution proposal and evaluation research	[SMP 6] [SMP 113]	2
	Diagrams &Solution proposal and validation study	[SMP 51] [SMP 54] [SMP 58] [SMP 65] [SMP 122]	5
	Diagrams &Validation Study	[SMP 109]	1
	Diagrams & Solution proposal and experience		0
	Diagrams & Experience paper and validation study		0
3	Curriculum & Experience paper	[SMP 19] [SMP 30] [SMP 43] [SMP 44] [SMP 52] [SMP 55] [SMP 62] [SMP 76] [SMP 119]	9
	Curriculum & Opinion		0
	Curriculum & Evaluation research	[SMP 49] [SMP 127]	2
	Curriculum & Solution proposal	[SMP 4] [SMP 21] [SMP 23] [SMP 42] [SMP 46]	5
	Curriculum & Solution proposal and evaluation research		0
	Curriculum & Solution proposal and validation study	[SMP 24]	1

	Curriculum & Validation Study	[SMP 27]	1
	Curriculum & Solution proposal and experience		0
	Curriculum & Experience paper and validation study		0
4	Course & Experience paper	[SMP 7] [SMP 10] [SMP 26] [SMP 30] [SMP 38] [SMP 48] [SMP 55] [SMP 62] [SMP 63] [SMP 92] [SMP 93] [SMP 94] [SMP 117] [SMP 118] [SMP 119]	15
	Course & Opinion	[SMP 31] [SMP 40] [SMP 105] [SMP 116]	4
	Course & Evaluation research	[SMP 9] [SMP 112] [SMP 120]	3
	Course & Solution proposal	[SMP 23] [SMP 83] [SMP 104]	3
	Course & Solution proposal and evaluation research		0
	Course & Solution proposal and validation study	[SMP 24] [SMP 70]	2
	Course & Validation Study	[SMP 27]	1
	Course & Solution proposal and experience		0
	Course & Experience paper and validation study		0
5	Others & Experience paper	[SMP 16] [SMP 18] [SMP 34] [SMP 57] [SMP 66] [SMP 72] [SMP 82] [SMP 121] [SMP 123]	9
	Others & Opinion	[SMP 8] [SMP 64] [SMP 67] [SMP 106]	4
	Others & Evaluation research	[SMP 3] [SMP 12] [SMP 68] [SMP 75] [SMP 100]	5
	Others & Solution proposal	[SMP 13] [SMP 25] [SMP 69] [SMP 102] [SMP 103] [SMP 125]	6
	Others & Solution proposal and evaluation research	[SMP 20]	1
	Others & Solution proposal and validation study	[SMP 60] [SMP 99] [SMP 101]	3
	Others & Validation Study		0
	Others & Solution proposal and experience	[SMP 81] [SMP 126]	2
	Others & Experience paper and validation study		0

