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Promoting Future Internet Enterprise Systems Research

"Envisioning, Supporting and Promoting Future Internet Enterprise Systems Research through Scientific Collaboration"

Deliverable D2.3

EISB Basic Elements Report

Workpackage:	WP2 - EISB Development
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Executive Summary

This deliverable documents the work that has been carried out during ENSEMBLE's EISB 1st Wave, following the Action Plan that has been defined in the ENSEMBLE EISB Development Plan (Deliverable D2.2). In this context, the deliverable at hand deals with the identification and description of open scientific problems and proposals for the definition of initial EISB foundations and deals with the 1st EISB Wave elements that result from concentrating on the basic ideas and concepts for the EISB knowledge base.

As an initial starting point, this wave tries to firstly define the initial taxonomy of the EI domain and at a second stage proposes an EISB ontology concept that will be further developed and extended during the next waves. Following such an approach, this wave aims at generating a common understanding amongst the various EI terms and concepts, which are put into debate in the EISB Knowledge Base (FInES Wiki) for constant evolution and enhancement.

At the same time, an initial set of formal and other descriptive methods defining EI problems and solutions is provided, as well as critical research questions, amongst which is also the questioning of the EI community for the need of developing from scratch EI specific formal methods. Such methods, coming from both the EI domain and from neighbouring domains will help to identify the needs of the domain and will support the transfer of knowledge from other domains that may actively contribute to the ever-standing problems.

Furthermore, this deliverable proposes an initial EISB concept with an EI problem and solution spaces delimitation for circulation of ideas within the EISB community. It will undertake each one of the identified issues, and will distribute the accomplished results to a wider audience for attracting the interest of the major stakeholders of the domain and of other external experts and stakeholders, belonging to neighbouring domains.

Finally, after presenting an overview of the EISB Community Synthesis, the deliverable presents the achievements of ENSEMBLE so far regarding the 1st Wave and an updated version of the Action Plan for ENSEMBLE's EISB Wave 2 is provided in order to coordinate activities for the following semester. In summary, the ENSEMBLE EISB Wave 1 has been conducted following the plan, and most of the objectives have been tackled in the envisaged period. However, as already predicted in the ENSEMBLE EISB Development Plan, ENSEMBLE will not be able to close all the wave activities and will only serve as kick-off concerning the EISB formulation.

The results documented in the present deliverable are envisioned as a "live" document that will be sustained in the FInES wiki while they will also be available for consultation to the ENSEMBLE Experts Scientific Community and the FInES Cluster in the next period.

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1 Introduction

Research has significantly advanced the field of Enterprise Interoperability (EI) in a number of areas over the past few years. Nowadays, it is a well-established applied research area, studying the problems related with the lack of interoperability in organizations, and proposing novel methods and frameworks to contribute with innovative solutions for inter and intra-communications, specifically the dynamic exchange of information and knowledge behind the cooperation-competition. Pragmatically, in spite of the research developed so far, nowadays the scientific foundations for EI have not been yet established. This is a deficit recognized by the EI research community, hindering the generalization and reuse of the methods and tools that have been developed [34].

Thanks to the ENSEMBLE dissemination activities and public participation in events such as the Samos 2011 Summit[1], the invited session "Science Base for Enterprise Interoperability in the Advent of the Future of Internet" within the CENT 2011 conference[2] and the workshop on "Future Enterprise Systems" in the frame of the ICE 2011 conference[3] we are getting feedback that the above need is not shared exclusively by EI researchers, but also by other communities working closely with interoperability. According to some of the feedback collected, with a proper definition of an EISB, industry and society would:

- Gain access to new ways to measure success;
- Be able to create faster, cheaper, and better enterprises;
- Enlarge benefits to ICT suppliers;
- Free market enablers;
- Gain numerous educational benefits;
- Be proactive and able to prevent future industrial and economic crises.

1.1 Purpose of the document

The purpose of this document is to present the advances of the implementation of ENSEMBLE's work on the 1st EISB "Wave", kicking-off the identification and description of open scientific problems and proposals for the definition of initial EISB foundations. After the identification of the EISB state of play [35] and the definition of the action plan towards the formulation of a science base for Enterprise Interoperability [36], this is the third document produced by the EISB workpackage.

Besides reasoning on the comments received to the first two documents and readjusting some of the methodologies initially followed, the 1st "Wave" deals with the investigation of basic ideas and concepts for the EISB knowledge base. In an ideal EI framework with semantic concerns, both tacit and explicit knowledge should be addressed and processable to achieve more advanced stages of intelligence, such as understanding and wisdom [11], [103]. In this context, this wave will firstly define the initial taxonomy of the EI domain and at a second stage will propose an EISB ontology that will be further developed and extended during the next waves.

[1] http://samos-summit.blogspot.com/
[2] http://www.fines-cluster.eu/fines/jm/ENSEMBLE-News/cent-2011-ensemble-invited-session.html
[3] http://www.fines-cluster.eu/fines/jm/ENSEMBLE-News/ensemble-workshop-in-ice-2011.html

To contribute to this goal, this deliverable identifies in section 3 a set of initial formal and other descriptive methods to define EI problems and solutions, patterns identification, as well as critical research questions, amongst which is also the questioning of the EI community for the need of developing from scratch EI specific formal methods.. It has to be noted that specific methodologies are probably needed for each interoperability facet, which generates the need for diversified spectrum of formal methods for each EI scientific area, which may be ported from relevant neighbouring domains. The formalisation of those problems and abstraction of their description will empower the ability of researchers to similarly identify, describe and resolve other related problems, with the identification, analysis and abstraction of the solution space and its included methods.

Finally, this deliverable will propose an initial EISB concept with an EI problem and solution spaces delimitation for circulation of ideas within the EISB community. It will undertake each one of the identified issues, and will distribute the accomplished results to a wider audience for attracting the interest of the major stakeholders of the domain and of other external experts and stakeholders, belonging to neighbouring domains.

1.2 EISB Previous Work

1.2.1 EISB State of Play

A review of the definitions and structures of science bases in neighbouring sciences (ENSEMBLE Deliverable D2.1) [35] reveals that there is no common structure or content to such science bases. However a methodology, which might be applied in defining a science base, emerged based on application of generally accepted scientific principles. This was discussed and elaborated to provide the basis of a methodology for definition of the EISB that will be fully developed and applied in the following ENSEMBLE activities.

The definition and objectives of a science base for Enterprise Interoperability were also analysed, leading to an outline structure for an EISB to include formalised problem and solution spaces as well as structured EI domain knowledge divided into twelve (12) main Scientific Themes of Enterprise Interoperability: Data Interoperability; Process Interoperability; Rules Interoperability; Objects Interoperability; Software Interoperability; Cultural Interoperability; Knowledge Interoperability; Services Interoperability; Social Networks Interoperability; Electronic Identity Interoperability; Cloud Interoperability; Ecosystems Interoperability.

The current state of research and application in each of these themes was analysed in depth, based on published results and European Framework Programme funded projects, specific scientific events, and research or application initiatives.

1.2.2 EISB Action Plan

Upon studying the fundamentals in creating a science as depicted in the history of science and epistemology, the action plan (ENSEMBLE Deliverable D2.2) [36] of related scientific disciplines was analyzed and designated the perspectives and lessons learnt from their paradigm.

The Action Plan for the Enterprise Interoperability Science Base evolves in 3 waves for which corresponding objectives and actions are identified:

- Wave 1: Basic Elements that includes the Foundational Principles and the Core Concepts Formulation.
- Wave 2: Hypothesis and Experimentation with the Development and Extension, & Internal Enhancement and Exploration phases.
- Wave 3: Empowerment providing External Enhancement and Exploration, & Popularization to the Science Base.

1.3 Methodology

In order to develop a meticulous but intelligible deliverable, the following steps have been followed during the duration of the ENSEMBLE's EISB Wave 1:

- **Step 1: Neighbouring Domains Relationship with EISB.** 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. The strategy first presented in the EISB State of Play report to recognize these domains is here revisited and fine-tuned so that EISB can learn from the neighbouring domains, and at the same time be strengthened with an analysis of relevance in the context of each scientific domain.
- **Step 2: EISB Knowledge Base.** There is no view of the definition of a science base common to all, thus it has been agreed by ENSEMBLE 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. To keep all this knowledge integrated, wave 1 proposes the creation of an EISB knowledge base that will start with an overall taxonomy of the EI domain and at a second stage will propose an EISB ontology.

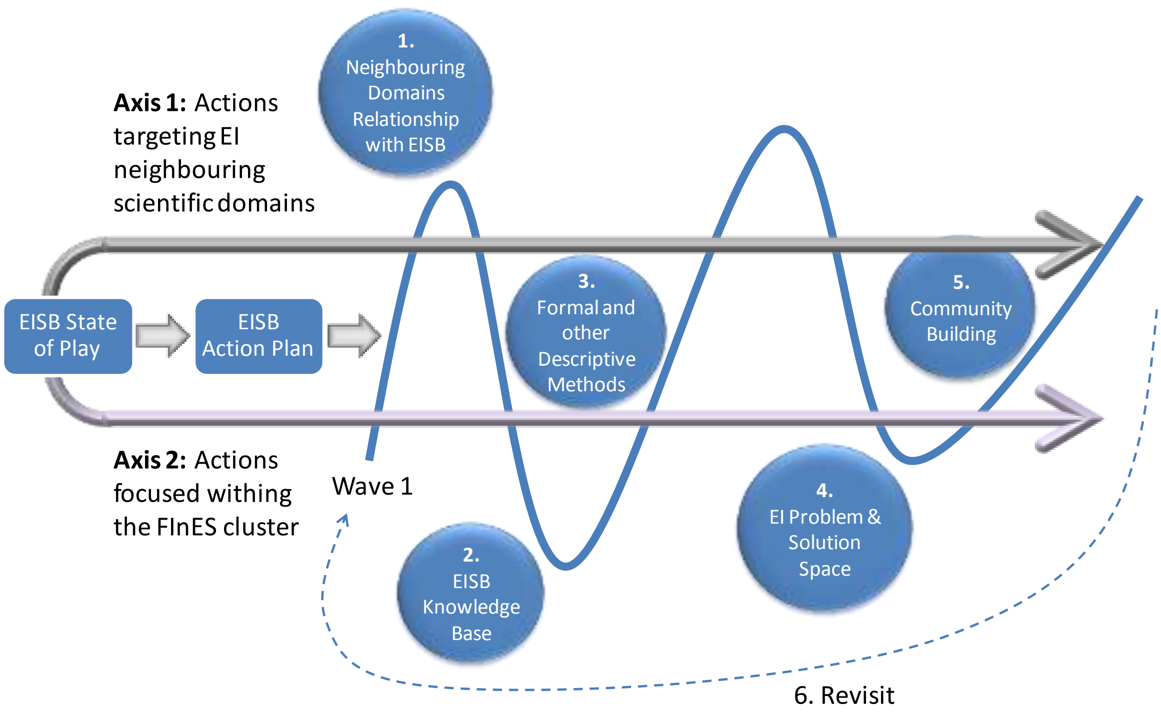

Figure 1-1: ENSEMBLE's EISB Wave 1 Methodology

- **Step 3: Formal and other Descriptive Methods.** Formalization and structured description of issues will not answer all questions nor solve all problems, but nearly everyone would agree that such methods play a central role in assessing the correctness of a solution to a conceptual problem or the construction of an explicit foundation empowering researchers to similarly identify, describe and resolve other related EI problems. Step 3 investigates the evidence of formal and other descriptive methods in EI and in other, neighbouring domains.
- **Step 4: EI Problem & Solution Space.** The next step on the methodology is related to the first formulation of the EISB concept, namely identifying the EI problem and solution spaces based on a vast and deep "knowledge mining" performed on the inputs gathered in the EISB state of play and action plan. With these spaces defined and the formal methods identified, EISB has the grounds to begin providing solid and properly defined input to the knowledge base.
- **Step 5: Community Building.** In parallel, this wave will aim to formulate the research community, which will undertake each one of the identified issues, and will distribute the accomplished results to a wider audience for attracting the interest of the major stakeholders of the domain and of other external experts and stakeholders, belonging to neighbouring domains. The community will also provide a group of experts to validate and contribute towards the results of the previous steps.
- **Step 6: Revisit.** The EISB Wave 1 does not end with this deliverable (which only documents the ENSEMBLE's EISB Wave 1 work) and, despite the beginning of Wave 2 in ENSEMBLE (ENSEMBLE's EISB Wave 2) project, it needs to be iterated reviewing and refining the results obtained in the previous steps not only during the whole duration of the ENSEMBLE project but also during the whole EISB Wave 1 lifecycle.

As illustrated in Figure 1-1, Wave 1 cross-cuts both activity axis that come out of the EISB State of Play deliverable [35]. They have been simplified, but in short, **Axis 1** continues to symbolize all EISB activities targeting the neighbouring scientific domains while **Axis 2** is self-contained within the FInES cluster and the EI domain. For this reason, some of the steps explained above are represented closer to one of the axis, e.g. step 1 is much closer to Axis 1, and step 2 to Axis 2.

1.4 Structure of the Deliverable

This deliverable is organised as follows:

- Section 2 reports of the second step of the methodology of Figure 1-1 revisiting and fine-tuning the strategy to recognize the closest neighbouring scientific domains, as well as their relationship with EI.
- Section 3 presents a strategy for EISB ontology building and reports on the initial advances, i.e. the lexicon for the knowledge base envisaged by step 3. This section also reports the achievements of the fourth step of the methodology of Figure 1-1, gathering a list of formal and other descriptive methods for EI Problems and solutions description.
- Section 4 reviews in detail the EISB previous works (as summarized in section 1.2) delimiting the EI problem and solution spaces.

- Section 5 briefly summarizes the EISB community groups and some of the evidences and initiatives outreaching the neighbouring domains.
- Section 6 concludes the deliverable reviewing the action plan of wave 2.
- Annex A cites the relevant bibliography and references.

2 Approach for Recognizing Neighbouring Scientific Domains and their Relationship with EISB

An action plan for establishing the scientific foundations of a domain defines a concrete set of activities that need to be collectively undertaken by stakeholders with different backgrounds in a logical time frame in order to eventually lead to the general recognition of its scientific rigorousness.

In fact, the action plan for the EISB formulation has been initially drafted in ENSEMBLE deliverable D2.2 [36]. However, before that action plan can be fully implemented, a number of steps need to be overcome, after which the refinement of that plan will probably be required. Recognizing them, we have drawn a recursive methodology towards the EISB formulation considering inputs from neighbouring domains (Figure 2-1). It is based on 6 steps:

1. **Process Awareness** - The first is related to the analysis of processes followed by other newly born sciences. A very successful example is the one of Software science, but others also exist (e.g. web science, complexity science). ENSEMBLE deliverable D2.2 [36] reports on the results of this step.

