Towards the definition of a Science Base for Enterprise Interoperability: A European Perspective

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ABSTRACT

Research on Enterprise Interoperability (EI) has evolved to meet real pragmatic needs to support the ever more collaborative nature of, for example, enterprise supply chains, and virtual enterprises. Research outputs have therefore focused on generating solutions to current problems, rather than to developing a body of knowledge which is structured for ease of re-use.

In Europe there is move to define just such a structure: an Enterprise Interoperability Science Base (EISB). We explore here the current state of this ongoing research, reviewing the understanding gained so far, and looking to the likely future outcomes. However this is clearly not just a European research domain. The main purpose of presenting the European perspective is to stimulate interaction with researchers in all regions who have an interest in the domain.

We therefore address three issues. We review the development of neighbouring sciences, identifying science base structures, and methodologies for their development. The definition and objectives of a science base are analysed, leading to an outline structure for an EISB to include formalised problem and solution spaces as well as structured EI domain knowledge. Twelve Scientific Themes of EI are identified and the current state of research in each is briefly discussed.

Keywords: Enterprise Interoperability; Science base..

1. INTRODUCTION

The need for definition of an Enterprise Interoperability Science Base (EISB)was first documented in the Enterprise Interoperability Research Roadmap version 4 [1] published in 2006 by the European Commission. Here the definition of an EISB was specified as one of 4 main Grand Challenges to be addressed by researchers in the domain. This challenge was recognised by the Enterprise Interoperability Cluster promoted by the European Commission, and in 2008 the Cluster formed a small task force to work on the EISB. This reported back to Cluster meetings through 2008 and 2009, and compiled much of the source material which is summarised in the chapters below. This work was published in [2] in 2010.

During 2009 the European Commission sponsored an "Enterprise Interoperability Science Base Meeting" to which members of the Future Internet Enterprise Systems (FInES) Cluster (previously the Enterprise Interoperability Cluster mentioned above) as well as international scientific experts were invited. This discussed the possible purpose and structure of the EISB, and led to the EC call for a Coordinating and Support Action under Framework Programme 7 in October 2009. The ENSEMBLE project was proposed and subsequently funded as a result of this call.

Any scientific domain exists in an ecosystem of neighbouring scientific domains, and must therefore recognise its relationship with these domains and with formal definitions of science bases already established for these domains. This relationship will include at least:

1. Boundaries between application fields, which may be fuzzy in the sense that there are some applications which could be addressed from the perspective of either domain. Formally, it may be appropriate to define membership functions to applications to recognise and resolve this overlap.
2. Shared methodologies, techniques and tools which may be applicable to problems in more than one domain. Recognition of such sharing provides opportunity for domains to advance by absorbing methodological and technical advances from related disciplines.
3. Conflicts in approach may also exist, and present possible barriers to interdisciplinary research or application. Formal documentation of such conflict areas will reduce risk of failure in projects arising out of the application of incompatible approaches.

For this reason we review below the definitions and structures of science bases in neighbouring sciences reveals that there is no common structure or content to such science bases. However a methodology emerges which might be applied in defining a science base, based on application of generally accepted scientific principles. Specifically we examine the lessons to be learned from not only applied sciences, where perhaps enterprise interoperability science may be based, but also social sciences, in recognition that enterprises are also social organisations and their interactions are societal in nature. Lessons from formal sciences are also relevant to support the formalisation and structuring of the EISB. There are clear interoperability issues identified in each of these three domains. There is no generally accepted definition of a "Science Base", which can describe comparable constructs in a range of scientific domains. We therefore propose below a definition of the scope, purpose and content of an EISB. This definition will guide initial research on the EISB, but the authors would be unsurprised to see development of the definition during the course of that research. This seems both inevitable and desirable in the absence of any pre-existing definition of the term.

Finally we review the established Scientific Areas in the Enterprise Interoperability domain identifying 12 major Scientific Themes of Enterprise Interoperability (see below). Since domain research has continued for than a decade, there is a significant body of reported research and application, which contributes to the EISB. This is a first review of this content and will in future support the classification of methodologies, techniques and tools within the EISB.