Table 60 Relationship between Research type & Manual Classification

12.18 Relationship between Contribution type & Manual Classification

Relationship between Contribution type & Manual Classification			
ID	Relationship	Articles	Count
1	Languages and process	[SMP 2] [SMP 9] [SMP 10] [SMP 11] [SMP 14] [SMP 15] [SMP 22] [SMP 23] [SMP 26] [SMP 28] [SMP 29] [SMP 31] [SMP 35] [SMP 38] [SMP 39] [SMP 40] [SMP 42] [SMP 43] [SMP 45] [SMP 48] [SMP 55] [SMP 56] [SMP 59] [SMP 61] [SMP 62] [SMP 73] [SMP 74] [SMP 86] [SMP 90] [SMP 92] [SMP 94] [SMP 105] [SMP 107] [SMP 108] [SMP 109] [SMP 110] [SMP 112] [SMP 115] [SMP 117] [SMP 118] [SMP 119] [SMP 124] [SMP 128]	43
	Languages and Method	[SMP 17] [SMP 32] [SMP 33] [SMP 37] [SMP 53] [SMP 79] [SMP 84] [SMP 91] [SMP 114] [SMP 116] [SMP 130]	10
	Languages and Tool	[SMP 5] [SMP 6] [SMP 51] [SMP 58] [SMP 65] [SMP 71] [SMP 85] [SMP 87] [SMP 88] [SMP 95] [SMP 96] [SMP 97] [SMP 98]	13
	Languages and Method*Process	[SMP 41] [SMP 50] [SMP 131]	3
	Language and Measurement	[SMP 111] [SMP 113] [SMP 127] [SMP 129]	4
	Languages and Model	[SMP 77] [SMP 78]	2
	Languages and Process * Tool		0
2	Diagram and process	[SMP 36] [SMP 40] [SMP 45] [SMP 46] [SMP 89] [SMP 107] [SMP 109] [SMP 110] [SMP 122] [SMP 124]	10
	Diagram and Method	[SMP 32] [SMP 37] [SMP 47] [SMP 54] [SMP 78] [SMP 84] [SMP 116] [SMP 130]	8
	Diagram and Tool	[SMP 6] [SMP 51] [SMP 58] [SMP 65] [SMP 87] [SMP 96]	6
	Diagram and Method*Process	[SMP 1]	1
	Diagrams and Measurement	[SMP 113] [SMP 127] [SMP 129]	3
	Diagrams and Model		0
	Diagram and Process * Tool		0
3	Curriculum and process	[SMP 19] [SMP 21] [SMP 23] [SMP 24] [SMP 27] [SMP 30] [SMP 42] [SMP 43] [SMP 52] [SMP 55] [SMP 62] [SMP 76] [SMP 119]	13
	Curriculum and Method	[SMP 4]	1
	Curriculum and Tool		0
	Curriculum and Method*Process	[SMP 1] [SMP 49]	2
	Curriculum and Measurement	[SMP 127]	1
	Curriculum and Model		0
	Curriculum and Process * Tool		0
4	Course and process	[SMP 7] [SMP 9] [SMP 10] [SMP 23] [SMP 24] [SMP 26] [SMP 27] [SMP 30] [SMP 31] [SMP 38] [SMP 40] [SMP 48] [SMP 117]SMP 48] [SMP 55] [SMP 62] [SMP 63] [SMP 70] [SMP 80] [SMP 83] [SMP 92] [SMP 94] [SMP 104] [SMP 105] [SMP 112] [SMP 117] [SMP 118] [SMP 119]	28
	Course and Method	[SMP 116]	1
	Course and Tool		0
	Course and Method*Process	[SMP 93]	1
	Course and Measurement	[SMP 120]	1
	Course and Model		0
	Course and Process * Tool		0
5	Others and process	[SMP 3] [SMP 8] [SMP 13] [SMP 16] [SMP 25] [SMP 34] [SMP 57]	18

		[SMP 60] [SMP 64] [SMP 66] [SMP 67] [SMP 68] [SMP 72] [SMP 75] [SMP 82] [SMP 106] [SMP 121] [SMP 123]	
	Others and Method	[SMP 18] [SMP 81] [SMP 125]	3
	Others and Tool	[SMP 20] [SMP 99] [SMP 100] [SMP 101]	4
	Others and Method*Process	[SMP 12] [SMP 126]	2
	Others and Measurement		0
	Others and Model	[SMP 69] [SMP 102]	2
	Others and Process * Tool	[SMP 103]	1