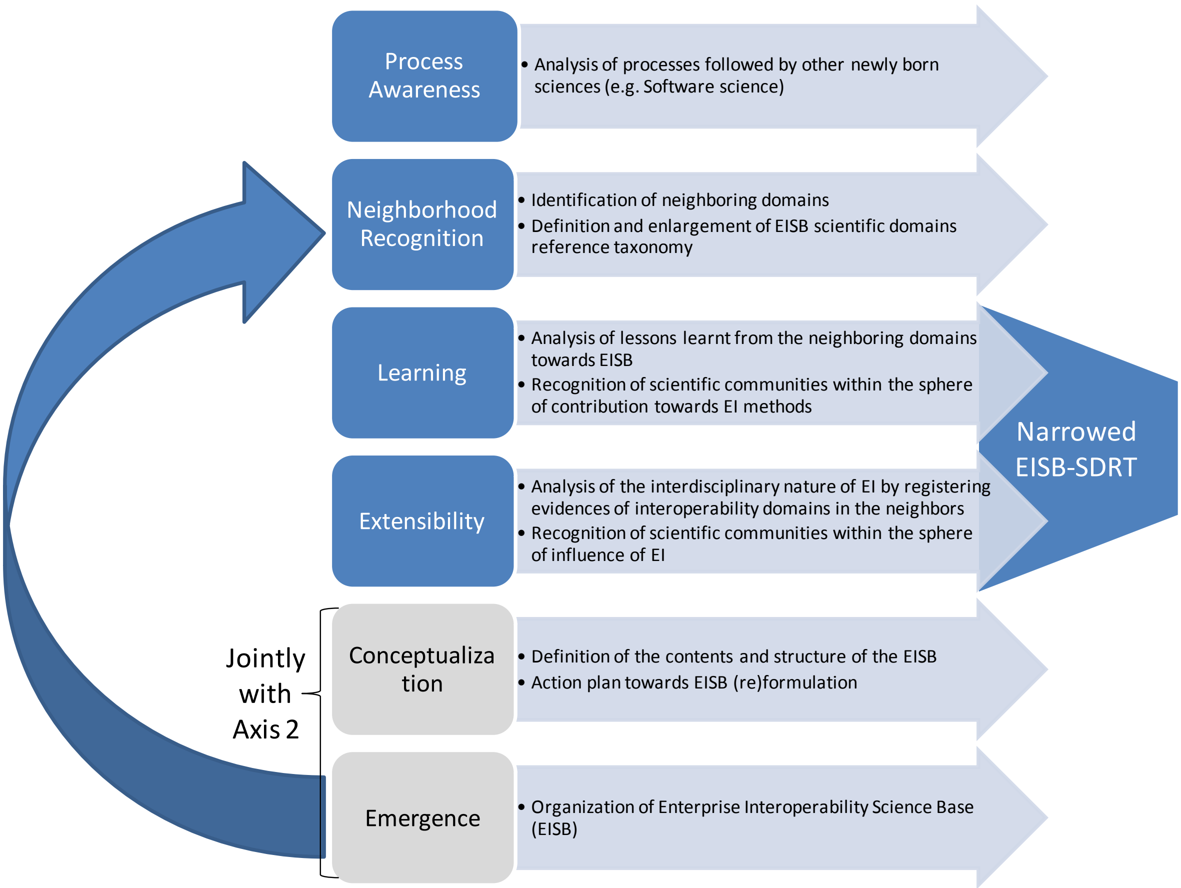

Figure 2-1: Methodology for Recognizing Neighbouring Scientific Domains and their Relationship with EISB

2. **Neighbourhood Recognition** - After the process awareness, and following the rationale behind axis 1 of ENSEMBLE deliverable D2.1 [35], follows the core steps for this deliverable

section, i.e. the identification and structuring of the relevant neighbouring domains (section 2.1), which enable "learning" and "extensibility" steps.

3. **Learning** - In the "learning" step (section 2.2), those neighbours are analyzed in terms of contributions with formal methods for EI problems and solutions description.
4. **Extensibility** - The "extensibility" step (section 2.3) evaluates the interdisciplinary nature of EI, by recognizing evidences of interoperability in the neighbouring scientific domains.
5. **Conceptualization** - Finally, having concluded both of them, "conceptualization" can formalize the definitions of contents and structure of the EISB framework, which will be instantiated through the more detailed, and EI focused action plan, refined each time this step is taken. The wave 1 work on "conceptualization" is reported on sections 3.1 and 4 of this deliverable.
6. **Emergence** - Leads to emergence of a new science, i.e. EISB. However this is not a straightforward process thus it needs to be iterative with the previous steps, namely from step number 2 forward. In fact, each of the EISB waves [36] executes such iteration, thus contributing to a more refined EISB.

Also, the emergence of a new science cannot occur only based on neighbouring domains. In fact, these are not even the main ingredients, thus the last two steps of this methodology are conducted in parallel with axis 2 activities (see Figure 1-1) merging the EI findings with the neighbourhood findings.

Even if not presented with this level of detail, the initial iteration of the methodology of Figure 2-1 has been presented in ENSEMBLE deliverable D2.1 [35]. For this reason, the current deliverable will only present the relevant updates on each of the steps.

2.1 Neighbourhood Recognition

Social sciences, applied sciences and natural sciences are recognized in the general classification of scientific domains. In all of them, characteristics of interoperability are identified, and ENSEMBLE considers them to be promising contributors for the EISB formulation, thus propose in a three-level deep structure for the EISB scientific domain reference taxonomy (EISB-SDRT) divided into the following branches:

- "**Social & behavioural sciences**" is commonly used as an umbrella term to refer to a plurality of fields outside of the natural sciences. These include: anthropology, business administration, communication, economics, education, government, linguistics, international relations, political science and, in some contexts, geography, history, law, and psychology. However not all are identified as relevant neighbours of EI. Creative arts such as music or dancing can also be of interest and explored inside this domain. In fact, a lot of research has been developed concerning psychology of music and performance, performance sciences, etc.
- "**Applied sciences**" is the application of scientific knowledge transferred into a physical environment. Fields of engineering are closely related to applied sciences, which are very important for technology development. Its use in industrial settings is usually referred to as research and development (R&D).
- **"Natural sciences"** which are the branches of science that seek to elucidate the rules that govern the natural world by applying an empirical and scientific method to the study of the

universe. The term "natural sciences" is used to distinguish them from the social sciences. Unlike other sciences, the natural formal sciences are branches of knowledge that are concerned with the properties of formal systems based on definitions and rules. Despite not being all classified as relevant neighbours, fundamental subjects like mathematics or physics, interdisciplinary ones as computer science, and also life sciences are found under this category.

The classification of neighbouring scientific domains under these three categories must be faced with the proper flexibility of any classification exercise. ENSEMBLE has tried to find the most relevant "hat" for each neighbouring domain, however, many times these cross-cut social, natural and applied sciences (e.g. economics has branches in all of them) are not independent of each other (e.g. mathematics is used by many others as the basis for formalisation). This is recognized, thus the taxonomy presented bellow illustrates a relationship between the 3 categories.

2.1.1 EISB Scientific Domain Reference Taxonomy (EISB-SDRT)

The model presented in (Figure 2-2) is a refinement of the one previously presented in ENSEMBLE deliverable D2.1 [35]. Thanks to the deliberations of the results by the ENSEMBLE Experts Scientific Committee and the public validation in events such as the Samos 2011 Summit or the invited session on "Science Base for Enterprise Interoperability in the Advent of the Future of Internet" within the CENT 2011 conference, we have been able to refine the EISB-SDRT and make sure no important domain is being missed.

The initial structure was inspired by several classification structures such as: 1) the AMS mathematics subject classification [6]; 2) the ACM computing classification system [7]; 3) the European Science Foundation research areas [43]; and 4) the SCIENCE magazine subject collections [5]. The rationale for the selected scientific sub-domains and proposed taxonomy is related with the identification of evidences of interoperability issues/problems/solutions in each of the scientific sub-domains foreseen. For example, EI implies seamless communications within networked enterprise environments, which are complex systems, emerging in many forms and from different application domains, consisting of many facets whose proper understanding requires the contribution from multiple disciplines. This way, the scientific foundations related with the major EI research topics can be worked out based on the proposed EISB-SDRT and then connected with the results of the existing applied research, e.g. with the scientific domains of systems complexity, network science, information theory, or web science (refer to sections 3 and 4 of this document).

Naturally the areas enumerated in the EISB-SDRT are far too large to be analysed in detail along the duration of this project, but the purpose of this exercise is to keep record of all possible important neighbours of EI. According to the methodology presented in Figure 2-1, they are to be gradually analysed in the "learning" and "extensibility" steps, and thus continue to be considered as important contributors for the EISB (i.e. for the problem or the solution space) or eliminated from the EISB-SDRT. Since the project is now at the end of wave 1, EISB-SDRT is now at its maximum size and will be reduced and scientific areas identified and properly validated along with the EISB formulating during the following waves that will iterate through the methodology as explained before.

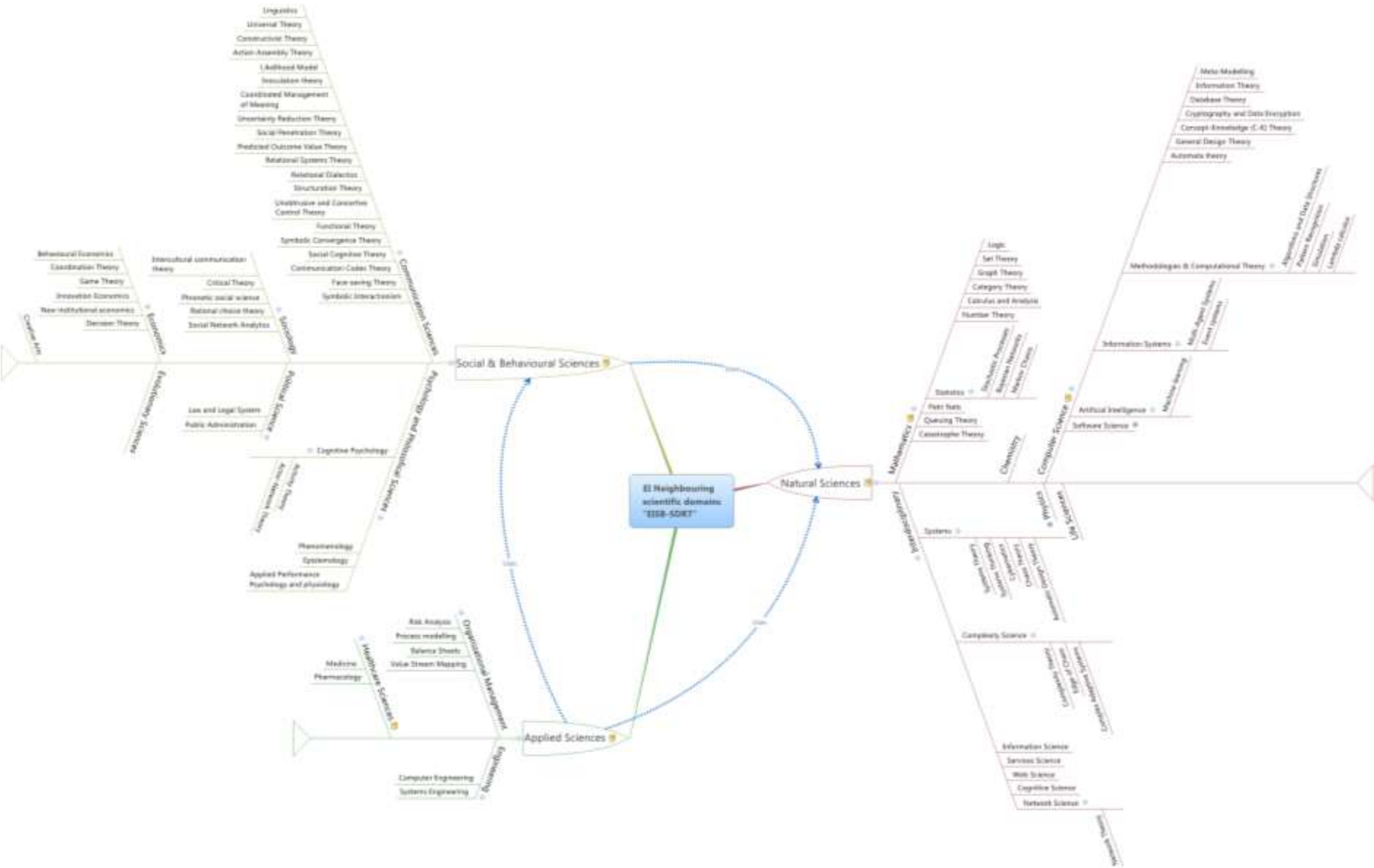

Figure 2-2: Version 2 of the EISB Scientific Domain Reference Taxonomy (EISB-SDRT)

At the end of the project, if some neighbours are yet to be validated, they will be marked in the EISB-SDRT as such and left only for consideration of future iterations. However, the target is to end up with a consistent, but not too extensive, set of EI neighbouring domains. In fact recommendations from experts have directed us to focus on a tangible set of neighbours at the risk of not getting results by the end of the project.

2.2 Learning from Neighbouring Domains

This step analyses the scientific domains in the EISB-SDRT, focusing on how they can contribute to the establishment of the EISB. This analysis started with the work of [20], which identified practical applications connected with scientific domains to be used as a reference to formally describe the interoperability problems; was continued in the EISB state of play report [35] where sociology, medicine, and complexity have been subject to a high level analysis verifying their relevance towards the EISB formulation; and is now being continued at a deeper level, in search for formal methods that can be re-used for EI problems and solutions description (see section 3.2 of this deliverable) and take part of the future EISB problem and solution spaces.

Naturally, before identifying which concepts, theories and principles (from the list gathered in the EISB-SDRT) are useful for formalising interoperability problems, it is necessary first to clearly identify the set of interoperability problems as envisaged in axis 2 activities (see Figure 1-1) and drafted in section 4 of this document.

2.3 Extensibility to Neighbouring Domains

By analyzing the EISB-SDRT scientific domains to evaluate where there is evidence of usage of interoperability-based solutions, one can determine whether EI is relevant in the context of each scientific domain. Therefore, the rationale of this exercise is opposite to the one of "learning", i.e. instead of looking for formal contributions from the neighbouring domains to the EISB, we are envisaging to which domains EI is relevant.

An initial analysis to validate the usefulness of this exercise has been conducted within the state-of-play report [35] and presented at different workshops (e.g. Samos 2011 Summit) and scientific publications [2]. This analysis confirms the inter-relationship(s) that other domains have with EI, namely its interdisciplinary nature. However, that analysis has been conducted according to an old categorization of the EI scientific domains (business, knowledge, applications and data, semantics as in [89] and [14] and lacks community validation from experts from within the neighbouring domains. As presented in [36] and in section "3.1.3.2 - EISB Taxonomy", 12 scientific areas for EI have been identified and therefore, a new extensibility analysis is required.

The aim is to cross-match the EISB-SRDT with the EISB taxonomy and according to the methods identified on the foundational principles and the solutions in the concept formulation, at the end of wave 1, analyse the EI shared content among neighbouring domains. We need to be careful about the mix-and-match approach since people coming from EI (and especially those with more of an engineering than a scientific starting perspective) may not fully understand the bits they borrow from neighbouring domains, as well as practitioners from those domains may not understand the EI phenomena.