2. NEIGHBOURING SCIENCES

The concept of science is generally related with observable knowledge, described in the form of testable laws and theories [3], [4]. Nevertheless, there is a plurality of sciences that differ very much from each other. Physics is accepted as a well defined science, but there are others that are not universally accepted, e.g., history and linguistics. Therefore, the definition of science is difficult and ambiguous, but it can be agreed that formalisms like logic and mathematics are an integral part of every science, i.e., they are essential for physics, less important for chemistry and biology, and their significance continues to decrease towards the more social and humanistic sciences [5].
Modern sciences introduce a paradigm shift since, unlike the traditional philosophy of science, they usually do not apply to a single domain, being interdisciplinary and eclectic. Modern sciences search for their methods and raise research questions in broad areas, crossing borders and engineering different scientific fields. For example, the modern computer science embraces formalisms and algorithms created to support particular desired behaviour using concepts from physics, chemistry, biology [5], [6]. Thus, being also a multi-disciplinary domain by nature, the establishment of an EISB should be developed comprising concepts and theories from related neighbouring sciences and scientific domains [2].
Based on the previous work from Charalabidis et al. [2], an initial analysis of the sciences that could contribute to EI is depicted in Figure 1. Due to its characteristics where interoperability issues can be identified, the general classification of scientific domains recognizes the social sciences, the applied sciences and the formal sciences [10] as promising contributors for the EISB formulation, and categorise the work developed so far within four levels of scientific elements of interoperability (semantics, models, tools, orchestration) [2]:

- At the level of semantics, the mathematical domains of logic, set theory, graph theory and information theory seem to have practical applications for describing interoperability problems in a formal way. A mention to patterns has also to be made in this area, both in the form of design patterns [2] and also in the more mathematical form of general pattern theory.
- At the level of models and tools, one should look for existing knowledge in the neighboring domains of systems theory, systems engineering, computer algorithms or operational research. Service science [7] should also not be overlooked in the needed definitions of models and tools for interoperability, at this level. Systemic simulation approaches, such as the System Dynamics approach [8].
- At the orchestration level, where more generic formulations are needed, the social sciences provide a sound scientific corpus, in the face of economics, legal science or even public administration and management.

In addition to the above directions towards the EISB formulation, some literature draws special attention on approaches and propositions for a formal framework to describe interoperability such as the category theory application to semantic interoperability [9], combined category theory and calculus approaches [10], or knowledge discovery metamodel application to interoperability of legacy systems [11].
For the higher levels of interoperability, that is the organisational and enterprise interoperability facets, the scientific domains of systems complexity, network science and information science seem to have a high degree of relevance and applicability [12]. As well, relevance for the establishment of the scientific foundations has been identified with domains such as distributed systems, evolving applications, dynamics and adaptation of networked organizations on a global scale.
All these domains possess strong theoretical background, based on domains tagged as “neighbours” of EI, and serve as an input to the work presented on section 2.3 “EI Neighbouring scientific domains reference taxonomy”.