Table 61 Relationship between Contribution type & Manual Classification

12.19 Rigor & Relevance for SMP studies

	Rigor					Industrial Relevance					
SNO	**SMP**	**Context**	**Study Design**	**Validity Threats**	**Total**	**SMP**	**Context**	**Subject**	**Scale**	**Research Method**	**Total**
1	1	1	1	0	2	1	0	0	0	0	0
2	3	1	0.5	0	1.5	3	0	0	0	0	0
3	5	1	0	0	1	5	0	0	0	0	0
4	6	1	0.5	0	1.5	6	0	0	0	0	0
5	7	0.5	0.5	0	1	7	0	0	0	0	0
6	9	0.5	0	0	0.5	9	0	0	0	0	0
7	10	1	1	0	2	10	0	0	0	1	1
8	12	1	1	0.5	2.5	12	0	0	0	1	1
9	13	1	0.5	0	1.5	13	0	0	0	0	0
10	16	1	0.5	0	1.5	16	0	0	0	1	1
11	17	1	1	0	2	17	0	0	0	1	1
12	18	1	1	0.5	2.5	18	0	0	0	1	1
13	**20**	**1**	**1**	**1**	**3**	**20**	**1**	**1**	**0**	**1**	**3**
14	**22**	**1**	**1**	**1**	**3**	22	0	0	0	1	1
15	24	1	1	0	2	24	0	0	0	0	0
16	28	1	1	0	2	28	0	0	0	0	0
17	29	0.5	1	0	1.5	29	0	0	0	0	0
18	30	1	1	0	2	30	0	0	0	1	1
19	32	1	1	0	2	32	0	0	0	0	0
20	33	1	1	0	2	33	0	0	0	0	0
21	35	1	1	0	2	35	0	0	0	1	1
22	36	1	1	0	2	36	0	0	0	0	0
23	**37**	**1**	**1**	**1**	**3**	37	0	0	0	1	1
24	39	1	1	0.5	2.5	39	0	0	0	0	0
25	**41**	**1**	**1**	**1**	**3**	41	0	0	0	0	0
26	**45**	**1**	**1**	**1**	**3**	45	0	0	0	0	0
27	49	1	0.5	0	1.5	49	0	0	0	0	0
28	50	1	1	0	2	50	0	0	0	1	1
29	52	1	1	0.5	2.5	52	0	0	0	0	0
30	54	1	1	0	2	54	0	0	0	0	0
31	55	0.5	1	0	1.5	55	0	0	0	0	0
32	58	1	1	0	2	58	0	0	0	0	0
33	60	1	1	0	2	60	0	0	0	1	1
34	61	1	1	0	2	61	0	0	0	1	1
35	63	1	1	0	2	63	0	0	0	0	0
36	65	1	1	0	2	65	0	0	0	1	1
37	68	1	1	0	2	**68**	**1**	**1**	**0**	**1**	**3**
38	70	1	0.5	0	1.5	70	0	0	0	0	0
39	71	1	1	0.5	2.5	**71**	**1**	**1**	**0**	**1**	**3**
40	72	1	1	0	2	72	0	0	0	0	0
41	73	1	0.5	0	1.5	73	0	0	0	0	0
42	**74**	**1**	**1**	**1**	**3**	74	0	0	0	0	0
43	75	1	1	0	2	75	0	0	0	1	1
44	76	1	1	0	2	76	0	0	0	1	1
45	77	1	1	0	2	**77**	**1**	**1**	**0**	**1**	**3**
46	78	1	1	0	2	78	0	0	0	0	0
47	80	1	1	0	2	80	0	0	0	0	0

48	81	1	1	0	2	81	0	0	0	0	0
49	82	0	1	0	1.5	82	0	0	0	0	0
50	84	0.5	1	1	2.5	84	0	0	0	1	1
51	86	1	1	0	2	86	0	0	0	1	1
52	87	1	1	0	2	87	0	0	0	0	0
53	89	1	0.5	0	1.5	89	0	0	0	0	0
54	90	0.5	0.5	0	1	90	0	0	0	0	0
55	91	1	1	0	2	91	0	0	0	0	0
56	92	1	1	0	2	92	0	0	0	0	0
57	93	1	1	0.5	2.5	93	0	0	0	1	1
58	94	1	0.5	0	1.5	94	0	0	0	0	0
59	95	1	1	0	2	**95**	**1**	**1**	**0**	**1**	**3**
60	96	1	0.5	0	1.5	**96**	**1**	**1**	**0**	**1**	**3**
61	97	1	0	0	1	97	1	0	0	1	2
62	98	1	1	0.5	2.5	**98**	**1**	**1**	**0**	**1**	**3**
63	99	1	1	0	2	99	0	0	0	0	0
64	100	1	1	0	2	100	0	0	0	1	1
65	101	1	0.5	0	1.5	**101**	**1**	**1**	**0**	**1**	**3**
66	102	1	0.5	0	1.5	102	0	0	0	0	0
67	103	1	0.5	0	1.5	103	0	0	0	0	0
68	104	1	0.5	0	1.5	104	0	0	0	0	0
69	105	1	1	0	2	105	0	0	0	0	0
70	106	1	0.5	0	1.5	106	0	0	0	0	0
71	107	1	0.5	0	1.5	107	0	0	0	1	1
72	**108**	**1**	**1**	**1**	**3**	108	0	0	0	1	1
73	**109**	**1**	**1**	**1**	**3**	109	0	0	0	1	1
74	110	1	1	0	2	110	0	0	0	0	0
75	**111**	**1**	**1**	**1**	**3**	111	0	0	0	1	1
76	112	1	1	0	2	112	0	0	0	1	1
77	113	1	1	0.5	2.5	113	0	0	0	0	0
78	114	1	1	0	2	114	0	0	0	1	1
79	115	1	0.5	0	1.5	115	0	0	0	0	0
80	**117**	**1**	**1**	**1**	**3**	117	0	0	0	0	0
81	118	1	0.5	0	1.5	118	0	0	0	0	0
82	119	1	0.5	0	1.5	119	0	0	0	0	0
83	120	1	1	.5	2.5	120	0	0	0	1	1
84	121	1	1	0	2	121	0	0	0	1	1
85	122	1	1	0	2	122	0	0	0	0	0
86	126	1	0.5	0	1.5	126	0	0	0	0	0
87	127	1	1	0	2	127	0	0	0	1	1
88	128	1	1	0	2	128	0	0	0	0	0
89	129	0.5	1	0.5	2	129	0	0	0	1	1