The next subsections present both the template to be used to collect knowledge and the benchmarking strategy for collecting results within the neighbouring areas.

2.4 Assessment plan for Learning and Extensibility

In pursue of the short list of EI neighbouring domains, the methodology presented in Figure 2-1 targets to evaluate neighbours in terms of lessons they can provide to EISB and also to analyse to which extent EI methods and solutions are important to the neighbouring scientific domains.

At this stage of ENSEMBLE (i.e. the end of ENSEMBLE's EISB Wave 1), these steps of the methodology should be conducted with the close support of the neighbouring experts. In fact, a dialogue and a dialectic approach are needed (with EI scientists as mediators) to maximize the efficiency and the quality of results. So far, this dialogue has been conducted during dedicated workshops (e.g. Samos 2011 Summit) or through informal conversations; however, a more methodical approach is needed from now on, focusing on:

1. **What to assess**: formal methods from neighbouring domains (learning) and relevance of EI solutions for the neighbouring domains (extensibility);
2. **Assessment targets**: experts from neighbouring communities from within the EISB community groups and the FInES cluster groups (section 6.1), as well as participants to ENSEMBLE events as the Samos Summit or other workshops;
3. **Means to assess (How):** Preferably face-to-face contact in ENSEMBLE events, FInES events, presence in workshops and conferences, but also through ENSEMBLE´s social media mechanisms. An online questionnaire will also be available on the FInES wiki during the ENSEMBLE period;
4. **Time Plan:** Wave 2 and 3 of ENSEMBLE with results presented at the end of wave 2;
5. **Collect and analyse data:** In order not to lose results due to lack of time necessary to put them on paper after one of those events, a template is available for guidance and traceability in the collection of results.

2.4.1 Templates to collect results

Table 2-1: "Learning" stage template

<table>
<tr><th>Neighbouring domain (EISB-SDRT level 2)</th><th>Formal Methods / Systemic Approaches</th><th>Benefits and contributions for EISB</th></tr>
<tr><td rowspan="2"></td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Table 2-2: "Extensibility" stage template

<table>
<tr><th rowspan="2">EI Scientific Area</th><th>Neighbouring domain:
(EISB-SDRT level 3)</th><th></th><th rowspan="2">Notes</th></tr>
<tr><th colspan="2">Relevance to Neighbouring domain</th></tr>
<tr><td rowspan="2"></td><td colspan="2">☐ None ☐ Little ☐ Some ☐ Strong</td><td></td></tr>
<tr><td colspan="2">☐ None ☐ Little ☐ Some ☐ Strong</td><td></td></tr>
</table>

3 EISB Foundational Principles

3.1 EISB Knowledge Base

Data can exist in multiple ways, independently of being usable or not. In the raw format, it does not have meaning in and of itself. However, information is data that has been given meaning by way of relational connection to a context [17]. Still, in information, this "meaning" can be useful for some, but not necessarily to all. It embodies the understanding of a relationship of some sort, possibly cause and effect, thus, people might "memorize" information (as less-aspiring students often do). Nevertheless, they would still be unable to understand it since they require a cognitive and analytical ability, i.e. knowledge [11].

In this context, Nonaka et al. [77] define two kinds of knowledge:

1) Tacit, that people carry in their minds, an which provides context for people, places, ideas, and experiences;
2) Explicit, that has been or can be articulated, codified, and stored in certain media such as an OWL ontology.

In an ideal EI framework with semantic concerns, both should be addressed and processed to achieve more advanced stages of knowledge, such as understanding and wisdom [11], [103]. The major research challenge nowadays is to gather the tacit knowledge domain stakeholders hold, in interpretable knowledge bases, thus transforming it to explicit knowledge stored in a structured organized way. For reaching that purpose, literature suggests the usage of knowledge representation technologies such as dictionaries (domain, technical and natural language), glossaries, taxonomies, thesaurus and also ontologies, to build sustainable knowledge bases [65].

3.1.1 Methodology for EISB Ontology Building

For the EISB formulation, explicit knowledge is proposed to be handled by a reference ontology (section 0). It produces a common language for sharing and reusing knowledge about phenomena in a particular domain, i.e. EI in our case.

An ontology is an agreed specification of how to describe all the concepts, (objects, people, processes, relationships, transactions, etc.), of a particular domain of interest. Indeed, by defining concepts and relationships used to describe and represent an area of knowledge it provides a common understanding of the same, that before may have had different views and interpretations from the different practitioners [13], [53], [51]. Following very simple modelling principles, it uses classes, properties and relationships to define a hierarchical view of the world (designated by taxonomy). An ontology is engineered by members of a domain which try to represent a reality as a set of agreed upon terms and logically-founded constraints on their use [73].

This reference ontology will be the EISB knowledge front-end, enabling terminology sharing and interoperability terms, problems, solutions and experts cross-referencing. Since normally ontology building is a long process, and involves gathering human knowledge from many experts, ENSEMBLE proposes a four-step methodology as described on Figure 3-1.

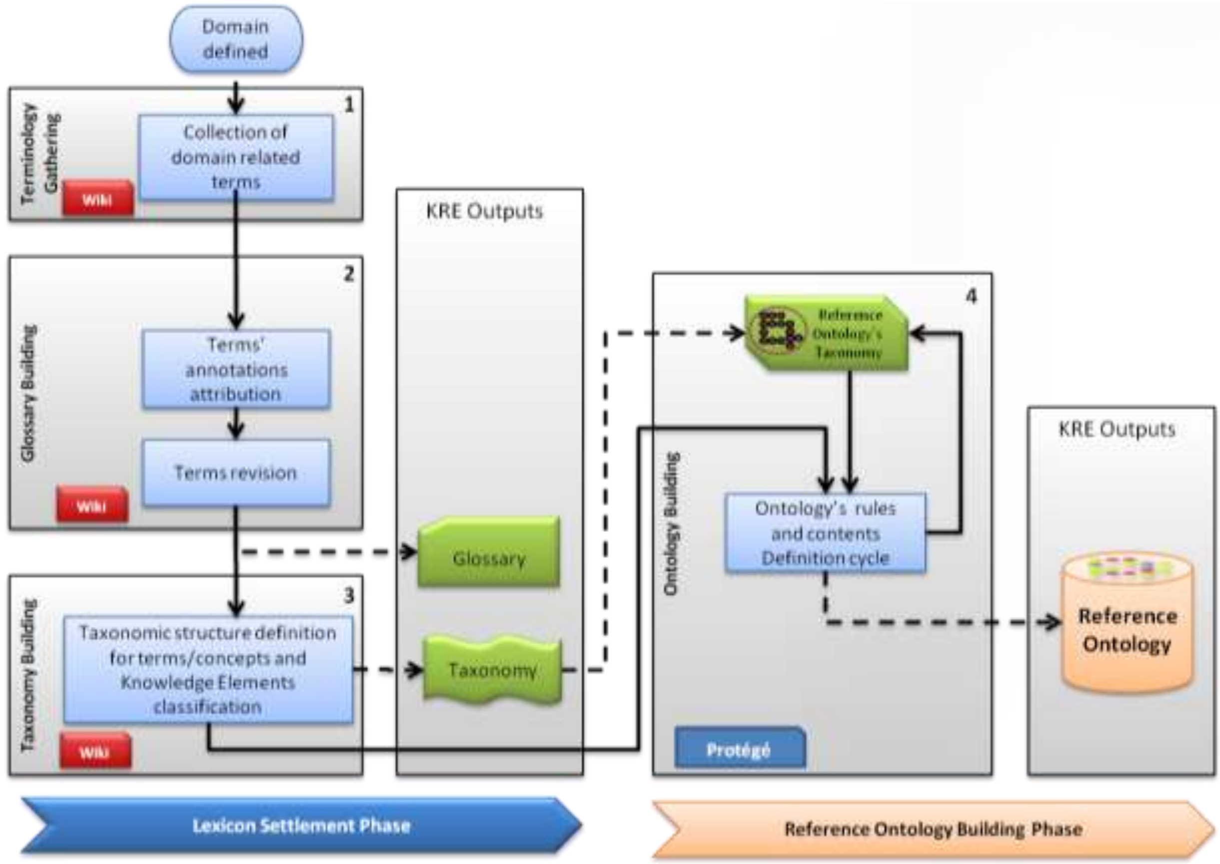

Figure 3-1: Methodology for EISB ontology building

This methodology is based on MENTOR - Methodology for Enterprise Reference Ontology Development, by Sarraipa et al. [92], which is a collaborative methodology developed for helping a group of people, or enterprises, sharing their knowledge with others from the same domains. MENTOR is also used for ontologies harmonization. However those steps have been removed from the EISB ontology building, since ENSEMBLE is building the first ontology for the enterprise interoperability science base.

Therefore, the proposed methodology is divided on 2 stages including in total four steps, as follows.

3.1.1.1 The Lexicon Settlement, or Phase 1

This stage represents the knowledge acquisition by getting a collection of terms and related definitions from all participants. This phase is divided into three steps: Terminology Gathering, Glossary Building, and Taxonomy Building.

1) The first step is a very simple one, and represents the knowledge gathering from all participants in the ENSEMBLE collaborative network for EISB formulation, in a form of a list of EI terms. This step can use the Wiki as a supporting tool for the elicitation of terms and concepts.
2) In the Glossary Building step, a glossary is built after a series of discussions about the terms that every participant contributed to the network on the previous step. These discussions are supported also with the Wiki tool, with all participants being able to assign definitions for the

terms, and having an administration role to deciding which of them are valid and compose the glossary.

3) Finally, the last step of this phase is composed by a cycle where the EI knowledge experts define a taxonomic structure with the glossary terms. If there is an agreement in both structure and classified terms, the taxonomy is defined and we have the backbone on the EISB ontology. The EISB wiki should be updated accordingly, thus reflecting the agreed classification.

3.1.1.2 Reference Ontology Building, or Phase 2

This is the phase where the reference ontology is actually built. This phase, unlike the first one, only has one step, i.e. Ontology Building.

4) This step comprehends the acquisition of the taxonomic backbone structure from the previous step, thus ensuring a seamless integration with the Wiki. First, using a Protégé[4] based environment, a discussion and voting process about the reference ontology rules takes place to enable inference/reasoning mechanisms. This process may result in the update of the taxonomy and/or classification which therefore needs to be reflected as well in the Wiki. If the backbone is kept harmonized at all times, the contents collection for the ontology knowledge base can be done automatically from the EISB Wiki (see section 3.1.4.1 for more details on the architecture to accomplish this).

3.1.2 EISB Knowledge Representation Elements (KREs)

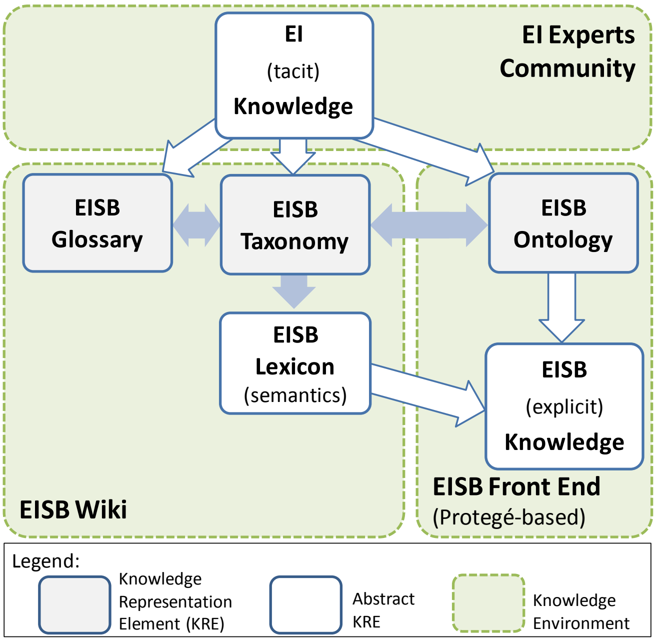

Figure 3-2: EISB knowledge architecture

As evidenced before, the goal of the EISB knowledge base is to gather the tacit knowledge that EI experts hold into machine interpretable knowledge bases. For reaching that objective, ENSEMBLE is

[4] http://protege.stanford.edu/

proposing to integrate the EISB reference Ontology that embraces terms and concepts classification to its related EI properties, with the EISB Lexicon, which embodies the reference concepts and semantics. This leads to the knowledge architecture definition where the integrated knowledge is composed by 3 Knowledge Representation Elements (KREs): the EISB Ontology, the EISB Taxonomy, and the EISB Glossary (Figure 3-2).

For a good explicit knowledge representation, it is needed to have significant input from the tacit source (i.e., domain experts). Thus, such characteristic requires a knowledge architecture enabling the management of the evolution between the KREs:

- The evolution of the first two KREs leads to the EISB Lexicon establishment which is an abstract KRE because it does not have a physical representation by itself. In this case we can say that the Wiki will act as the knowledge environment for the lexicon;
- On the other hand, the EISB explicit knowledge is another abstract KRE since it is composed by the addition of the lexicon with the ontology. The EISB explicit knowledge represents all the EI machine interpretable knowledge and can be interfaced by web front-end that could be integrated in the ENSEMBLE website at the same level of the Wiki.

3.1.2.1 Glossary KRE Definition

Glossary is a list (mostly in alphabetic order) of specialized terms, sometimes unique to specific subject. Each term is composed by its corresponding description. It includes descriptive comments and explanatory notes, such as definitions, synonyms, references, etc.

A glossary can be used when communicating information in order to unify knowledge sharing. It is understood as a set of terms and their definitions, and is bound to the source document or domain where these definitions are set.

The EISB glossary is the output of the first and second steps of the methodology for EISB ontology building, and is available on section 3.1.2.1.

3.1.2.2 Taxonomy KRE Definition

A taxonomy is a classification system that categorizes all the information in a class/subclass relationship, representing a simple tree structure. At the top of this structure is a single classification, the root node that applies to all objects. The root node represents the most general category of all things that the domain is related to. Nodes below this root are more specific classifications that apply to subsets of the total set of classified objects [70].

The EISB taxonomy is the output of the third step of the methodology for EISB ontology building, and is available on section 3.1.3.2.

3.1.2.3 Ontology KRE Definition

An ontology is an explicit specification of a conceptualization [50]. Thus, ontologies could provide a basis for expressing and structuring the knowledge of an organisation. They are used to standardize terminologies, classify different concepts, map requirements, and organize them systematically thus facilitating integration of systems [33], [51], [68], [85].

Ontologies are related to but different from taxonomies, typologies, concept hierarchies, thesauri, and dictionaries [46]. They are tools for systematizing the description of complex systems, which in turn, could facilitate in the formalization of the EISB.

The EISB reference ontology is the output of the final step of the methodology for EISB ontology building. The ontology is not yet available in this deliverable since according to the EISB action plan, it will only be the part of the output of subsequent waves.

