

# Knowledge Integration Framework: A Systematic Review

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## ABSTRACT

Knowledge integration within the organization translates the raw knowledge into actionable knowledge to solve organization problems. Knowledge used in this process can have different formalism that fall in two categories, logical based approach like first order logic, descriptive logic and, the other is non-logical based approach like natural language, ontology, semantic network etc. Many knowledge integration frameworks have been proposed to ease this complex process to ensure the result knowledge meet some quality attributes i.e. soundness, completeness etc. The aim of this study is to explore and analyse existing research in knowledge integration framework focusing on the formalism of raw knowledge and actionable knowledge as well as techniques used by knowledge integration framework and the limitations of those knowledge integration frameworks. This paper presents a systematic review of several researches which propose knowledge integration framework in last five years. We found most of researches use single formalism for raw and result knowledge. Little research insure actionable knowledge quality. Integration technique mainly depends on the formalism of raw and actionable knowledge.

**Keywords:** Knowledge Formalism, Knowledge Integration, Knowledge Integration Framework.

## I INTRODUCTION

Adams and Graham (2017) consider the knowledge as critical competitive resource for firms that increasingly exploit resources and capabilities of the firm. Researchers define the knowledge integration in different ways. Yang (2005) defines the knowledge integration as translates the raw knowledge into actionable knowledge based on accurate understanding of the business context. Traverso, Bonifacio and Bouquet (2002) define the raw knowledge as the knowledge created dependent on the context of production, such as the daily practice of work. Argyris (1996) defines actionable knowledge as knowledge required to implement the external validity (relevance) in that world. Knowledge integration framework term seemed likely do not have any special definition in all researches.

Aldakhil (2011) conceptualizes the knowledge integration as the gathering, processing diverse knowledge to perform the specific activities and solve problems. On top of that, Hassan (2017) proposes a theoretical framework to show the relation between knowledge integration and organizational performance.

Knowledge used in this process can have different formalism that fall in two categories; logical approach like first order logic, descriptive logic; and the other is non-logical approach like natural language, ontology, semantic network and many others. Many knowledge integration frameworks have been proposed to ease and ensure the quality attributes of resulting knowledge.

The aim of this study to explore and analyse existing researches in knowledge integration framework with respect to knowledge formalization dimension and techniques used by knowledge integration framework. In addition to show the limitations of these knowledge integration frameworks to find the gap in this research area.

The organization of this paper is as follows: Section 2 describes the research method. Section 3 provides more detail the results of our research. Section 5 concludes the paper.

## II RESEARCH METHOD

In this section, we will detail out the process we used to perform a systematic literature review for knowledge integration frameworks.

### A. Research Questions

1. What is formalism of raw knowledge used by knowledge integration framework?
2. What is formalism of result knowledge used by knowledge integration framework?
3. What is the technique used by the knowledge integration framework?
4. What are the observable limitations in the knowledge integration framework?

### B. Search Strategy Used for Primary Studies

This involved searching via IEEE, ScinceDirect and SpringerLink for the following criteria: "Knowledge Integration" AND Framework for recent five years researches.

### C. Study Select Criteria and Procedure for Inclusion and Exclusion for Primary Studies

We include researches that focus on integration knowledge using framework. We excluded researches that discuss integration knowledge framework without illustrating the integration technique.

### D. Search Process

Figure 1 represents a search process to show results in term of the number of studies in each filtering step.

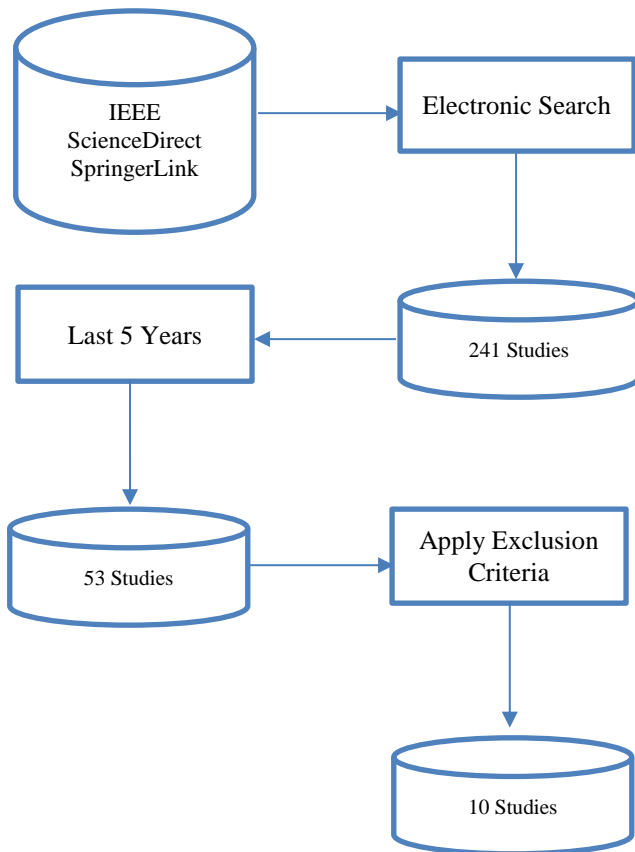


Figure 1. Search Process Steps

## III RESULTS

Subsequent sections represent the obtained results against each research question:

### A. Raw Knowledge Formalism

Table 1 tabulates the summary for data by raw knowledge formalism. It can be summarized as follows:

1. 30% of studies use logical formalism of raw knowledge.
2. 50% of studies use text formalism of raw knowledge. This percent reflects high demand of integrating text knowledge.

3. 10% of studies use data structured to represent the raw knowledge.
4. 10% of studies use context of source knowledge to represent the raw knowledge.

Table 1. Raw Knowledge Formalism

Reference	Formalism
Ghidini and Serafini (2017)	First Order Logic
Baudrit, Destercke and Wuillemin (2016)	Probabilistic Knowledge
Tran, Vo, and Nguyen (2014)	Belief Set
Du, He and Sugumaran (2016) Santos França et al. (2015) Getman and Karasiuk (2014) Yan, Wang, Cheng, Gao, and Zhou (2016) Rossetti, Pareschi, Stella, and Fontana (2014)	Text
Maleszka and Nguyen (2015)	Data Structure
Brewka et al. (2018)	Context of Knowledge Source

### B. Actionable Knowledge Formalism

Table 2 categorizes the summary for data by actionable knowledge formalism and it can be summarized as following:

1. 30% of studies use logical formalism of actionable knowledge. Which means all logical formalism for raw knowledge produced same formalism for result knowledge.
2. 30% of studies use ontology formalism of actionable knowledge. Which means 60% of studies uses text formalization of raw knowledge prefer to translate it to ontology knowledge to give understanding about semantic of the raw knowledge.
3. 10% of studies use knowledge graph to represent the actionable knowledge. Which means 20% of studies uses text formalization of raw knowledge translate it to knowledge graph to give understanding about the entities and its relations exists in the raw knowledge i.e. books names, information about USA president.

4. 10% of studies use probabilistic topic modeling to represent the actionable knowledge. Which means 20% of studies uses text formalization of raw knowledge translate it to probabilistic topic modeling to give understanding about the importance of topics in the raw knowledge.
5. 10% of studies use data structured to represent the actionable knowledge. These studies try to focus find the nodes on data structures to connect the raw knowledge.
6. 10% of studies use contextual information to represent the actionable knowledge. These studies focus on investigating the raw knowledge to identify the information suitable for required context.

**Table 2. Result Knowledge Formalism**

Reference	Formalism
Ghidini and Serafini (2017)	First Order Logic
Baudrit et al. (2016)	Credal Set
Tran et al. (2014)	Belief
Du et al. (2016) Santos França et al. (2015) Getman and Karasiuk (2014)	Ontology
Yan et al. (2016)	Knowledge Graph
Rossetti et al. (2014)	Probabilistic Topic Modeling
Maleszka and Nguyen (2015)	Data Structure
Brewka et al. (2018)	Contextual Information

### C. Knowledge Integration Technique

Table 3 categorizes the summary for data by knowledge integration technique and can be described as below:

1. 20% of studies use bridge rule technique to translate specific items of the raw knowledge to actionable knowledge. The process performed manually and preferred when the number of raw knowledge pieces is relatively small. When the raw knowledge and actionable knowledge use same formalism, the actionable knowledge can include the raw knowledge as it is. The bridge rule technique can ensure the quality attribute on actionable knowledge formally as it based on logical

rules. This technique can apply in dynamic mode in order to let actionable knowledge produce raw knowledge again.

2. 10% of studies use unifying parameter learning to solve a problem. This technique should include a method to detect the accuracy of result knowledge about the problem as it based on probabilistic knowledge.
3. 10% of studies use belief negotiation technique to decide which belief agreed by majority. This technique ensures the performance of integration algorithm for large population.
4. 30% of studies use ontology integration to represent the semantic of raw knowledge. This technique includes intermediate step to extract and validate the ontology elements form the raw knowledge.
5. 10% of studies use knowledge graph builder to get actionable knowledge. This technique uses sophisticated system to extract entities, it's relation and interference from the raw knowledge.
6. 10% of studies use knowledge topic transitions algorithm technique to get actionable knowledge. The technique give ability to conceptualize the raw knowledge in higher level network.
7. 10% of studies use path completeness algorithm technique to get actionable knowledge. The technique connects all piece of tree together to produce actionable knowledge which show the holistic view of knowledge tree.