Table 62 Rigor and Relevance for SMP studies

12.20 Citation count and ranking of SMP studies

S.no	Article ID	Title	Citations	Rank
1	[SMP 81]	A Laboratory For Teaching Object-Oriented Thinking	636	**1**
2	[SMP 107]	How UML IS USED	221	**2**
3	[SMP 20]	Tool Support for Cooperative Object-Oriented Design: Gesture Based Modeling on an Electronic Whiteboard	138	**3**
4	[SMP 113]	Early measures for UML class diagrams	85	**4**
5	[SMP 95]	An E-whiteboard Application to Support Early Design-Stage Sketching of UML Diagrams	65	**5**
6	[SMP 91]	Supporting collaborative learning and problem-solving in a constraint-based CSCL environment for UML class diagrams	56	**6**
7	[SMP 80]	Role Playing in an Object-Oriented World	54	**7**
8	[SMP 111]	An Empirical Study on Using Stereotypes to Improve Understanding of UML Models	53	**8**
9	[SMP 130]	Nice Class Diagrams Admit Good Design?	52	**9**
10	[SMP 108]	Does UML make the grade? Insights from the software development community	48	**10**
11	[SMP 106]	What is a Model?	44	**11**
12	[SMP 12]	Object-Oriented System Modeling with OMT		
13	[SMP 75]	Can Graduating Students Design Software Systems?	43	**12**
14	[SMP 13]	Do We Really Teach Abstraction?	39	**13**
15	[SMP 60]	Concept Identification in Object-Oriented Domain Analysis: Why Some Students Just Don’t Get It	33	**14**
16	[SMP 37]	Evaluating the Effect of Composite States on the Understandability of UML State chart Diagrams		
17	[SMP 71]	Creative Object-Oriented Modeling: Support for Intuition, Flexibility, and Collaboration in CASE Tools	32	**15**
18	[SMP 124]	37 Things that Don't Work in Object-Oriented Modeling with UML	31	**16**
19	[SMP 84]	An Initial Experimental Assessment of the Dynamic Modeling in UML		
20	[SMP 82]	Reflections on CRC Cards for OO Design	27	**17**
21	[SMP 36]	object oriented real world modeling revisited	26	**18**
22	[SMP 6]	A Constraint-Based Collaborative Environment for Learning UML Class Diagrams	25	**19**
23	[SMP 121]	Identifying Novice Difficulties in Object Oriented Design		
24	[SMP 1]	Improving CRC Card Role Play with Role Play Diagrams	23	**20**
25	[SMP 72]	Thinking in Object Structures: Teaching Modelling in Secondary Schools	22	**21**
26	[SMP 109]	The impact of structural complexity on the Understandability of UML state chart diagrams	21	**22**
27	[SMP 105]	Using UML To Facilitate The Teaching Of Object-Oriented Systems Analysis And Design	19	**23**
28	[SMP 28]	Executable/Translatable UML in Computing Education	18	**24**
29	[SMP 33]	tool support for Collaborative teaching and learning of Object-Oriented Modeling		
30	[SMP 17]	Facilitating the Definition of General Constraints in UML	17	**25**
31	[SMP 78]	On the Contribution of UML Diagrams to Software System Comprehension		
32	[SMP 123]	Teaching Object Oriented Modelling With CRC-Cards And Role playing Games		
33	[SMP 98]	SUMLOW: Early Design-Stage Sketching of UML Diagrams on an E-whiteboard	16	**26**
34	[SMP 101]	Calico: A Tool for Early Software Design Sketching		
35	[SMP 110]	Inconsistencies in Student Designs		
36	[SMP 5]	A Flyweight UML Modelling Tool for Software Development in Heterogeneous Environments	14	**27**
37	[SMP 65]	Minim UML: A Minimalist Approach to UML Diagramming for Early	12	**28**