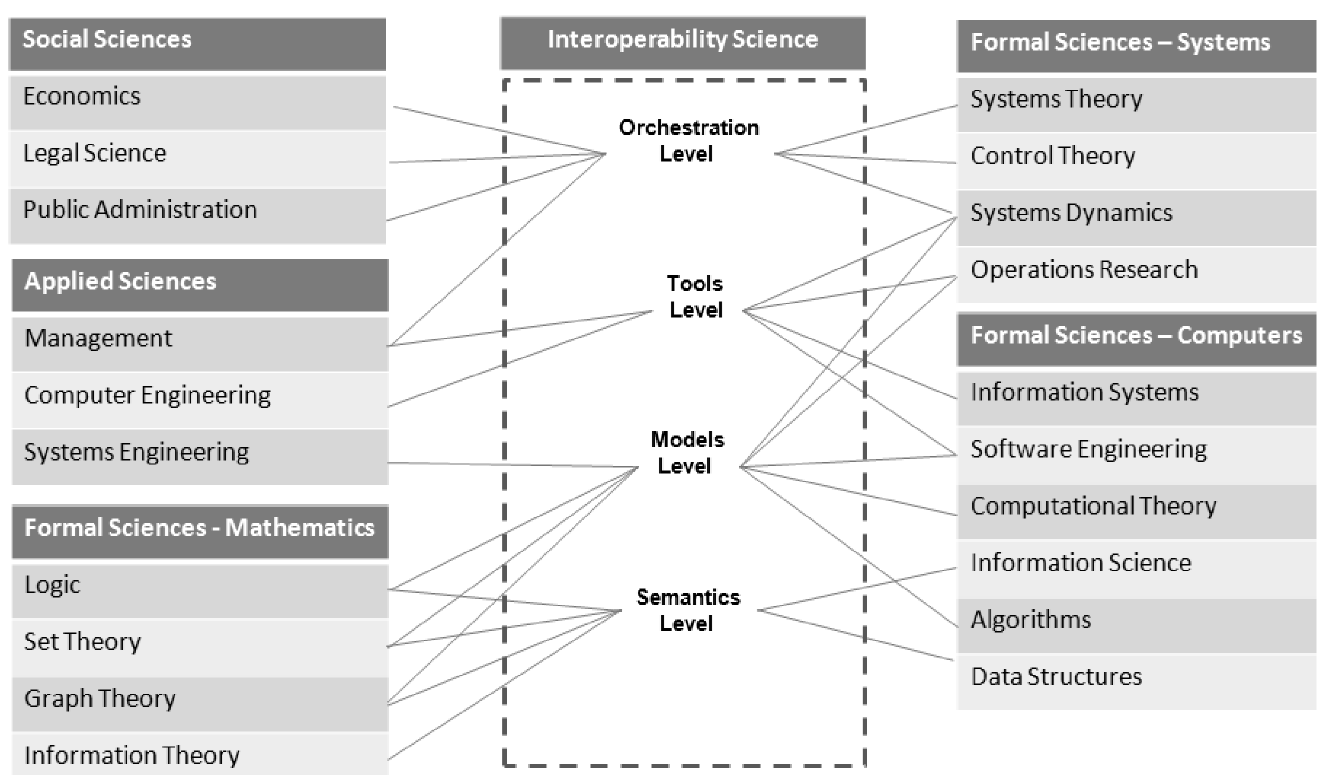

Figure 1: Interoperability Science and Neighbouring Domains

3. DEFINITION AND CONTENT OF A SCIENCE BASE FOR ENTERPRISE INTEROPERABILITY

There is no view of the definition of a science base common to all, or even a related set of, scientific domains, although good examples exist, including for example that for software engineering science [13]. We therefore submit that the definition of a science base is to a degree dependent on the nature of the domain and the purpose for which it is designed and maintained, and indeed the definition for a particular domain will evolve as the needs of the domain evolve with its maturity.

Scope and Content

The content of a science base for an applied science may therefore consist of the following categories of knowledge:

- Formalisation of the Problem space: a taxonomy of the range of application and theoretical problems addressed by the domain, organised so as to be used to characterise real applications and to link these to elements of the solution space.
- Formalisation of the Solution space: the converse of the problem space, this provides a taxonomy of knowledge available for the solution of domain application problems. In turn this links to methodologies and tools in the domain knowledge base.