ENSEMBLE EISB and research roadmap teams will coordinate to avoid overlaps with the knowledge repository that is planned for the Roadmap implementation (FInES RR). Despite having different purposes and focus efforts are complementary, i.e. the EISB ontology is the mean of harmonizing the language of experts of different science spaces and is focused on the basic scientific topics and neighbouring sciences, while the FInES RR repository as a wider scope and might address some of the same concepts, as exemplified by the 4 knowledge spaces described in ENSEMBLE D3.3.1 [37].

3.1.3 EISB Lexicon

As stated before, the main purpose of the existence of the EISB is to identify, classify, and conduct a deeper research in the major issues of Enterprise Interoperability towards the scientific establishment of a well-defined corpus material that would act as the fundamental Enterprise Interoperability knowledge. This material will play a very important role not only in the future evolution of the domain of Enterprise Interoperability, but will also support the restructuring of the domain based on a more scientific approach, clearing out any current inconsistencies and promoting a common understanding amongst all stakeholders.

To this end, we need an EISB Lexicon that will be in a position to describe in a unanimous way the major concepts of the domain, and provide a well-defined structure for the various EISB elements and that can be used and extended by every stakeholder. The following sections provide an initial version of the EISB Lexicon, which at the current state includes a glossary presenting the main concepts of the work undertaken so far, a preliminary view of the EISB Taxonomy and a description of the EISB supporting Wiki platform. It has to be noted, that the current version of the EISB Lexicon presents only a first attempt to document at a high level these elements and will be further elaborated and populated during the next waves of the ENSEMBLE project.

3.1.3.1 EISB Glossary - Key Terms & Definitions

The following EISB glossary (or vocabulary) is the first version of an alphabetical list of terms of the EI domain with the definitions for those terms. The version presented in this section includes the major elements of the glossary. The full glossary, at its present state can be found in the EISB Knowledge Base (FInES Wiki) at the Glossary Category[5], where the terms are presented and can be edited.

[5] http://www.fines-cluster.eu/fines/mw/index.php?title=Category:EISB_Glossary

Table 3-1: Initial Version of EISB Glossary – Main Extract

Term	Definition
Enterprise Interoperability	The capacity of two or more enterprises, including all the systems within their boundaries and the external systems that they utilize or are affected by, in order to cooperate seamlessly in depth of time for a common objective
Enterprise	A system designed to provide goods, services, or both to consumers, based on the following main ingredients: • Infrastructures referring to all facilities and non-human assets. • Data used for the business transactions within and outside its boundaries • Processes including all structured business activities or tasks. • Policies embracing the different rules applied due to external or internal factors. • Human resources that are part of the system.
Scientific Area	A high level specific domain of knowledge of an Enterprise Interoperability related issue reflecting a core element of an Enterprise or a combination of those.
Scientific Sub-Area	A deeper and more specific domain of knowledge belonging to an Enterprise Interoperability Scientific Area.
Problem Space	The range of application and theoretical problems addressed by the Enterprise Interoperability domain.
Solution Space	The range of application and theoretical solutions that are capable of addressing the issues included in the Problem Space.
Problem – Solution Path	A mapping of how an issue included in the Problem Space can be solved using elements that belong to the Solution Space.
Concepts	Definitions accompanying an idea, a methodology, a tool or an architecture for Enterprise Interoperability at a very conceptual level, as well discussions on issues that reflect the personal opinion, experience and expertise of the writer or an organization.
Methods	Scientific approaches that employ formal/informal methods and validated models for the problem and / or the solution definition, specifications, architectures, verifications and theorem provers.
Proof-of-concept	The application of a method, a tool or a specific problem – solution path in a specific environment in order to test their validity.
Tools	Software prototypes and other tangible or intangible tools providing a specific problem – solution path.
Experiments	The process and results of conducting a controlled test or investigation, consisting either of Laboratory exercises or of field tests.
Case Studies	Processes and attempts that are investigating a single phenomenon (e.g., a problem, a solution or their combination) in an organization over a logical time

Term	Definition
	frame.
Surveys- Empirical Data	Data and evidence acquired through methods of collecting quantitative information, experiments or observations.
Standards	Formal documents that establish uniform engineering or technical criteria, methods, processes and practices and are available for consideration and use worldwide.
Data Interoperability	The ability of data (including documents, multimedia content and digital resources) to be universally accessible, reusable and comprehensible by all transaction parties (in a human-to-machine and machine-to-machine basis), by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches.
Process Interoperability	The ability to align and connect processes of different entities (enterprises), in order for them to exchange data and to conduct business in a seamless way.
Rules Interoperability	The ability of entities to align and match their business and legal rules for conducting legitimate automated transactions that are also compatible with the internal business operation rules of each other.
Objects Interoperability	Objects interoperability refers to the networked interconnection of everyday objects. Devices or hardware components interoperability can be seen as a particular case of the object interoperability domain.
Software Interoperability	Software Interoperability refers to the ability of an enterprise software application to work with other enterprise software application.
Cultural Interoperability	The degree to which knowledge and information is anchored to a unified model of meaning across cultures.
Knowledge Interoperability	The ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilise it, and to further extend them through cooperation.
Services Interoperability	The ability of an entity to seamlessly and automatically discover, aggregate and utilise a service that belongs to another entity.
Social Networks Interoperability	The ability of enterprises to utilise social networks for collaborations and interconnection purposes, by aligning part of their internal structure and functions to the characteristics of the social networks.
Electronic Identity Interoperability	The ability of different eID systems to collaborate in order to automatically authenticate entities and to pass on security roles and permissions to eID holders, regardless the system that they originate from.
Cloud Interoperability	The ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud dependant.
Ecosystems Interoperability	The ability of instant and seamless collaboration between different ecosystems, ecosystems and independent entities, entities within the

Term	Definition
	ecosystems and the ability of different independent entities to formulate virtual structures for specific purposes.
Semantic Data Representation	Semantic Data Representation refers to the enrichment and representation of data using semantics towards increasing the degree of comprehending the information carried.
Data Standardization	Data Standardization refers to the use of the same set of codes to create generic, yet expandable data standards to be used by all enterprise systems.
Schema Matching	Schema matching refers to identifying the existence of semantic relationships between data objects and mapping them to each other.
Data Mediation	Data Mediation refers to the translation and transformation of data between two or more different schemas.
Process Modelling	Process Modelling refers to the activities of describing a process or a set of processes through a specific representation method called modelling methodology.
Process Reengineering	Process Reengineering refers to activities employed with the transformation of processes to more generic ones in order to follow same patterns.
Process Standardization	Process standardization refers to the definition of universal standard processes that have to be operated by enterprises of any kind.
Process Alignment	Process Alignment refers to the creation of generic process models accompanied with the underlying mapping procedures towards enabling interoperability between processes belonging in different enterprises.
Automated Process Execution	Automated Process Execution refers to the ability to generate and execute business processes directly from business process models, enabling the automatic generation of processes based on requests from third parties also.
Rules Modelling	Rules Modelling refers to documentation and the development of expandable and re-usable models that are able to represent rules (legal or business specific).
Legislation Homogenisation/Alignment	Legislation Alignment refers to aligning the different legislative environments of different territories in order to enable the legitimate conduct of transactions in all involved domains.
Rules Execution	RFID interoperability refers to tags from any vendor to be able to communicate with RFID readers from any vendor, and also to when a given tagged object is able to be identified by RFIED readers of any user in a wide variety of application conditions.
Device Interoperability	Interoperability between physical devices that involves transferring information through communication channel, using services of different devices, and understanding the meaning of information unambiguously.
Service Oriented Architecture (SOA) and Web Services	Service-oriented architecture (SOA) is a set of design principles used during the phases of systems development and integration in computing. A system based on a SOA will package functionality as a suite of interoperable services

Term	Definition
	that can be used within multiple, separate systems from several business domains. Web services can implement a service-oriented architecture. Web services make functional building-blocks accessible over standard Internet protocols independent of platforms and programming languages. These services can represent either new applications or just wrappers around existing legacy systems to make them network-enabled.
Middleware	Middleware is computer software that connects software components or people and their applications. The software consists of a set of services that allows multiple processes running on one or more machines to interact. This technology evolved to provide for interoperability in support of the move to coherent distributed architectures.
Software Interoperability Conformance & Testing	Software Interoperability testing is the activity of proving that end-to-end functionality between (at least) two communicating systems as required by those systems' base standards.
Language Interoperability	Language interoperability refers to the automatic and seamless translation of languages.
Alignment in traditions, religions and ethics	Alignment in traditions, religions and ethics refers to finding ways of respecting each individual's cultural needs while at the same time promoting collaboration and cooperation.
Knowledge Sharing & Knowledge Repositories	Knowledge Sharing & Knowledge Repositories refers to the employment of methods and tools for recording and storing knowledge in a way that is retrievable and meaningful to every party that is allowed to access it.
Business Units Alignment	Business Units Alignment refers to the integration, sharing and collaboration of multiple business units in terms of knowledge in order to deliver a product or a service.
Ontology Matching	Ontology matching refers to the determination of relationships and correspondences between various knowledge concepts that are incorporated in ontologies.
Automatic service discovery, description, composition, negotiation	Automatic service discovery, description, composition, negotiation refers to tools, methodologies and infrastructures enabling the automatic discovery of services offered by enterprises and the dynamic composition of them in order to conduct business in an automated manner with no extra modification in the enterprise systems.
Enterprise Mashups	An enterprise mashup, also referred to as a business mashup, is an application that combines data from multiple internal and public sources and publishes the results to enterprise portals, application development tools, or as a service in an SOA cloud. Enterprise mashups must also interoperate with enterprise application technologies for security, governance, monitoring, and availability.
Service Co-Design	Service Co-Design in an enterprise involves the individuals from all levels of an organization or outside the organization (i.e. customers) in the innovation process—empowering them as co-designers of service concepts so they can develop a more cohesive experience at the point of use.

Term	Definition
Service Level Agreements	A service-level agreement (SLA) is a contract between a network service provider and a customer that specifies, usually in measurable terms, what services the network service provider will furnish.
Social Network Integration	Social network Integration refers to the integration of specific social media aspects and characteristics in the organisational structure of an enterprise in order to be able to utilise seamlessly such infrastructures and their functions.
Digital Signatures Interoperability	The mutual recognition of electronic signatures among countries, that involves overcoming of the current legal (legislation, management authorities) as well as technical heterogeneities in terms of attributes, validation, format and algorithms [59].
Federated Identity Management Systems	A Federated Identity Management system supports the technologies, standards and use-cases which serve to enable the portability of identity information across otherwise autonomous security domains
Unified Cloud Interfaces	Unified Cloud Interfaces refers to the design of standard interfaces for direct communication and interoperation between clouds from different providers
Cloud Federation	Cloud Federation refers to the ability to utilise heterogeneous cloud resources as a unified and universal computing environment without experiencing the issues that can be caused by this differentiation.
Business Ecosystems Interoperation	Business Ecosystems Interoperation refers to the ability of Business Ecosystems to cooperate in order to dynamically converge and operate towards a common goal.
Virtual Enterprise Integration	Virtual Enterprise Integration refers to the ability of two or more virtual enterprises to be able to communicate and collaborate in all business levels in a seamless and automated way.

3.1.3.2 EISB Taxonomy

This section outlines the major Scientific Areas and the underlying sub-areas that have been identified so far during the initial steps of the project and the 1st Wave of ENSEMBLE. These sub-areas will be subject to debate amongst the ENSEMBLE Experts Scientific Committee, the Validation Community and the FInES Cluster and will be further developed / amended during the next waves of the project, in order to formulate a solid and globally accepted taxonomy for EISB. It has to be noted, that only the more "concrete" sub-areas of the whole EISB Taxonomy (see Figure 3-3) are analysed in the following section, as the work in this direction is still under development and various sub-areas that appear in the taxonomy are subject to debate.

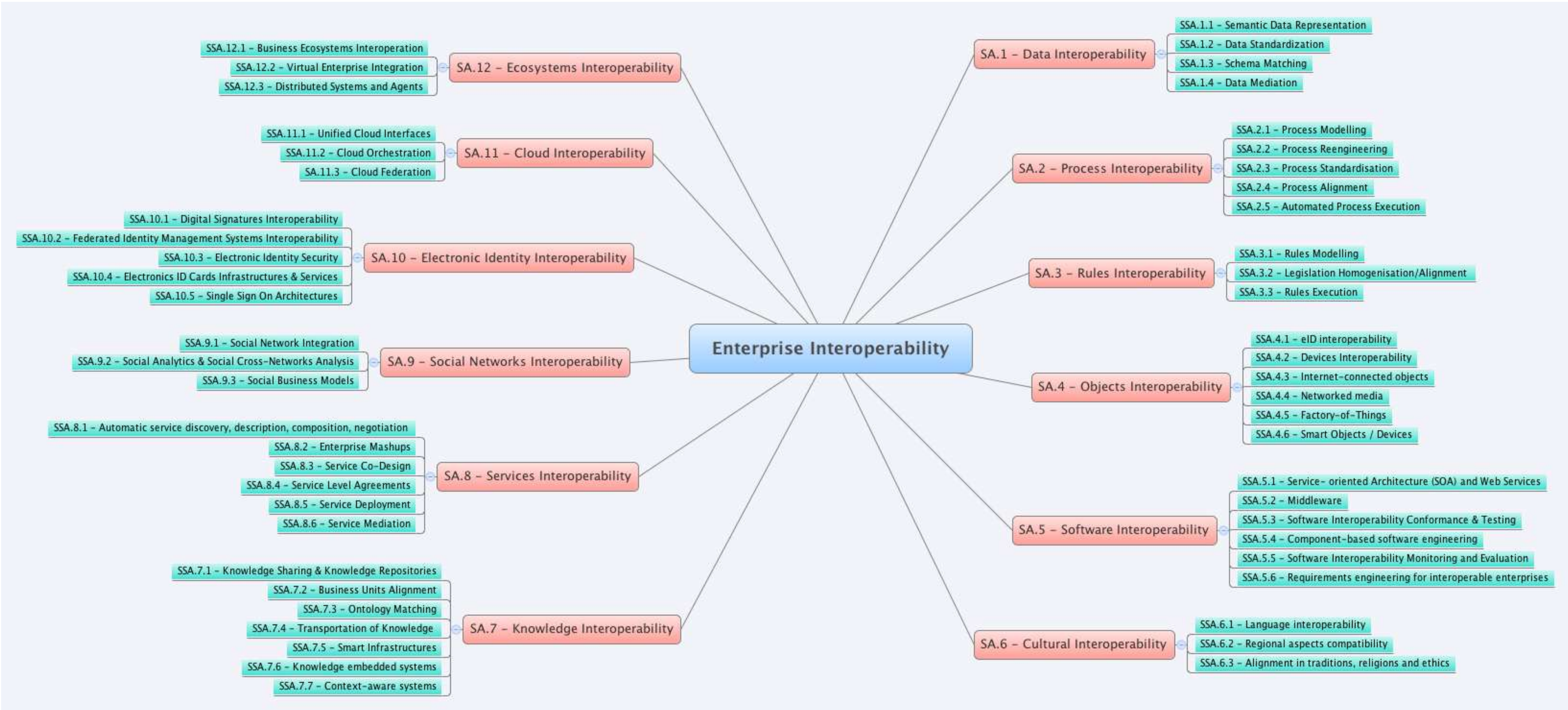

Figure 3-3: EISB Taxonomy Representation (initial phase)

SA 1: Data Interoperability

This category of the taxonomy concerns the ability of data (including documents, multimedia content and digital resources) to be universally accessible, reusable and comprehensible by all transaction parties (in a human-to-machine and machine-to-machine basis), by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches.