		Computer Science Education		
38	[SMP 88]	A Constraint-Based Tutor for Learning Object-Oriented Analysis and Design using UML		
39	[SMP 99]	Supporting Several Levels of Restriction in the UML		
40	[SMP 3]	Software Engineering Education Needs Adequate Modeling Tools	11	**29**
41	[SMP 38]	Best Practices for Teaching UML Based Software Development		
42	[SMP 40]	UML for undergraduate software engineering		
43	[SMP 74]	Can Graduating Students Design: Revisited		
44	[SMP 18]	Teaching More Comprehensive Model-Based Software Engineering: Experience With Objectory's Use Case Approach	10	**30**
45	[SMP 45]	Empirical Validation of Measures for UML Class Diagrams: A Meta-Analysis Study		
46	[SMP 85]	Student UML: An Educational Tool Supporting Object-Oriented Analysis and Design		
47	[SMP 96]	Pen-based Input of UML Activity Diagrams for Business Process Modeling		
48	[SMP 11]	Using UML and Agile Development Methodologies to Teach Object-Oriented Analysis & Design Tools and Techniques	9	**31**
49	[SMP 15]	On the Education of Future Software Engineers		
50	[SMP 30]	Software Modeling Techniques for a First Course in Software Engineering: A Workshop-Based Approach		
51	[SMP 44]	Exploring Teachers’ Attitudes Towards Object Oriented Modelling and Programming in Secondary Schools		
52	[SMP 76]	Modelling: A Neglected Feature in the Software Engineering Curriculum		
53	[SMP 97]	Enhancing UML Sketch Tools with Digital Pens and Paper		
54	[SMP 125]	A Cooperation Model for Teaching/Learning Modeling Disciplines		
55	[SMP 129]	Using Controlled Experiments for Validating UML Using Controlled Experiments for Validating UML State chart Diagrams Measures		
56	[SMP 53]	Teaching Object-Orientation with the Object Visualization and Annotation Language (OVAL)	8	**32**
57	[SMP 116]	Teaching object oriented software engineering with UML		
58	[SMP 26]	Teaching UML Is Teaching Software Engineering Is Teaching Abstraction	7	**33**
59	[SMP 51]	The EasyCRC Tool		
60	[SMP 62]	Implementation of Object-Orientation Using UML in Entry Level Software Development Courses		
61	[SMP 128]	UML 2 Teaching at Postgraduate Studies –Prerequisites and Practice		
62	[SMP 41]	Teaching UML Using Umple: Applying Model-Oriented Programming in the Classroom	6	**34**
63	[SMP 48]	Teaching Object-Oriented Modeling and UML to Various Audiences		
64	[SMP 50]	Using Pantomime in Teaching OOA&OOD with UML		
65	[SMP 61]	Teaching Software Modeling in a Simulated Project Environment		
66	[SMP 94]	Teaching Models @ BIG: How to Give 1000 Students an Understanding of the UML		
67	[SMP 115]	Teaching Object-Oriented Design with UML –A Blended Learning Approach		
68	[SMP 10]	Novel Communication Channels in Software Modeling Education	5	**35**
69	[SMP 55]	Experiences in Threading UML Throughout a Computer Science Program		
70	[SMP 64]	How to Teach Software Modeling		
71	[SMP 67]	Teaching Novice Conceptual Data Modellers to Become Experts		
72	[SMP 117]	A Phased Highly-Interactive Approach to Teaching UML-based Software Development		
73	[SMP 39]	The UML Is More Than Boxes and Lines	4	**36**
74	[SMP 58]	A web-based e-learning tool for UML class diagrams		
75	[SMP 59]	Teaching UML Modeling Before Programming at the High School Level		
76	[SMP 73]	Teaching Models @ BIG: On Efficiently Assessing Modeling Concepts		