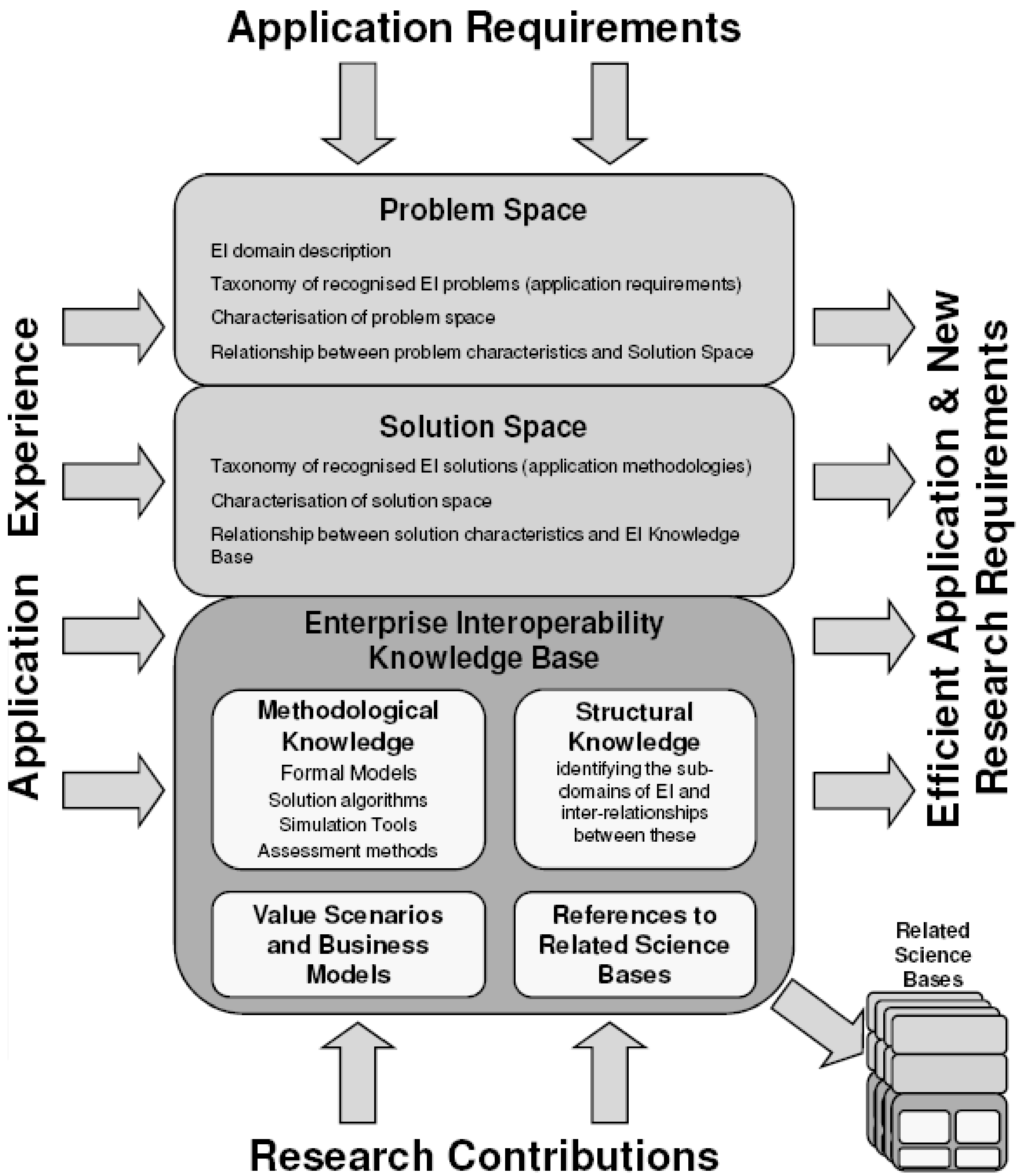

Figure 2: A view of EISB content

- Domain Knowledge Base: the domain knowledge base contains both structuring and methodological knowledge. The former defines the structure of the domain as perceived by its participant stakeholders:
  - a taxonomy of topics within the domain knowledge;
  - the scientific principles which provide the foundation of knowledge in the domain, and of both future research and application;
  - relationships between these topics, the problem space and the solution space;
  - relationships between domain knowledge and knowledge embedded in related scientific domains.

This is further illustrated in Figure 2.

4. SCIENTIFIC THEMES OF ENTERPRISE INTEROPERABILITY

Review of the state of the art (SoTA) of EI related research suggests analysis of published results along 3 dimensions:

- An Enterprise Interoperability Dimension that indicates the interoperability aspect it concerns.
- A Science Base Dimension that classifies the type of the approach, i.e. is it a method developed or a proof-of-concept or a survey?
- A SoTA Dimension capturing the type publication (eg. journal publication, conference proceedings, etc.).

These are illustrated in Figure 3.

Literature on EI research can also be categorised under a set of 12 main Scientific Themes:

1. Process Interoperability
2. Rules Interoperability
3. Ecosystems Interoperability
4. Knowledge Interoperability
5. Data Interoperability
6. Cultural Interoperability
7. Services Interoperability
8. Social Networks Interoperability
9. Cloud Interoperability
10. Electronic Identity Interoperability
11. Objects Interoperability
12. Enterprise Software Interoperability

Study of the state of the art of research on interoperability in general identifies distinct layering of political, organisational, semantic and technical interoperability, and EI is represented in all of these layers. The 12 Scientific Themes can be mapped on to the interoperability layers as shown in Figure 4.