Table 3-2: Data Interoperability – Metadata Table

ID	SA.1	Title	Data Interoperability
Description			The ability of data (including documents, multimedia content and digital resources) to be universally accessible, reusable and comprehensible by all transaction parties (in a human-to-machine and machine-to-machine basis), by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches
Hierarchical Links			**Backlinks** • - **Outbound Links** • Social Networks Interoperability • Services Interoperability • Knowledge Interoperability
Indicative Scientific Sub-Areas			• Semantic Data Representation • Data Standardization • Schema Matching • Data Mediation
Tags			Semantic Information Exchange, Data Sharing, Data Integration, Schema Matching, Data Mash-ups

SSA.1.1: Semantic Data Representation

Data is regarded amongst one of the most important element of information systems, as it is the medium, which contains information that is exchanged in order to execute the various business activities. As such, throughout the years, huge amount of data have been created resulting in the data deluge of today, where systems, not to mention humans, are unable to fully interpret and handle these amounts of information. In order to overcome this obstacle, data needs to be more comprehensible by both systems and humans and in this direction, semantic enrichment of data, leading to semantic representation, is a necessity for being able to understand and eventually process data resulting from various sources.

Table 3-3: Semantic Data Representation – Metadata Table

ID	SSA.1.1	Title	Semantic Data Representation
Scientific Area			**Data Interoperability**
Description			Semantic Data Representation refers to the enrichment and representation of data using semantics towards increasing the degree of comprehending the information carried.
Related Terms/Tags			*Semantic Annotation, Enriched Data*

SSA.1.2: Data Standardization

The diversity of information systems and the huge amount of data they handle, alongside with the different scopes and aims these systems are used for has resulted since the beginning of computer science to various data formats and standards which classify and store data using different methods, patterns and algorithms. These differentiations have resulted in non-compatible data elements, which need to be tackled by introducing common flexible standards that would fit to every system/activity.

Table 3-4: Data Standardisation – Metadata Table

ID	SSA.1.2	Title	Data Standardization
Scientific Area			**Data Interoperability**
Description			Data Standardization refers to the use of the same set of codes to create generic, yet expandable data standards to be used by all enterprise systems.
Related Terms/Tags			Data Homogenization, Common Standards

SSA.1.3: Schema Matching

Another important sub-area of data interoperability is that of Schema Matching (and Mapping). Heterogeneous data is encapsulated in different schemas, used by specific information systems that are able to interpret and process them. In order to promote interoperability, it is essential to seek ways for identifying whether two schemas are related and how one should proceeding with mapping the various artefacts of one to the other [10]. In this way, today research in schema matching seeks to provide automated support to the process of finding semantic matches between two schemas and of automatically mapping the various elements.

Table 3-5: Schema Matching – Metadata Table

ID	SSA.1.3	Title	Schema Matching
Scientific Area			**Data Interoperability**
Description			Schema matching refers to identifying the existence of semantic relationships between data objects and mapping them to each other.
Related Terms/Tags			Data Matching, Data Mapping, Schema Mapping, Schema Interrelation

SSA.1.4: Data Mediation

Another very important and active sub domain of data interoperability is that of data mediation, which refers to the transformation of data (through a mediator) from a specific format or schema to another one. The mediator is a program that is responsible of translating data between two systems with different data schemas in order to allow the flawless exchange and process of data between different systems. Today there are numerous languages available for data transformation, such as AWK[6], Perl[7] and Extensible Stylesheet Language Transformations) (XSLT)[8].

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[6] http://cm.bell-labs.com/cm/cs/awkbook/index.html
[7] http://www.perl.org/
[8] http://www.w3.org/TR/xslt20/

Table 3-6: Data Mediation – Metadata Table

ID SSA.1.4 **Title**	**Data Mediation**
Scientific Area	**Data Interoperability**
Description	Data Mediation refers to the translation and transformation of data between two or more different schemas.
Related Terms/Tags	Data Transformation

Scientific Area 2: Process Interoperability

Process Interoperability refers to the ability to align and connect processes of different entities (enterprises), in order for them to exchange data and to conduct business in a seamless way.

Table 3-7: Process Interoperability – Metadata Table

ID SA.2 **Title**	**Process Interoperability**
Description	The ability to align and connect processes of different entities (enterprises), in order for them to exchange data and to conduct business in a seamless way
Hierarchical Links	**Backlinks** • - **Outbound Links** • Knowledge Interoperability • Services Interoperability
Indicative Scientific Sub-Areas	• Process Modelling • Process Reengineering • Process Standardisation • Process Alignment • Automated Process Execution
Tags	Process, Process Modelling, Process, Reengineering, Tasks, Patterns

SSA.2.1: Process Modelling

Process Modelling refers to the activities of describing a process or a set of processes through a specific representation method called modelling methodology. The main target in process modelling is to construct specific process models in order to document, improve and optimise the processes that are running in an organisation [107]. Especially, when talking about Enterprise Interoperability, process modelling is an essential activity as it may point out incompatibilities between processes, which result in the inability for systems to collaborate.

Throughout the last century, many techniques towards process modelling have been designed [57], [4] such as Flow charts, Block Diagrams, Gantt Charts, Pert diagrams, the IDEF method, UML and BPMN.

In the last years, there has been a substantial progress in this area, as it is essential for enterprises to possess a detailed documentation of their processes. For this reason, many companies that specialise in the offering of business process modelling services have been launched, while the market has been populated by a large amount of tools (such as ARIS, ADONIS, CaseWise, etc.) that support different (and in most cases more than one) modelling methodologies.

However, although the intense research in this area, there is still no general framework on what a process modelling technique should include to be successful, while at the same time the uncoordinated research has resulted in the fragmentation of this are, which is neither well structures nor classified properly [4].

Table 3-8: Process Modelling – Metadata Table

ID	**SSA.2.1**	**Title**	**Process Modelling**
Scientific Area			**Process Interoperability**
Description			Process Modelling refers to the activities of describing a process or a set of processes through a specific representation method called modelling methodology.
Related Terms/Tags			Business Process Modelling, Business Process Management, Modelling, Process Models, Models

SSA.2.2: Process Reengineering

The different types of enterprises and the various sectors and markets the latter operate has resulted in the generation of various versions of processes, which deal with almost the same things but are executed in different ways. In order to be able to overcome the various obstacles created by the differentiation of processes, enterprises need to employ process reengineering methods so that they can analyse, evaluate redesign and eventually transform the already running processes to more interoperable friendly ones.

Business process re-engineering is the analysis and design of workflows and processes within an organization. According to Davenport & Short [30], a business process is a set of logically related tasks performed to achieve a defined business outcome. Re-engineering is the basis for many recent developments in management

Table 3-9: Process Reengineering – Metadata Table

ID	**SSA.2.2**	**Title**	**Process Reengineering**
Scientific Area			**Process Interoperability**
Description			Process Reengineering refers to activities employed with the transformation of processes to more generic ones in order to follow same patterns.
Related Terms/Tags			Process Transformation, Process Homogenization

SSA.2.3: Process Standardisation

According to Tregear [104], "every organization would like to avoid uncoordinated business process activity with isolated business units constantly re-inventing the wheel". In order to refrain from such circumstances of control loss and of inability to co-ordinate not only external but also external processes, organizations must work towards standardizing their processes so that they are well defined and commonly acknowledged by both their employees, their clients and their business partners. As De Vries [32] states, process standardization offers particularly in the services industry technical interchangeability, compliance with regulations, and improved customer confidence. This has been since long time realised also in the eBusiness domain and therefore many frameworks have been proposed, which are nothing less that standards for this exact purpose and they might also combine other standards, specifications, and classifications and cover both the business and technical aspects of communication [79]. Users of these standards are mostly companies that seek seamless interaction and interoperability, while at the same time they seek to sort out and strictly define the process flow in themselves as well.

However, as the bibliographical research and the actual domain knowledge points out, throughout these years there have been numerous attempts regarding this scientific issue, which had little to medium success due to the fact that there was no globally acceptable standard. Their uptake was heavily influenced by the company's IT orientation and their networks of collaborators, but the plethora of solutions available derailed the track towards a sustainable and inclusive interoperable framework.

In this context, Enterprise Interoperability has to re-evaluate the different available eBusiness standards and frameworks with respect to the process dimension, and research towards defining universal standard processes that should be implemented, respected and operated by organizations of any kind (for example one single and universal process for invoicing, one single and universal process for quoting, etc.).

Table 3-10: Process Standardization – Metadata Table

ID	SSA.2.3	Title	Process Standardization
Scientific Area			Process Interoperability
Description			Process standardization refers to the definition of universal standard processes that have to be operated by enterprises of any kind
Related Terms/tags			Standards, Frameworks, Patterns, Specifications

SSA.2.4: Process Alignment

The differentiation of processes between the various enterprises is a major issue contributing to the lack of interoperability, as simple processes are in many cases not compatible due to some extra calls or internal workflow design that makes them unable to interoperate and complete a transaction. To this end, researches are constantly trying to identify generic models of processes and of underlying mapping rules that could be taken up by enterprises in order to guarantee the right communication and collaboration of processes amongst the various systems.

Table 3-11: Process Alignment – Metadata Table

ID	SSA.2.4	Title	Process Alignment
Scientific Area			Process Interoperability
Description			Process Alignment refers to the creation of generic process models accompanied with the underlying mapping procedures towards enabling interoperability between processes belonging in different enterprises.
Related Terms/tags			Generic Processes, Process Matching, Process Mapping

SSA.2.5: Automated Process Execution

Although during the last years much progress has been recorded regarding the domain of process modelling, the automated extraction of those models from the various blueprints and their automatic execution is still behind, as only a few attempts have been made in this direction, with the most notable being BPEL4WS. Automated Process Execution is expected to benefit in a very heavy and positive manner the problem of Enterprise Interoperability, as it will not only allow the minimization of resources for transforming the models to the actual workflow, but it will also boost dynamic cooperation (and thus interoperability degree) as processes could be implemented on the fly by request coming from third parties in the form of process models.

Table 3-12: Automated Process Execution – Metadata Table

ID	SSA.2.3	Title	Automated Process Execution
Scientific Area			**Process Interoperability**
Description			Automated Process Execution refers to the ability to generate and execute business processes directly from business process models, enabling the automatic generation of processes based on requests from third parties also.
Related Terms/tags			Process Execution Engines, Process Automators, Automated Process Composition

Scientific Area 3: Rules Interoperability

The ability of entities to align and match their business and legal rules for conducting legitimate automated transactions that are also compatible with the internal business operation rules of each other.

Table 3-13: Rules Interoperability – Metadata Table

ID	SA.3	Title	Rules Interoperability
Description			The ability of entities to align and match their business and legal rules for conducting legitimate automated transactions that are also compatible with the internal business operation rules of each other.
Hierarchical Links			**Backlinks** • - **Outbound Links** • Services Interoperability • Knowledge Interoperability • Electronic Identity Interoperability
Indicative Scientific Areas			• Rules Modelling • Legislation Homogenisation/Alignment • Rules Execution
Tags			Rules, Legislation, Business Rules, Legal Rules

SSA.3.1: Rules Modelling

In direct comparison with data and processes, rules need also to be modelled in order to document the organisational policies and procedures [52] of a system and thus to be aware how it shall react to specific inputs that influence its state. As stated in [31], "Modeling such rules is not an easy task since in general it is hard to arrive at the precise understandings and agreements, which they formulate; furthermore these rules may change regularly according to changes in these business aspects." As rules are very closely related with data and processes in the eBusiness transaction world, most of the attempts conducted so far towards modelling legal or business rules take as granted the engravement of rules as supplementary elements into the methodologies for modelling the various processes and data. This is in most cases how most process and data modelling methodologies and software tools contain procedures that are able to bind the elements under investigation with various rules that they are subject to.

However, this issue, although having a major impact on interoperability, is not tackled by its own and in most cases is treated as a supplementary issue, which does not offer the possibility of really tackling this issue. Instead, working but not expandable and case specific rule models appear, which cannot be reused in the future. Rules should be modelled separately in the logical model (i.e. not in the implementation level) [31] and they should also be modelled in a declarative manner, in order to enhance their maintainability and reusability through the years [47], as in most cases there are no radical changes in both the legislation and in the business domain, but small corrections and amendments.

All the above dictate that rules modelling is an open issue for Enterprise Interoperability, as currently the different set of business and legal rules present are not only hindering the ability of systems to interoperate, but are much more complex to capture [54] and require innovative and focused solutions in order to be solved. However, they also need to be comprehensible and suitable from business analysts and programmers in order to build the systems and the infrastructures to support them and to execute them.

Table 3-14: Rules Modelling – Metadata Table

ID	**SSA.3.1**	**Title**	**Rules Modelling**
Scientific Area			**Rules Interoperability**
Description			Rules Modelling refers to documentation and the development of expandable and re-usable models that are able to represent rules (legal or business specific)
Related Terms/Tags			Rules Modelling, Rules Representation

SSA.3.2: Legislation Homogenisation/Alignment

One of the major obstacles in Enterprise Interoperability which is classified under the Rules Interoperability scientific area is the fact that electronic transactions are held back by legislative issues which does not allow or make automation too complex.

Legal rules are different in each country and the way of conducting transactions has been tailored throughout the centuries to apply with those rules, which in most cases date back for many years and are quite inflexible.

In order to allow the growth of enterprises and enable the full automation between enterprise systems, a flexible legislation environment has to be set up, where enterprises should operate under the same generic rules. Towards these directions, countries are beginning to amend their legislation according to the directives issued by the EC in order to bring their national laws closer to each other in order to foster cooperation and at the same time protect all bodies that take part in a transaction, while legitimating the action in both territories.

However, there is still much way to cover until we reach such a legislation environment, as such changes cannot happen very fast. It is essential therefore for Enterprise Interoperability to seek ways of aligning and homogenizing these legislative areas that are closer to the scope and the application area of electronic transactions.

Table 3-15: Legislation Homogenisation/Alignment – Metadata Table

ID	SSA.3.2	Title	Legislation Homogenisation/Alignment
Scientific Area			**Rules Interoperability**
Description			Legislation Alignment refers to aligning the different legislative environments of different territories in order to enable the legitimate conduct of transactions in all involved domains.
Related Terms/Tags			Legislative homogenization, Legislation matching

SA.3.3: Rules Execution

In parallel to automated process execution, EI should also tackle the issue of intelligent rules execution engines in order for enterprises to be able to perform legitimate and rightful (according to their internal business rules) transactions with each other, without the need of human monitoring regarding the validity and the legitimacy of the transaction. To this end, rules execution engines and methodologies need to be able to include both business and process rules, to be flexible to include all future amendments and to inherit artificial intelligence characteristics in order to take decisions regarding different rules requirements between systems that take part in a business transaction.