77	[SMP 100]	How Interactive Whiteboards Can be Used to Support Collaborative Modeling		
78	[SMP 114]	“The Babel Experiment”: An Advanced Pantomime-based Training in OOA&OOD with UML		
79	[SMP 25]	Learning object-oriented software design at a distance	3	**37**
80	[SMP 27]	If I had a Model, I’d Model in the Mornin’		
81	[SMP 49]	Applying Pantomime and Reverse Engineering Techniques in Software Engineering Education		
82	[SMP 118]	Teaching Experiences with UML at The University of Texas at Dallas		
83	[SMP 16]	A Systematic Approach to Teaching Abstraction and Mathematical Modeling	2	**38**
84	[SMP 22]	Technologies and Strategies for Integrating Object-Oriented Analysis and Design Education with Programming		
85	[SMP 47]	Teaching Object Oriented Concepts with Eclipse		
86	[SMP 52]	Evolving an Integrated Curriculum for Object-Oriented Analysis and Design		
87	[SMP 69]	Teaching Software Design Using a Case Study on Model Transformation		
88	[SMP 92]	How Should Teaching Modeling and Programming Intertwine?		
89	[SMP 102]	Teaching Object-Oriented Analysis and Design: A cognitive approach.		
90	[SMP 131]	Dynamic Object Structures as a Conceptual Framework for Teaching Object Oriented Concepts to Novices		
91	[SMP 4]	Teaching Object-Oriented Software Design within the Context of Software Frameworks	1	**39**
92	[SMP 7]	Analyzing Course Configurations for Teaching Object-Oriented Modeling and Design		
93	[SMP 24]	Modeling with Plato: The Unified Modeling Language in a Cultural Context		
94	[SMP 32]	The Role of Collaboration Diagrams in OO Software Engineering Student Projects		
95	[SMP 35]	Fostering UML Modeling Skills and Social Skills through Programming Education		
96	[SMP 43]	Applying Case Method Approach to a Unified Modeling Language Curriculum		
97	[SMP 54]	Teaching Undergraduate Students to Model Use Cases Using Tree Diagram Concepts		
98	[SMP 56]	Teaching Consistency of UML Specifications		
99	[SMP 57]	Current Issues in Teaching Software Modeling: Educators Symposium at MODELS 2008		
100	[SMP 66]	If You’re Not Modeling, You’re Just Programming:Modeling Throughout an Undergraduate Software Engineering Program		
101	[SMP 68]	Mismatches between Industry Practice and Teaching of Model-Driven Software Development		
102	[SMP 70]	The Theory and Practice of Bilingual Teaching in “Object-Oriented Software Engineering”		
103	[SMP 77]	Toward Better Logical Models in UML		
104	[SMP 79]	Formalism, technique and rigor in Use Case Modeling		
105	[SMP 83]	Initial classification of related issues: teaching modeling		
106	[SMP 89]	An Evaluation of Pedagogical Feedbacks in DIAGRAM, a Learning Environment for Object-Oriented Modeling		
107	[SMP 90]	Evaluating a Collaborative Constraint-based Tutor for UML Class Diagrams		
108	[SMP 103]	Object oriented design: a teaching environment		
109	[SMP 120]	Using Experiments in Software Engineering as an Auxiliary Tool for Teaching – A Perspective of Students’ Learning Process		
110	[SMP 122]	Threshold Concepts in Object-Oriented Modelling		
111	[SMP 2]	Using Of Object Oriented Approach Design Models Learning In Information Software Engineering	0	**40**
112	[SMP 8]	Teaching Modeling: Why, When, What?		
113	[SMP 9]	Teaching Object-Oriented Modelling Using UML		