**Table 3. Techniques Used in Knowledge Integration Framework**

Reference	Technique
Ghidini and Serafini (2017) Brewka et al. (2018)	Bridge Rule
Baudrit et al. (2016)	Unifying Parameter Learning
Tran et al. (2014)	Belief Negotiation
Du et al. (2016) Santos França et al. (2015) Getman and Karasiuk (2014)	Ontology Integration

Yan et al. (2016)	Knowledge Graph Builder
Rossetti et al. (2014)	Topic Transitions Algorithm
Maleszka and Nguyen (2015)	Path Completeness Algorithm

Figure 2 categorizes the knowledge integration framework techniques based on the technology of knowledge formalism it works on.

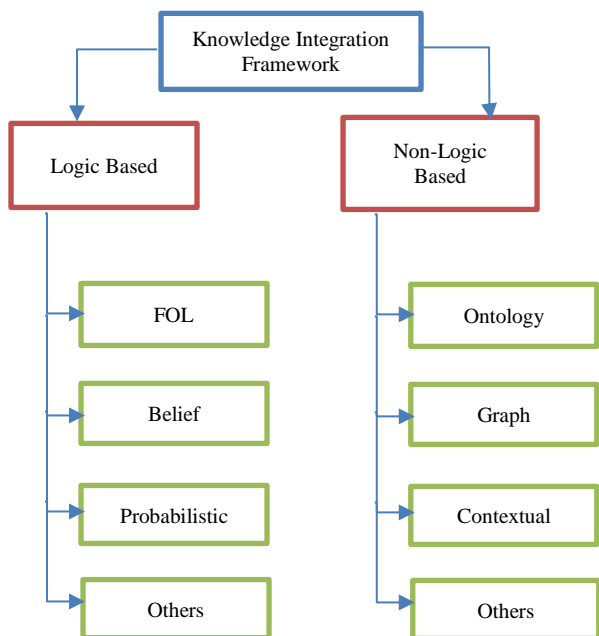


Figure 2. Knowledge Integration Framework Categorization Based on Knowledge Formalism

#### D. Limitation

The summary for limitation data in Table 4 which represents the matrix of limitation against studies are as follow:

1. Use single formalization for raw knowledge: All the knowledge integration framework uses single formalism for the raw knowledge even the raw knowledge is not always in single formalism.
2. Use single formalization for actionable knowledge: All the knowledge integration framework results single formalism for the actionable knowledge even actionable knowledge is not always in single formalism.
3. Use manual steps: 30% percent of studies specially which have raw knowledge in text formalism use manual steps to extract and validate the translation of raw knowledge. This limitation will make the process knowledge integration in too costly.

4. Do not ensure the quality of result knowledge: Although the quality of actionable knowledge is very important, few studies ensure the quality of actionable knowledge. A study conducted by Ghidini and Serafini (2017) ensure the completeness and soundness of using bridge rule technique while (Tran et al., 2014) study ensure the performance of knowledge integration.

Table 4. Limitation in Knowledge Integration Framework

Reference	Limitations			
	Use Single Formalism for Row Knowledge	Use Single Formalism for Result Knowledge	Use Manual Steps	Don't Ensure the Quality of Result Knowledge
Ghidini and Serafini (2017)	√√	√√		√
Baudrit et al. (2016)	√√	√√		√√
Tran et al. (2014)	√√	√√		√
Du et al. (2016)	√√	√√	√√	√√
Santos França et al. (2015)	√√	√√	√√	√√
Getman and Karasiuk (2014)	√√	√√	√√	√√
Yan et al. (2016)	√√	√√		√√
Rossetti et al. (2014)	√√	√√		√√
Maleszka and Nguyen (2015)	√√	√√		√√
Brewka et al. (2018)	√√	√√		√√

Note: √√ donate full limitation and √ donate partial limitation

#### IV CONCLUSION

All the knowledge integration framework use single formalism for raw knowledge even raw knowledge is not always in single formalism.

All the knowledge integration framework use single formalism for actionable knowledge even actionable knowledge is not always in single formalism.

In some cases, if raw knowledge and actionable knowledge have the same formalism, actionable knowledge includes the raw knowledge as it is.

The highest percent of knowledge integration framework technique is ontology integration even it almost required manual effort to review the generated ontology.

Only Ghidini and Serafini (2017) proposed a knowledge integration framework that ensures some quality attribute of integration technique like completeness and soundness.

All knowledge integration framework do not ensure the quality attribute of raw knowledge and actionable knowledge.

Even the quality of characteristic of the knowledge is very important, most knowledge integration framework don't take into account the quality for raw, actionable knowledge and technique.

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