Table 3-16: Rules Execution – Metadata Table

ID	SSA.3.2	Title	Rules Execution
Scientific Area			**Rules Interoperability**
Description			Rules Execution refers to the dynamic processing and handling of rules by systems in order to be able to comply with both legislative and business rules that embrace business processes and transactions
Related Terms/Tags			Rules Engines

<u>Scientific Area 4: Objects Interoperability</u>

Objects interoperability refers to the networked interconnection of everyday objects. Devices or hardware components interoperability can be seen as a particular case of this domain.

Table 3-17: Objects Interoperability – Metadata Table

ID	SA.4	Title	Objects Interoperability
Description			Objects interoperability refers to the networked interconnection of everyday objects. Devices or hardware components interoperability can be seen as a particular case of the object interoperability domain.
Hierarchical Links			**Backlinks** • - **Outbound Links** • Knowledge Interoperability • Electronic Identity Interoperability

Indicative Scientific Sub-Areas	• RFID interoperability • Devices Interoperability • Internet-connected objects • Networked media • Factory-of-Things • Smart Objects / Devices
Tags	Interoperability in Internet of Things, RFID interoperability, Smart Objects / Devices / Controllers, Internet-connected objects, Networked media

SSA.4.1: RFID interoperability

RFID has traditionally been implemented in closed systems by a single integrator for a single user or a tightly controlled community of users. In order for RFID to successfully penetrate into large and open enterprise systems, RFID Interoperability is a necessity. Not only must tags from any vendor be able to communicate with RFID readers from any vendor, but a given tagged object must be able to be identified by readers of any user in a wide variety of application conditions [108]. In short, not only must tags and readers be interoperable, but more specifically, tagged objects and their aggregations must be interoperable with readers and their unique installations This can only be realized if tags from any vendor are able to communicate with readers from any vendor, and a given tagged object can be identified by readers of any user in any of the wide variety of possible application conditions it may encounter [93]. This defines RFID interoperability. Currently there is a vast amount of literature that focuses on dealing RFID interoperability by proposing various protocol standards [91]. Protocol standards, however, are not enough – information about product capabilities, expected levels of performance, and assurance that products, if applied correctly, will be interoperable, are also necessary. A properly designed compliance and certification program, currently missing, can address these issues and lay the groundwork for ensuring RFID interoperability.

Table 3-18: RFID interoperability – Metadata Table

ID	**SSA.4.1**	**Title**	**RFID interoperability**
Scientific Area			**Objects Interoperability**
Description			RFID interoperability refers to tags from any vendor to be able to communicate with RFID readers from any vendor, and also to when a given tagged object is able to be identified by RFIED readers of any user in a wide variety of application conditions
Tags			Radio Frequency Identification Tag Interface, tagged objects, RFID reader assembly

SSA.4.2: Device Interoperability

Device Interoperability refers to interoperation between physical devices that involves transferring information through communication channels, using services of different devices, and understanding the meaning of information unambiguously [98]. Device Interoperability for the foundation of "Smart environments" and "Smart Spaces" [67] is based on the idea to share the information of embedded devices using a common communication interface that guarantees that information is understood similarly in each device module and that enables the development of multi-device, multi-vendor and cross-domain applications based on information mash-ups.

The core elements of device interoperability include lightweight and flexible technologies such as Web Services, Universal Plug and Play (UPnP), Semantic Web (RDF, OWL, etc) and NoTA[9]. In building environments, implementing integrated functions such as switching the power off from certain appliances, cutting off water supply and activating the burglar alarm with one single 'leaving home' command has required a lot of dedicated cabling and custom devices, installed by experts. Different communication standards have been defined in order to provide more feasible solutions, such as LON[10], KNX[11] and ModBus[12]. However, none of these has become a global standard that all manufacturers would support.

Currently the trend is going towards 'protocol converters' that make device information available through Internet protocols and SOA. The 'protocol converter' can be an ordinary computer or a cheaper and more energy-efficient solution, such as the Home Control Center[13] proposed by Nokia. Device connectivity is implemented through adapters that convert the underlying protocols into a generic internet interfaces such as browser-compatible formats (HTML and others) for user interfaces and XML messages for machine-readable information. For successful machine-to-machine communication, the semantics of the XML messages have to be understood in the same way by both parties. The currently most used method for describing message semantics is XML Schemas. In building automation, the Open Building Information Xchange (OBIX)[14], is an example of such a protocol. Devices Profile for Web Services (DPWS) is another initiative with similar goals. In addition to these, more generic messaging protocols exist that are intended for communication with any kind of devices (not only related to building automation). The PROMISE Messaging Interface (PMI)[15] is an example of such an interface. The IP for Smart Objects (IPSO) alliance[16] has similar objectives but it is unclear whether they have yet specified any messaging protocols. In practice, none of these has obtained global acceptance.

Table 3-19: Device Interoperability – Metadata Table

ID	**SSA.4.2**	**Title**	**Device Interoperability**
Scientific Area			**Objects Interoperability**
Description			Interoperability between physical devices that involves transferring information through communication channel, using services of different devices, and understanding the meaning of information unambiguously.
Related Terms/Tags			Smart devices, sensor network research, ad-hoc networking, Context awareness, Internet-of-Things

[9] http://www.notaworld.org/
[10] http://www.lonmark.org
[11] http://www.knx.org
[12] http://www.modbus.org
[13] http://smarthomepartnering.com/cms/
[14] http://www.obix.org/
[15] http://cl2m.com/wiki/104
[16] http://www.ipso-alliance.org

Scientific Area 5: Software Interoperability

Software Interoperability refers to the ability of an enterprise software application to work with other enterprise software application.

Table 3-20: Software Interoperability – Metadata Table

ID	**SA.5**	**Title**	**Software Interoperability**
Description			Software Interoperability refers to the ability of an enterprise software application to work with other enterprise software application
Hierarchical Links			**Backlinks** • - **Outbound Links** • Services Interoperability • Electronic Identity Interoperability
Indicative Scientific Sub-Areas			• Service- oriented Architecture (SOA) and Web Services • Middleware • Software Interoperability Conformance & Testing • Component-based software engineering • Software Interoperability Monitoring and Evaluation • Requirements engineering for interoperable enterprises
Tags			Application Interoperability, Application Middleware, SOA, B2B gateways, Software Agents, Software Adapters, SOA, ESB, RMI

SSA.5.1: Service- oriented Architecture (SOA) and Web Services

Service-oriented architecture (SOA) is a set of design principles used during the phases of systems development and integration in computing [38]. The SOA implementations rely on a mesh of software services. Services comprise unrelated, loosely coupled units of functionality that have no calls to each other embedded in them. Each service implements one action, such as filling out an online application for an account, or viewing an online bank statement, or placing an online booking or airline ticket order. Rather than services embedding calls to each other in their source code, they use defined protocols that describe how services pass and parse messages using description metadata. SOA developers associate individual SOA objects by using orchestration. In the process of orchestration the developer associates software functionality (the services) in a non-hierarchical arrangement using a software tool that contains a complete list of all available services, their characteristics, and the means to build an application utilizing these sources [87].

Web services can implement a service-oriented architecture. Web services make functional building blocks accessible over standard Internet protocols independent of platforms and programming languages. These services can represent either new applications or just wrappers around existing legacy systems to make them network-enabled [23]. Web services are a platform- and language independent means of developing and delivering distributed applications that users can access directly, easily and efficiently via the Internet or Intranet, based on accepted infrastructure standards. Web services enable transactions that are more secure, and functionality that is replicable and reusable.

Besides its initial goal the myriad of Web services standards and specifications in existence today creates a challenge to achieving interoperability among multiple vendor solutions and to successful system deployment. The vendor SOA frameworks do not conform to common open standards. This is a major obstacle to achieve "true" interoperability between multiple vendors. To address this problem major industry participants combined resources forming the Web Services Interoperability (WS-I) Organization to facilitate and move web service standards forward in a non-proprietary and open manner [72]. WS-I[17] comprises a diverse community of Web services leaders from a wide range of companies and standards development organizations (SDOs). WS-I committees and working groups create Profiles and supporting Testing Tools based on Best Practices for selected sets of Web services standards.

Table 3-21: Service Oriented Architecture (SOA) and Web Services – Metadata Table

ID	**SSA.5.1**	**Title**	**Service Oriented Architecture (SOA) and Web Services**
Scientific Area			**Software Interoperability**
Description			Service-oriented architecture (SOA) is a set of design principles used during the phases of systems development and integration in computing. A system based on a SOA will package functionality as a suite of interoperable services that can be used within multiple, separate systems from several business domains. Web services can implement a service-oriented architecture. Web services make functional building-blocks accessible over standard Internet protocols independent of platforms and programming languages. These services can represent either new applications or just wrappers around existing legacy systems to make them network-enabled.
Related Terms/Tags			SOAP, XML, WCF, Glassfish, RESTful web services

SSA.5.2: Middleware

Middleware is computer software that connects software components or people and their applications. The software consists of a set of services that allows multiple processes running on one or more machines to interact. This technology evolved to provide for interoperability [18] in support of the move to coherent distributed architectures, which are most often used to support and simplify complex distributed applications. It includes web servers, application servers, and similar tools that support application development and delivery. Middleware is especially integral to modern information technology based on XML, SOAP and SOA architecture. Middleware sits "in the middle" between application software that may be working on different operating systems.

The most notable middleware technologies that dominate the market are:

- Enterprise Service Bus: Enterprise Service Bus (ESB) is defined by the Burton Group [40] as "some type of integration middleware product that supports both MOM and Web services".
- Message Oriented Middleware: Message Oriented Middleware (MOM) is middleware where transactions or event notifications are delivered between disparate systems or components by way of messages, often via an enterprise messaging system. With MOM, messages sent to the client are collected and stored until they are acted upon, while the client continues with other processing.

[17] http://www.ws-i.org/

- Enterprise messaging system: An enterprise messaging system is a type of middleware that facilitates message passing between disparate systems or components in standard formats, often using XML, SOAP or web services.
- Message broker: Part of an enterprise messaging system, message broker software may queue, duplicate, translate and deliver messages to disparate systems or components in a messaging system.
- Content-Centric Middleware: Content-centric middleware provides a simple provide/consume abstraction through which applications can issue requests for uniquely identified content, without worrying about where or how it is obtained. The middleware then adapts the underlying delivery to access the content from the source(s) that are best suited to matching the requirements.
- Embedded Middleware: Embedded middleware provides communication services and integration interface software/firmware that operates between embedded applications and the real time op.

There is a great amount of academic literature, tools and standards on Software Middleware. Nevertheless these conclusions and solutions are quickly deprecated indicating the need of light-weight, flexible and long-standing solutions.

Table 3-22: Middleware – Metadata Table

ID	SSA.5.2	Title	Middleware
Scientific Area			**Software Interoperability**
Description			Middleware is computer software that connects software components or people and their applications. The software consists of a set of services that allows multiple processes running on one or more machines to interact. This technology evolved to provide for interoperability in support of the move to coherent distributed architectures.
Tags			ESB, MOM, message brokers, middleware adapter

SSA.5.3: Software Interoperability Conformance & Testing

Software Interoperability testing is the activity of proving that end-to-end functionality between (at least) two communicating systems as required by those systems' base standards [39]. More specifically, it is the structured and formal testing of functions supported remotely by two or more items of equipment communicating by means of standardized protocols. Equipment implementing standardized protocols and services can be formally tested in two related but different ways, which each have benefits and limitations:

- Conformance testing can show that a product correctly implements a particular standardized protocol:
  - Establishes whether or not the implementation in question meets the requirements specified for the protocol itself. For example, it will test protocol message contents and format as well as the permitted sequences of messages.
- Interoperability testing can demonstrate that a product will work with other like products:
  - Assesses the ability of the implementation to support the required trans-network functionality between itself and another, similar implementation to which it is connected.

Conformance testing in conjunction with interoperability testing provides both the proof of conformance and the guarantee of interoperation.

Interoperability testing is highly beneficial in the development of standards-based B2B software. The cost of interoperability testing can be reduced through the development of tools to automate the manual-intensive parts of the testing process. The costs of developing test suites and tools can be further amortized by using them in other types of testing such as conformance testing [90]. Using tools and methods developed for the more formal conformance-testing environment in an interoperability testing scenario results in a more robust testing method. Not only are the results of the combined approach better than either approach in isolation, but the use of tools greatly reduces the time and cost of performing these tests. The net result is that more interoperable applications can be brought to the market in less time and for less cost. During the last years a number of notable Interoperability Testing specifications have appeared [39], although the specifications are expressed as recommendations rather than strict rules and leave enough freedom to allow test specifiers to adopt and adapt processes to suit each particular project while still ensuring that test specifications accurately reflect the requirements of the base standards and can be executed consistently across a range of configurations.

Table 3-23: Software Interoperability Conformance & Testing – Metadata Table

ID	**SAA.5.3**	**Title**	**Software Interoperability Conformance & Testing**
Scientific Area			**Software Interoperability**
Description			Software Interoperability testing is the activity of proving that end-to-end functionality between (at least) two communicating systems as required by those systems' base standards.
Related Terms/Tags			Conformance testing, test cases, Interoperability Test Specification

Scientific Area 6: Cultural Interoperability

The degree to which knowledge and information is anchored to a unified model of meaning across cultures.

Table 3-24: Cultural Interoperability – Metadata Table

ID	**SA.6**	**Title**	**Cultural Interoperability**
Description			The degree to which knowledge and information is anchored to a unified model of meaning across cultures
Hierarchical Links			**Backlinks** • - **Outbound Links** • Knowledge Interoperability • Social Networks Interoperability
Indicative Scientific Sub-Areas			• Language interoperability • Regional aspects compatibility • Alignment in traditions, religions and ethics
Tags			Culture, Context, Language, Linguistics

SSA.6.1: Language interoperability

In complete accordance to data and semantics, language interoperability is one of the most important interoperability issues when it comes to human resources. As the history of mankind points out, there is a need for a common language for being able to conduct trustworthy and efficient transactions. Today, with the trend of globalisation, it is important to research language interoperability in order to be able to seamlessly translate texts and speech towards formulating a common understanding of things amongst the different transaction parties.

Table 3-25: Language Interoperability – Metadata Table

ID	**SAA.6.1**	**Title**	**Language Interoperability**
Scientific Area			**Cultural Interoperability**
Description			Language interoperability refers to the automatic and seamless translation of languages
Related Terms/Tags			Translation, Words, Speech

SSA.6.2: Alignment in traditions, religions and ethics

Following the globalisation trend, enterprises and people working in those are everyday coming into contact with people from different cultures, having different traditions, ethics and religions. These factors, although they seem a bit neutral to the business world, play a very important role, especially when it comes to collaboration of people. In this context, there is a need to find ways of aligning those factors, without of course influencing them, in order to promote a more efficient and productive collaboration amongst people and organisations.