114	[SMP 14]	Using Constraints in Teaching Software Modeling		
115	[SMP 19]	Experiences of Teaching UML within the Information Systems Curriculum		
116	[SMP 21]	A new approach to teaching object oriented concepts and methodlogy to information techonology students		
117	[SMP 23]	The Two States of the Mind to Teach UML		
118	[SMP 29]	Interactive Exercises To Support Effective Learning of UML Structural Modeling		
119	[SMP 31]	UML Tools: What is their Role in Undergraduate Computer Science Courses?		
120	[SMP 34]	An Information Modelling Approach to Teaching Object-oriented Analysis		
121	[SMP 42]	A Method of Elicitation Teaching for Object-Oriented Analysis and Design Curriculum		
122	[SMP 46]	An Introduction to Class Based Domain Modelling		
123	[SMP 63]	Design for Object-Oriented Modeling Course Blending Individual and Collaborative Learning Activities		
124	[SMP 86]	Evaluation of Student UML: an Educational Tool for Consistent Modelling with UML		
125	[SMP 87]	UML grader: An Automated Class Diagram Grader		
126	[SMP 93]	Teaching Models @ BIG: Replacing Traditional Classroom Lectures with Lecture Videos – An Experience Report		
127	[SMP 104]	Teaching OOAD with active lectures and brainstorms		
128	[SMP 112]	A Prophylactic Approach to Teaching UML in an Undergraduate Introduction to Software Engineering Course		
129	[SMP 119]	Integrating Visual Modeling throughout the Computer Science Curriculum		
130	[SMP 126]	CRC-Cards and Role play Diagrams Informal Tools to Teach OO Thinking		
131	[SMP 127]	Object Oriented Analysis and Design: Do We Need More UML in the Classroom?		

Table 63 Citation count and ranking of SMP studies

12.21 Overall Ranking of the SMP studies

Article ID	Rigor	Relevance	Citations	$C_{Normalized}$	$Total_{Ri+Re+Cn}$	Rank
SMP [20]	**3**	**3**	138	0.69	6.69	**1**
SMP [71]	2.5	**3**	32	0.16	5.66	**2**
SMP [98]	2.5	**3**	16	0.08	5.58	**3**
SMP [95]	2	**3**	65	0.325	5.325	**4**
SMP [81]	2	0	636	3.18	5.18	**5**
SMP [68]	2	**3**	1	0.005	5.005	**6**
SMP [77]	2	**3**	1	0.005	5.005	**7**
SMP [101]	1.5	**3**	16	0.08	4.58	**8**
SMP [96]	1.5	**3**	10	0.05	4.55	**9**
SMP [111]	**3**	1	53	0.265	4.265	**10**
SMP [108]	**3**	1	48	0.24	4.24	11
SMP [37]	**3**	1	33	0.165	4.165	12
SMP [109]	**3**	1	21	0.105	4.105	13
SMP [22]	**3**	1	2	0.01	4.01	14
SMP [12]	2.5	1	44	0.22	3.72	15
SMP [84]	2.5	1	31	0.155	3.655	16
SMP [107]	1.5	1	221	1.105	3.605	17
SMP [18]	2.5	1	10	0.05	3.55	18
SMP [120]	2.5	1	1	0.005	3.505	19
SMP [93]	2.5	1	0	0	3.5	20
SMP [75]	2	1	43	0.215	3.215	21
SMP [60]	2	1	33	0.165	3.165	22
SMP [121]	2	1	25	0.125	3.125	23
SMP [17]	2	1	17	0.085	3.085	24
SMP [65]	2	1	12	0.06	3.06	25
SMP [74]	**3**	0	11	0.055	3.055	26
SMP [45]	**3**	0	10	0.05	3.05	27
SMP [30]	2	1	9	0.045	3.045	28
SMP [76]	2	1	9	0.045	3.045	29
SMP [129]	2	1	9	0.045	3.045	30
SMP [41]	**3**	0	6	0.03	3.03	31
SMP [50]	2	1	6	0.03	3.03	32
SMP [97]	1	2	6	0.03	3.03	33
SMP [10]	2	1	5	0.025	3.025	34
SMP [117]	**3**	0	5	0.025	3.025	35
SMP [100]	2	1	4	0.02	3.02	36
SMP [114]	2	1	4	0.02	3.02	37
SMP [35]	2	1	1	0.005	3.005	38
SMP [61]	2	1	0	0	3	39
SMP [86]	2	1	0	0	3	40
SMP [112]	2	1	0	0	3	41
SMP [127]	2	1	0	0	3	42
SMP [113]	2.5	0	85	0.425	2.925	43
SMP [39]	2.5	0	4	0.02	2.52	44
SMP [16]	1.5	1	2	0.01	2.51	45
SMP [52]	2.5	0	2	0.01	2.51	46
SMP [91]	2	0	56	0.28	2.28	47
SMP [80]	2	0	54	0.27	2.27	48
SMP [36]	2	0	26	0.13	2.13	49