It is significant to note the scale of research activity across these Scientific Themes. Figure 5 shows, in addition to the number of research publications identified, number of research projects relevant to the domain, the number of related events (conferences, workshops, etc.) and the number of initiatives (working groups, clusters, independent entities, standards bodies, etc.) which are current or recent. It is important to note the research project figure is for European activity only. This is not to suggest in any way that activity is limited to Europe: indeed it certainly is not, but the scope of this paper is to report the European perspective. The clear conclusion is that this is a highly active domain, and that efforts to formalise a science base, thus providing a theoretical base for future research as well as the links between the application problem space and the scientific solution space that are essential foundations for an applied science.

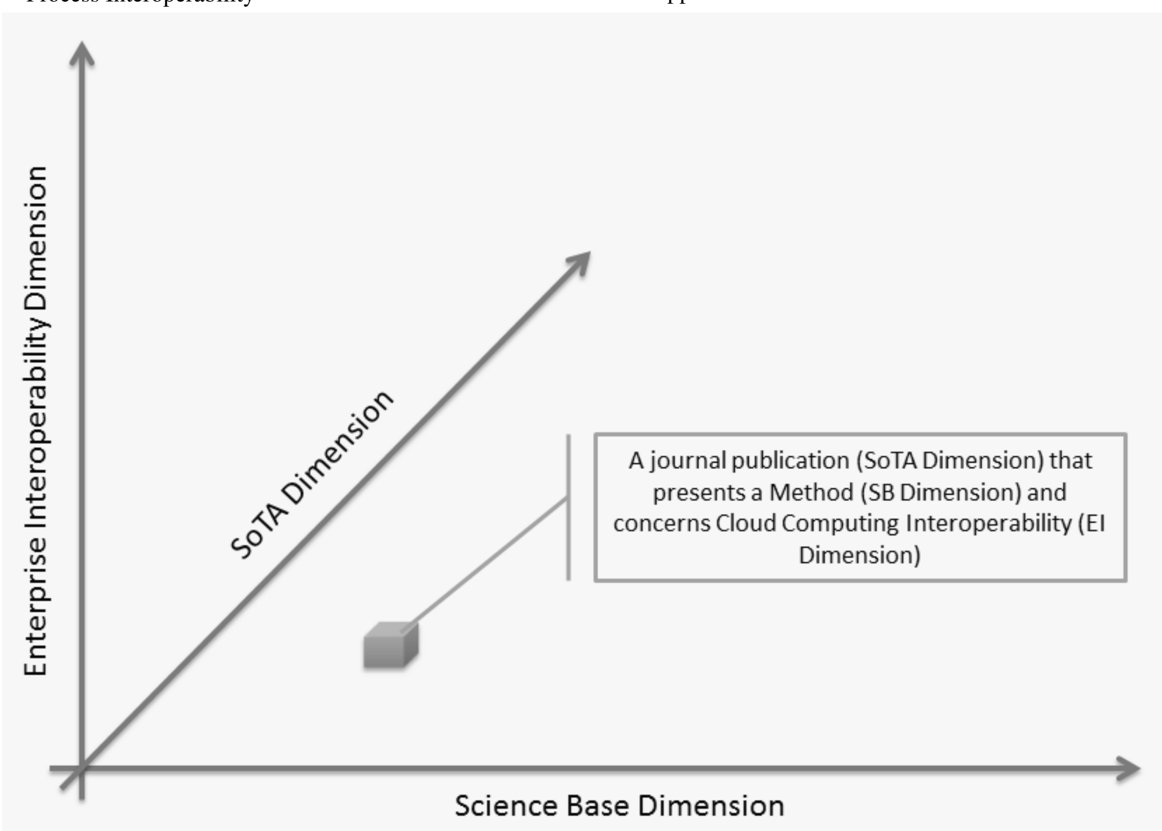

Figure 3: State of the Art Analysis Dimensions

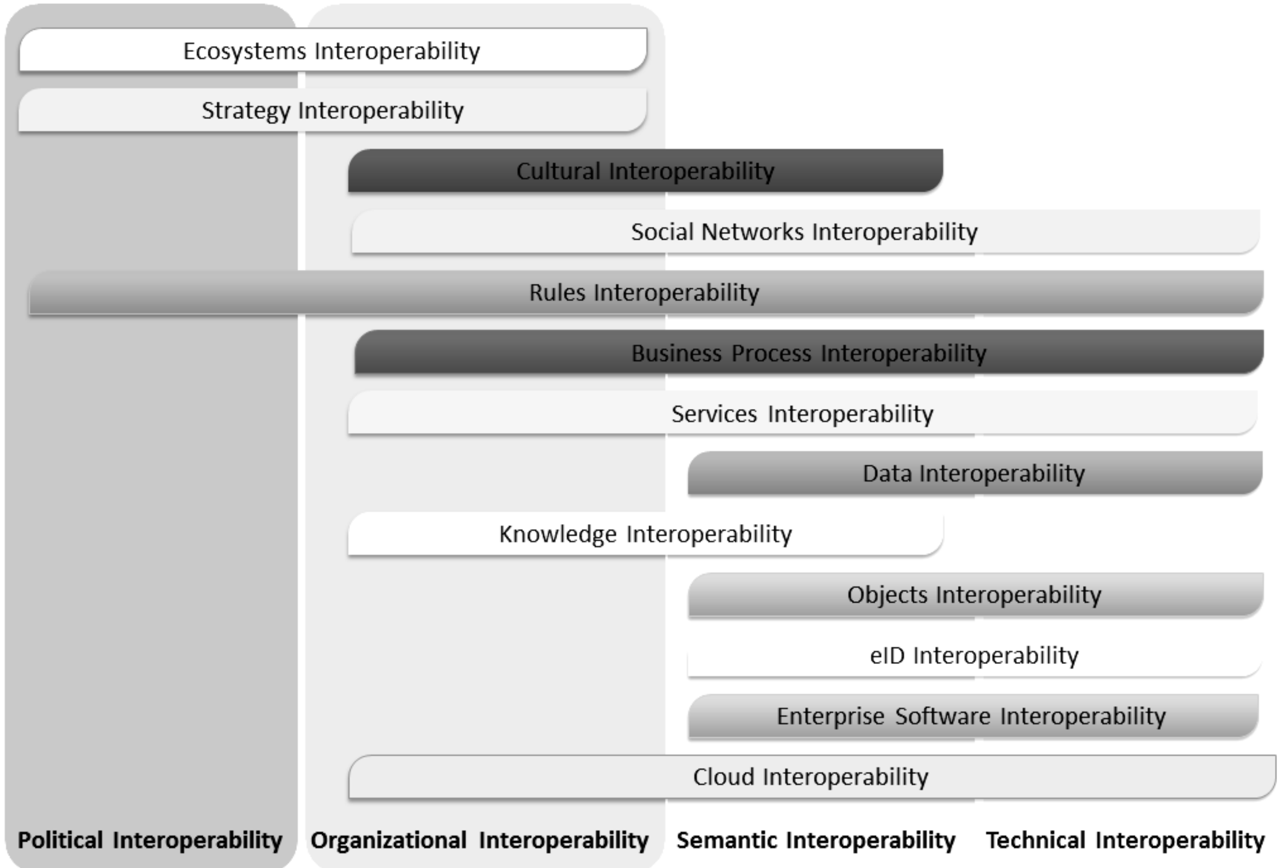

Figure 4: EI Scientific Areas Mapping to Interoperability Layers

5. CONCLUSION

The Enterprise Interoperability domain has clear links with a number of neighbouring scientific domains. Through drawing on these relationships, and identifying the unique contributions of EI research, it has been possible to draft a structure for an EISB which recognises the pragmatic, problem-solving purposes of EI as an applied science, whilst providing structure and content to domain knowledge. This latter must make domain knowledge accessible for application, as well as defining the underlying principle, axioms and theorems that are the foundation of EI.

However it is clear that the definition of an Enterprise Interoperability Science Base is not a parochial, European, interest. Initiatives are in place to develop a worldwide dialogue on the domain, of which this workshop is a part.

Total research contributions reviewed	544
European research projects relevant to EI	34
Relevant events worldwide	66
Relevant initiatives	13

Figure 5: Statistics indicative of level of EI research activity

6. ACKNOWLEDGEMENT

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