Table 3-26: Alignment in traditions, religions and ethics – Metadata Table

ID	**SAA.6.2**	**Title**	**Alignment in traditions, religions and ethics**
Scientific Area			**Cultural Interoperability**
Description			Alignment in traditions, religions and ethics refers to finding ways of respecting each individual's cultural needs while at the same time promoting collaboration and cooperation.
Related Terms/Tags			Ethics, Traditions, Religions

<u>Scientific Area 7: Knowledge Interoperability</u>

The ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilise it, and to further extend them through cooperation.

Table 3-27: Knowledge Interoperability – Metadata Table

ID	**SA.7**	**Title**	**Knowledge Interoperability**
Description			The ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilise it, and to further extend them through cooperation
Hierarchical Links			**Backlinks** • Data Interoperability • Process Interoperability

	• Rules Interoperability • Objects Interoperability • Cultural Interoperability **Outbound Links** • Cloud Interoperability
Indicative Scientific Areas	• Knowledge Sharing & Knowledge Repositories • Business Units Alignment • Ontology Matching • Transportation of Knowledge • Smart Infrastructures • Knowledge embedded systems • Context-aware systems
Tags	Knowledge, Intellectual Assets, IPR, Business Units, Intelligence, Knowledge Management, Ontologies

SSA.7.1: Knowledge Sharing & Knowledge Repositories

Information and knowledge are one of the most important intellectual assets of enterprises and play a very important role in the excellence of an organisation. When it comes to business transactions and collaborations, it is essential for enterprises to be able to communicate to each end the required knowledge, whether these refer to clients, suppliers or collaborators outside of the enterprise boundaries, or to human resources of the same enterprise. Until today, little has been done in order to record and classify in an integrated and complete manner the knowledge enterprises possesses. Attempts of using ontologies are in the right direction but when it comes to share this knowledge, the various design and implementation decisions taken during the recording and representation steps hinder the actual interoperation and collaboration. Therefore, Enterprise Interoperability should look in a more focused way into Knowledge Sharing & Knowledge Repositories in order to allow enterprises to be able to distribute their intellectual assists in a more efficient and collaborative way within themselves or with their surrounding organisations.

Table 3-28: Knowledge Sharing & Knowledge Repositories – Metadata Table

ID	**SAA.7.1**	**Title**	**Knowledge Sharing & Knowledge Repositories**
Scientific Area			**Knowledge Interoperability**
Description			Knowledge Sharing & Knowledge Repositories refers to the employment of methods and tools for recording and storing knowledge in a way that is retrievable and meaningful to every party that is allowed to access it.
Related Terms/Tags			Intellectual Assets, Knowledge Transfer, Knowledge Recording

SSA.7.2: Business Units Alignment

Business units are building blocks of enterprise organisations and typically include a number of members that are working as a team for a specific cause and under a specific method of work, sharing tools and methodologies that enable them to cooperate in an efficient manner in order to produce the anticipated results. Although business units work as a team, they are not isolated from the main enterprise structure and are in most cases required to collaborate with other units. Looking at the internal organisational structure of enterprises, it is evident that in most cases such units are able to cooperate in an acceptable degree. However, cross-organisation structures, business models that rely on virtual enterprises, or even enterprise alliances are unable to enjoy the same degree of collaboration between such units, as there are many differences regarding the knowledge and the assets each unit carries. For this reason, working towards Business Units Alignment is considered necessary so that such business units can share their knowledge in order to deliver a product (for example, assembling an automobile) or a service (different business units within a public administration).

Table 3-29: Business Units Alignment – Metadata Table

ID	**SAA.7.2**	**Title**	**Business Units Alignment**
Scientific Area			**Knowledge Interoperability**
Description			Business Units Alignment refers to the integration, sharing and collaboration of multiple business units in terms of knowledge in order to deliver a product or a service
Related Terms/Tags			Knowledge Sharing, Co-Design, Co-Production, Knowledge Transfer

SSA.7.3: Ontology Matching

As stated before, knowledge is more and more represented using ontologies. However, the way of storing knowledge in ontologies differs from case to case, not only because of the different tools and methodologies available, but also due to the understanding of the modellers and due to the purpose that led an enterprise to document this knowledge. Therefore it is essential to identify means to match the different ontologies in various schemas in order to transfer this knowledge to all interested parties in an automated and straightforward way.

Table 3-30: Ontology Matching – Metadata Table

ID	**SAA.7.3**	**Title**	**Ontology Matching**
Scientific Area			**Knowledge Interoperability**
Description			Ontology matching refers to the determination of relationships and correspondences between various knowledge concepts that are incorporated in ontologies.
Related Terms/Tags			Ontology, Knowledge Matching, Knowledge Translation

Scientific Area 8: Services Interoperability

The ability of an entity to seamlessly and automatically discover, aggregate and utilise a service that belongs to another entity.

Table 3-31: Services Interoperability – Metadata Table

ID	**SA.8**	**Title**	**Services Interoperability**
Description			The ability of an entity to seamlessly and automatically discover, aggregate and utilise a service that belongs to another entity.
Hierarchical Links			**Backlinks** • Data interoperability Rules Interoperability • Software Interoperability

	Outbound Links • Cloud Interoperability
Indicative Scientific Sub-Areas	• Automatic service discovery, description, composition, negotiation • Enterprise Mashups • Service Co-Design • Service Level Agreements • Service Deployment • Service Mediation
Tags	Services discovery, composition, provision, QoS

SSA.8.1: Automatic service discovery, description, composition, negotiation

Nowadays, more and more enterprises try to utilise the Internet as one of their main vehicles for conducting businesses with clients and other collaborating organisations. To this direction, the modern advancements in computer science and especial in service science have offered great benefits for enterprises in order to transform their traditional services to electronic ones. As such, we witness a huge number of online services being active today, offered by enterprises of any kind in order to facilitate interoperation and communication. However, this huge number of available services makes it impossible for enterprises to be aware of all the existing options, while it is quite effort consuming to optimise back office systems to collaborate with specific services. Therefore it is essential to research for methodologies, tools and infrastructures that allow the automatic discovery of services and the dynamic composition of them towards promoting interoperability and business cooperation.

Table 3-32: Automatic service discovery, description, composition, negotiation – Metadata Table

ID	**SSA.8.1**	**Title**	**Automatic service discovery, description, composition, negotiation**
Scientific Area			**Services Interoperability**
Description			Automatic service discovery, description, composition, negotiation refers to tools, methodologies and infrastructures enabling the automatic discovery of services offered by enterprises and the dynamic composition of them in order to conduct business in an automated manner with no extra modification in the enterprise systems
Related Terms			Service Composition, Service Discovery, Service Retrieval, Service Registries, Dynamic SLA Agreements

SSA.8.2: Enterprise Mashups

Mashups have gained popularity within the last few years, swept along with the momentum around Web 2.0. Early mashups took data from sources such as Craigslist and combined them with mapping services or photo services to create visualizations of the data (see for example HousingMaps[18],). Many of these early mashups were consumer-focused, although recently there has started to be both interest and acceptance of mashups in the enterprise [56]. Organizations are starting to realize that they can put their well-defined services that do discrete bits of business logic together with other existing services, internal or external to the organization, to provide new and interesting views on the data.

[18] http://housingmaps.com

An enterprise mashup, also referred to as a business mashup, is an application that combines data from multiple internal and public sources and publishes the results to enterprise portals, application development tools, or as a service in an SOA cloud [28]. Enterprise mashups must also interoperate with enterprise application technologies for security, governance, monitoring, and availability. An enterprise mashup has the following key characteristics:

- User-centric - Mashups are created for the consuming user, often by the users themselves. Unlike terse black-box back-end integration tools like ESBs, BPM, and BPEL, users can connect the data dots themselves. This implies many user-centric qualities:
  - Normalization of the data sources into a seamless virtual cloud of look-alike services
  - A visual drag-and-drop UI to wire the services together
  - A robust set of actions to tailor the output to the individual user's needs
  - Support for collaborative work such as tagging, searching, and sharing
- Bite-Size - Mashup users typically deal with small amounts of knowledge-oriented information (as opposed to IT-managed integrations that typically deal with large amounts of transactional information). Users are, in effect, performing micro-integrations that take minutes to hours to complete unlike major integration or BI efforts that have timelines of months to years. Most mashups are connecting to a limited set of services;
- Web-accessible - Increasingly popular standards-based interface/communication technologies (such as WSDL, REST, and RSS) make mashups possible. But the format is only part of the challenge. Mashups are built on data that could reasonably be displayed quickly in a Web browser or, more precisely, data that doesn't require too much manipulation for the user to make sense of it. Once built, mashups inherently produce information results that also conform to the "ready to be read in a browser" formats. And because of this portability of source data, mashups are most relevant when they involve a dynamic combination of external data sources and internal data source (public and private).

These qualities differentiate mashups from long-cycle IT-driven technologies like ESBs, BI, BPM, and enterprise portals. Interestingly, mashups also complement these technologies by either consuming their outputs from them (ESB) or providing inputs to them (BI, BPM, portals).

Enterprise mashups are still new enough that few qualified and quantified ROI studies exist, but recent findings indicate that the benefits of enterprise mashups can be substantial [71]. For business users, enterprise mashups address “long tail” information needs that are too infrequent (low latency) to justify great IT efforts. There's substantial value in mashups for IT as well, as they improve the return-on-assets of the existing systems mashups are built on.

Table 3-33: Services Interoperability – Metadata Table

ID	**SSA.8.2**	**Title**	**Enterprise Mashups**
Scientific Area			**Services Interoperability**
Description			An enterprise mashup, also referred to as a business mashup, is an application that combines data from multiple internal and public sources and publishes the results to enterprise portals, application development tools, or as a service in an SOA cloud. Enterprise mashups must also interoperate with enterprise application technologies for security, governance, monitoring, and availability
Related Terms			Service Front Ends, web application hybrid, service combination,

	visualization, and aggregation

SSA.8.3: Service Co-Design

The past few years have seen the emergence of a strong consensus around the promise of Service Co-Design. Service Co-Design in an enterprise involves the individuals from all levels of an organization as well as external users in the innovation process—empowering them as co-designers of service concepts so they can develop a more cohesive experience at the point of use [95]. Co-design promises to deliver direct, tangible results. For example, if users participate in an enterprise service design they are more likely to understand the difficulties in delivery, to empathize with providers, and to provide feedback in a systematic and efficient manner [48]. The user engagement at an early stage has the potential to bring significant crowd-sourcing benefits including the reduction of design errors, and the costs associated with those errors.

Co-design involves opportunities for users both to alter the specification of the design problem being addressed and to volunteer relevant resources unknown to the provider and perhaps unrecognised by the user. This is reflected in the features typically found in co-design approaches: a trial-and-error style of working and 'emergent design' processes.

The main elements of Service Co-design are the following:

- Participation: Co-design is collaboration. The collaborative nature of the process is enhanced and extended by several of its other features. There is a great deal of transparency involved in co-design: all participants are aware of the design methodology, its inputs and outputs, its goals and current status, etc. It is designing with clients, not merely for clients. This high level of participation requires continuity of user participants, to ensure the development of a close working relationship. The breadth of input from all parties is wide-ranging, ensuring a multiplicity of viewpoints and building wider community relationships between those involved.
- Development: Co-design is a developmental process. It involves the exchange of information and expertise relating to both the subject of the design process and the process itself. In this sense, co-design teaches co-design.
- Ownership and power: Co-design shifts power to the process, creating a framework that defines and maintains the necessary balance of rights and freedoms between participants. There is equality of legitimacy and value in inputs from all those involved, whether suggestions entail large- or small-scale changes. This combination of controlled abrogation of power by those with whom it usually rests, and the concomitant empowerment of those in a traditional 'client' role, serves to create a sense of collective ownership.
- Outcomes and intent: Co-design activities are outcome-based: they possess a practical focus, with clarity of vision and direction. Methodology and implementation seek to ensure a shared creative intent between all participants.

As co-design has matured services designed to work to diverse rules face significant challenges [95]. In shifting power towards users, inevitable tensions arise between this new approach and enterprises' established ways of working: between top-down strategy and bottom-up aspirations; between the demands of large-scale services and smaller, localised solutions; and between the new ideas and problems posed by users and the legacy of traditional service delivery. These tensions need to be resolved if co-design is to thrive as an established component of service design. Towards this direction the diversities within service providers need to be mapped in detailed. Scaling co-design to larger, high-level implementations requires a widening of scope, beyond the point of user–provider interaction, to look at collaboration and innovation within and across global enterprise networks. This 'systemic' co-design carries with it an ethos that will help co-design shift to the core of service provision business.

Table 3-34: Services Design– Metadata Table

ID	SSA.8.3	Title	Service Co-Design
Scientific Area			**Services Interoperability**
Description			Service Co-Design in an enterprise involves the individuals from all levels of an organization in the innovation process—empowering them as co-designers of service concepts so they can develop a more cohesive experience at the point of use.
Related Terms/Tags			Co-creation, customer value co-creation, crowd-sourcing, service-interoperability by design

SSA.8.4: Service Level Agreements

A service level agreement is a negotiated agreement between two parties wherein one is the customer and the other is the service provider [94]. This can be a legally binding formal or an informal "contract" (for example, internal department relationships). Contracts between the service provider and other third parties are often called SLAs — because the level of service has been set by the (principal) customer, there can be no "agreement" between third parties; these agreements are simply a "contract." Operating Level Agreements or OLAs, however, may be used by internal groups to support SLAs.

The SLA records a common understanding about services, priorities, responsibilities, guarantees, and warranties. Each area of service scope should have the "level of service" defined. The SLA may specify the levels of availability, serviceability, performance, operation, or other attributes of the service, such as billing. The "level of service" can also be specified as "target" and "minimum," which allows customers to be informed what to expect (the minimum), while providing a measurable (average) target value that shows the level of organization performance [16]. In some contracts, penalties may be agreed upon in the case of non-compliance of the SLA (but see "internal" customers below). It is important to note that the "agreement" relates to the services the customer receives, and not how the service provider delivers that service. SLAs commonly include segments to address: a definition of services, performance measurement, problem management, customer duties, warranties, disaster recovery, termination of agreement.

SLAs have been used since late 1980s by fixed line telecom operators as part of their contracts with their corporate customers. This practice has spread such that now it is common for a customer to engage a service provider by including a service level agreement in a wide range of service contracts in practically all industries and markets. Internal departments (such as IT, HR, and real estate) in larger organizations have adopted the idea of using service-level agreements with their "internal" customers — users in other departments within the same organization. One benefit of this can be to enable the quality of service to be benchmarked with that agreed to across multiple locations or between different business units, thus achieving interoperability at a business level. This internal benchmarking can also be used to market test and provide a value comparison between an in-house department and an external service provider.