SMP [1]	2	0	23	0.115	2.115	50
SMP [72]	2	0	22	0.11	2.11	51
SMP [105]	2	0	19	0.095	2.095	52
SMP [28]	2	0	18	0.09	2.09	53
SMP [33]	2	0	18	0.09	2.09	54
SMP [78]	2	0	17	0.085	2.085	55
SMP [110]	2	0	16	0.08	2.08	56
SMP [99]	2	0	12	0.06	2.06	57
SMP [128]	2	0	7	0.035	2.035	58
SMP [58]	2	0	4	0.02	2.02	59
SMP [92]	2	0	2	0.01	2.01	60
SMP [24]	2	0	1	0.005	2.005	61
SMP [32]	2	0	1	0.005	2.005	62
SMP [54]	2	0	1	0.005	2.005	63
SMP [122]	2	0	1	0.005	2.005	64
SMP [63]	2	0	0	0	2	65
SMP [87]	2	0	0	0	2	66
SMP [106]	1.5	0	44	0.22	1.72	67
SMP [13]	1.5	0	39	0.195	1.695	68
SMP [82]	1.5	0	27	0.135	1.635	69
SMP [6]	1.5	0	25	0.125	1.625	70
SMP [3]	1.5	0	11	0.055	1.555	71
SMP [55]	1.5	0	9	0.045	1.545	72
SMP [94]	1.5	0	6	0.03	1.53	73
SMP [115]	1.5	0	6	0.03	1.53	74
SMP [73]	1.5	0	4	0.02	1.52	75
SMP [49]	1.5	0	3	0.015	1.515	76
SMP [118]	1.5	0	3	0.015	1.515	77
SMP [102]	1.5	0	2	0.01	1.51	78
SMP [70]	1.5	0	1	0.005	1.505	79
SMP [89]	1.5	0	1	0.005	1.505	80
SMP [103]	1.5	0	1	0.005	1.505	81
SMP [29]	1.5	0	0	0	1.5	82
SMP [104]	1.5	0	0	0	1.5	83
SMP [119]	1.5	0	0	0	1.5	84
SMP [126]	1.5	0	0	0	1.5	85
SMP [5]	1	0	14	0.07	1.07	86
SMP [7]	1	0	1	0.005	1.005	87
SMP [90]	1	0	1	0.005	1.005	88
SMP [9]	0.5	0	0	0	0.5	89

Figure 64 Overall Ranking of SMP studies

12.22 Translation of Data Items to Higher Order Themes

Identifying themes from data items			
Codes	**Categories**	**Classes / Themes**	**Higher Order themes**
C1	Languages	Manual Classification	Research Area Contribution
C2	Diagrams		
C3	Course Design		
C4	Curriculum design		
C5	Others		
C6	Industry	Study Setting	Research Environment
C7	Academia		
C8	Students	Audience Type	
C9	Teachers		
C10	Software Engineers		
C11	Developers		
C12	Process	Contribution Type	Research Area Contribution
C13	Method		
C14	Tools		
C15	Measurement		
C16	Experiment	Research Method	Nature of the Research
C17	Interviews		
C18	Observational studies		
C19	Concept analysis		
C20	Interviews		
C21	Surveys		
C22	Case studies		
C23	Solution Proposal	Research Type	
C24	Evaluation research		
C25	Experience paper		
C26	Opinion paper		
C27	Validation research		

Figure 65 Translation of data items to Higher orders themes

13 GLOSSARY

Terms	Definitions
Search String	A combination of search terms employed to obtain studies related to the domain of research
Classification Scheme	A method to manually group the articles.
Classification Strategy	A methodology classify articles can be either automated classification or manual classification.
Classification Facet	A Predefined Classification or a class with predefined categories.
Class	A group of categories.
Category	A group of articles.

Table 64 Terms and Definitions

ACRONYMS

IEEE	Institute of Electrical and Electronics Engineers.
ACM	Association for Computing Machinery
SLR	Systematic Literature Review
SMP	Systematic Mapping
UML	Unified Modeling Language
OCL	Object constraint Language
OVAL	Open Vulnerability Assessment Language
CS	Computer Science
SE	Software Engineering

Table 65 List of Acronyms