Service level agreements are, by their nature, "output" based — the result of the service as received by the customer is the subject of the "agreement." The (expert) service provider can demonstrate their value by organizing themselves with ingenuity, capability, and knowledge to deliver the service required, perhaps in an innovative way. Organizations can also specify the way the service is to be delivered, through a specification (a service level specification) and using subordinate "objectives" other than those related to the level of service [101]. This type of agreement is known as an "input" SLA. This latter type of requirement is becoming obsolete as organizations become more demanding and shift the delivery methodology risk on to the service provider [94].

Table 3-35: Services Design – Metadata Table

ID	**SA.8.4**	**Title**	**Service Level Agreements**
Scientific Area			**Services Interoperability**
Description			A service-level agreement (SLA) is a contract between a network service provider and a customer that specifies, usually in measurable terms, what services the network service provider will furnish.
Related Terms/Tags			Negotiation agreement, Operating Level Agreements, B2B contract

Scientific Area 9: Social Networks Interoperability

This category of the EISB taxonomy concerns the ability of enterprises to utilise social networks for collaborations and interconnection purposes, by aligning part of their internal structure and functions to the characteristics of the social networks.

Table 3-36: Social Networks Interoperability – Metadata Table

ID	**SA.9**	**Title**	**Social Networks Interoperability**
Description			The ability of enterprises to utilise social networks for collaborations and interconnection purposes, by aligning part of their internal structure and functions to the characteristics of the social networks
Hierarchical Links			**Backlinks** • Data Interoperability • Cultural Interoperability **Outbound Links** • Ecosystems Interoperability
Indicative Scientific Areas			• Social Network Integration • Social Analytics & Social Cross-Networks Analysis • Social Business Models
Tags			Social Networks, Social Media, Web 2.0, Social Computing, Enterprise 2.0

SSA.9.1: Social Network Integration

Social networks are one of the major trends in the IT community during the latest years and they have built their own market, influencing many companies and enterprises, as they provide a modern channel to reach other organisations and to conduct business and collaborate. As such, enterprises need to integrated various aspects found in social networks to their internal structures in order to utilise those new infrastructures not only for promoting their image and their products, but also for conducting business using new characteristics and possibly re-organise their internal structures to more participative and collaborative ones, following the examples of various Web2.0 applications.

Table 3-37: Social Network Integration – Metadata Table

ID	**SA.9.1**	**Title**	**Social Network Integration**
Scientific Area			**Social Networks Interoperability**
Description			Social network Integration refers to the integration of specific social media aspects and characteristics in the organisational structure of an enterprise in order to be able to utilise seamlessly such infrastructures and their functions
Related Terms/Tags			Negotiation agreement, Operating Level Agreements, B2B contract

Scientific Area 10: Electronic Identity Interoperability

The ability of different eID systems to collaborate in order to automatically authenticate entities and to pass on security roles and permissions to eID holders, regardless the system they originate from.

Table 3-38: Electronic Identity Interoperability – Metadata Table

ID	**SA.10**	**Title**	**Electronic Identity Interoperability**
Description			The ability of different eID systems to collaborate in order to automatically authenticate entities and to pass on security roles and permissions to eID holders, regardless the system that they originate from
Hierarchical Links			**Backlinks** • Rules Interoperability • Objects Interoperability • Software Interoperability **Outbound Links** • Cloud Interoperability
Indicative Scientific Sub-Areas			• Digital Signatures Interoperability • Federated Identity Management Systems Interoperability • Electronic Identity Security • Electronics ID Cards Infrastructures & Services • Single Sign On Architectures
Tags			Electronic Identity, eID, Authentication, Authorisation, Permissions, Security, Access

SSA.10.1: Digital Signatures Interoperability

Digital Signature interoperability refers to the mutual recognition of electronic signatures among countries, that involves overcoming of the current legal (legislation, management authorities), as well as technical heterogeneities in terms of attributes, validation, format and algorithms [59]. Digital signature interoperability affects its main two applications: entity authentication and e-documents. For both of these applications crypto algorithms and certificate interoperability play an important role [86]. However, in the first case interoperability is affected by the way this signature is used while in the second, interoperability is affected by the signature format [86]. The term “signature format” is wide and encompasses the form of the data to be signed and the signature's relative position (detached, enveloped, or enveloping), as well as the structure and the contents of the signature/validation data themselves. During the lack of electronic signatures interoperability among countries has been recognized as one of the major barriers in conducting business at the European level [41].

To tackle these interoperability issues, the Digital Agenda for Europe announced a review of the eSignature Directive (1999/93/EC) [42] and an initiative on the mutual recognition of eIdentification and eAuthentication [100]. Moreover, the European Commission the last couple of years has been working towards the adoption of commonly accepted standards that can secure interoperable signature formats. These are the CMS Advanced Electronic Signature - CAdES (RFC 5126, ETSI 101 733), the XML Advanced Electronic Signature - XAdES (ETSI 101 903) and PDF Advanced Electronic Signature - PAdES (ETSI 102 778) (ETSI n.d.). The standards that are anticipated to be the preferred choice in the near future are those based on the widely adopted XML standard, namely XMLDSig and the enhanced to satisfy the advanced electronic signature (AES) requirements XAdES, and the ones that allow the inclusion of AES in the well-known and used PDF standard, i.e. PAdES. The aforementioned standards support different forms that satisfy different requirements:

- Basic Electronic Signature (*-BES): the signer's certificate must be part of the signed document and securely conveyed with it (combined with the information found in the Trusted List published by the certificate issuing country can help the verifier conclude on certificate and signature validity and acceptance)
- Explicit Policy Electronic Signatures (*-EPES): it identifies a valid policy that will guide signature verification
- Electronic Signature with Time (*-T): The signature data include a timestamp from a valid server to secure long term signature validity (the signature can be verified even if the certificate has expired or has been revoked).
- Electronic Signature with complete validation data references (*-C): as the name suggests the signature data include references to all the necessary information for validating the signature such as the certificate chain and the corresponding revocation information. As this method adds to *-T it conveys most of the info one needs for validating a signature.
- On top of the above one should add the more advanced forms *-X (AdES with eXtended validation data) and *-A (AdES with Archive validation data) used for very long term verification.

The forms that the European Commission promotes are the *-BES and *EPES without however prohibiting the use of the others, typically more advanced ones. These forms set the minimum requirements that a member state has to support regarding signature verification (a member state has to support all three technologies). Although this also affects signature generation, EC is not planning to impose any specific restrictions regarding signature generation and member states are free to choose any form of these three technologies satisfying their signature generation policy.

The wide adoption of these standards is by all means acceptable. However, they do not solve problems that relate to the much desired by many applications and services long term signatures, hence in some cases might prove insufficient or invalid. Moreover, the verifier should have the means to set and disseminate his/her requirements regarding signature generation which might go beyond the basic *-BES and *-EPES. Policy dissemination prior to signature generation can minimize the possibilities the signature is rejected by the verifier due to policy violation. Therefore, more has to be done on EU level for the robust exchange of signed documents including the wide adoption of policies regarding signature generation and acceptance and their communication to interested parties.

Table 3-39: Digital Signatures Interoperability – Metadata Table

ID	SSA.10.1	Title	Digital Signatures Interoperability
Scientific Area			Electronic Identity Interoperability
Description			The mutual recognition of electronic signatures among countries, that involves overcoming of the current legal (legislation, management authorities) as well as technical heterogeneities in terms of attributes, validation, format and algorithms [59].
Related Terms			Electronic signatures /eSignatures interoperability, eAuthentication, Trust Certificates
Related Terms/Tags			eSignature, authority authentication, signature interoperability

SSA.10.2: Federated Identity Management Systems Interoperability

A Federated Identity Management system supports the technologies, standards and use-cases which serve to enable the portability of identity information across otherwise autonomous security domains [15]. The ultimate goal of identity federation is to enable users of one domain to securely access data or systems of another domain seamlessly, and without the need for completely redundant user administration. Identity federation comes in many flavours, including "user-controlled" or "user-centric" scenarios, as well as enterprise controlled or B2B scenarios.

Federation is enabled through the use of open industry standards and/or openly published specifications, such that multiple parties can achieve interoperability for common use cases. Typical use-cases involve things such as cross-domain, web-based single sign-on, cross-domain user account provisioning, cross-domain entitlement management and cross-domain user attribute exchange.

Use of identity federation standards can reduce cost by eliminating the need to scale one-off or proprietary solutions [9]. It can increase security and lower risk by enabling an organization to identify and authenticate a user once, and then use that identity information across multiple systems, including external partner websites. It can improve privacy compliance by allowing the user to control what information is shared, or by limiting the amount of information shared. And lastly, it can drastically improve the end-user experience by eliminating the need for new account registration through automatic "federated provisioning" or the need to redundantly login through cross-domain single sign-on. The notion of identity federation is extremely broad, and also evolving. It could involve user-to-user, user-to-application as well as application-to-application use-case scenarios at both the browser tier as well as the web services or service-oriented architecture (SOA) tier. It can involve high-trust, high-security scenarios as well as low-trust, low security scenarios. The levels of identity assurance that may be required for a given scenario are also being standardized through a common and open Identity Assurance Framework [9]. It can involve user-centric use-cases, as well as enterprise-centric use-cases. The term "identity federation" is by design a generic term, and is not bound to any one specific protocol, technology, implementation or company. One thing that is consistent, however, is the fact that "federation" does describe methods of identity portability which are achieved in an open, often standards-based manner – meaning anyone adhering to the open specification or standard can achieve the full spectrum of use-cases and interoperability.

Identity federation can be accomplished in any number of ways, some of which involve the use of formal Internet standards [96], such as the OASIS Security Assertion Markup Language (SAML) specification, and some of which may involve open source technologies and/or other openly published specifications (e.g. [96] - Information Cards, OpenID, the Higgins trust framework or Novell's Bandit project).

Table 3-40: Federated Identity Management Systems – Metadata Table

ID	**SSA.10.2**	**Title**	**Federated Identity Management Systems**
Scientific Area			**Electronic Identity Interoperability**
Description			A Federated Identity Management system supports the technologies, standards and use-cases which serve to enable the portability of identity information across otherwise autonomous security domains
Related Terms/Tags			Single Sign-On, OpenID, SAML, federation identity

Scientific Area 11: Cloud Interoperability

The ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud dependant.

Table 3-41: Cloud Interoperability – Metadata Table

ID	**SA.11**	**Title**	**Cloud Interoperability**
Description			The ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud dependant.
Hierarchical Links			**Backlinks** • Services Interoperability • Knowledge Interoperability • eID Interoperability **Outbound Links** • Ecosystems Interoperability
Indicative Scientific Sub-areas			• Unified Cloud Interfaces • Cloud Orchestration • Cloud Federation
Tags			Cloud Computing, InterCloud, Cross-cloud Federation, Cloud Interconnection

SSA.11.1: Unified Cloud Interfaces

Clouds are becoming an everyday word of the IT and business world as they offer many advantages for enterprises. However, as with every IT innovation, the different options available have led enterprises in different paths regarding the clouds they choose and there have been already many problems recorded regarding the limited interoperation between the various deployed applications. In this context, cloud application interoperability is a very serious issue that needs to be tackled by the

Enterprise Interoperability community, as there is a need to align clouds by building unified interfaces so that applications deployed in different clouds could communicate and interoperate.

Table 3-42: Unified Cloud Interfaces – Metadata Table

ID	**SSA.11.1**	**Title**	**Unified Cloud Interfaces**
Scientific Area			**Cloud Interoperability**
Description			Unified Cloud Interfaces refers to the design of standard interfaces for direct communication and interoperation between clouds from different providers
Related Terms/Tags			Cloud Application Interoperability, Cloud Matching

SSA.11.2: Cloud Federation

As enterprises utilise different system software for supporting different aspects and functions of their everyday business, it is expected that they will continue working in such a manner even when on the cloud, using multiple clouds for different applications to match business needs. In such terms, various resources that operate in the different clouds need to be able to communicate and therefore all clouds need to have a common understanding of how applications should be deployed. Cloud federation targets exactly this specific point as it aims to create an interoperability layer between the various clouds so that they can be seen as a universal and unified computing environment when seen from a higher level.

Table 3-43: Cloud Federation– Metadata Table

ID	**SSA.11.2**	**Title**	**Cloud Federation**
Scientific Area			**Cloud Interoperability**
Description			Cloud Federation refers to the ability to utilise heterogeneous cloud resources as a unified and universal computing environment without experiencing the issues that can be caused by this differentiation.
Related Terms/Tags			Intercloud, Interconnected Clouds

<u>Scientific Area 12: Ecosystems Interoperability</u>

Ecosystems Interoperability concerns the ability of instant and seamless collaboration between different ecosystems, ecosystems and independent entities, entities within the ecosystems and the ability of different independent entities to formulate virtual structures for specific purposes.

Table 3-44: Ecosystems Interoperability – Metadata Table

ID	**SA.12**	**Title**	**Ecosystems Interoperability**
Description			The ability of instant and seamless collaboration between different ecosystems, ecosystems and independent entities, entities within the ecosystems and the ability of different independent entities to formulate virtual structures for specific purposes.
Hierarchical Links			**Backlinks** • Social Networks Interoperability • Cloud Interoperability

	Outbound Links • -
Indicative Scientific Sub-Areas	• Business Ecosystems Interoperation • Virtual Enterprise Integration • Distributed Systems and Agents
Tags	Business Ecosystems, Digital Ecosystems, Virtual Enterprises, Digital Enterprises, Virtual Factories, Factories of the Future, Business Sectors Interconnection, Business Domain Interconnection

SSA.12.1: Business Ecosystems Interoperation

The term "business ecosystems" describes a community build from various collaborating enterprises that have a common goal and collaborate towards the development of certain goods that utilise the collaborative knowledge of the whole ecosystems. The interoperation of such ecosystems is still an issue, as these high level organisational structures, in most cases use their own standards, mechanisms and tools, which aren't able to communicate with others of different ecosystems.

Table 3-45: Business Ecosystems Interoperation – Metadata Table

ID	**SSA.12.1**	**Title**	**Business Ecosystems Interoperation**
Scientific Area			**Ecosystems Interoperability**
Description			Business Ecosystems Interoperation refers to the ability of Business Ecosystems to cooperate in order to dynamically converge and operate towards a common goal.
Related Terms/Tags			Ecosystems Compatibility, Ecosystems Integration

SSA.12.2: Virtual Enterprise Integration

Virtual Enterprises according to [84] are a strategic alliance amongst non-competing companies who share forces – using mostly ICT – for the accomplishment of a specific goal without losing their autonomy – except for the undertakings set forth in the VE agreement – and with the aim of avoiding the formation of a new legal entity. In order to facilitate the smooth collaboration between the various engaged parties, interoperability issues between those entities are in most cases solved, and all entities are able to communicate with each other through a common medium, such as an enterprise service bus. However, this is not the case when it comes to interconnect two or more different virtual enterprises, as the various methods to make those abstract entities able to communicate (at all enterprise levels) may be different and not interoperable.

Table 3-46: Virtual Enterprise Integration – Metadata Table

ID	**SSA.12.2**	**Title**	**Virtual Enterprise Integration**
Scientific Area			**Ecosystems Interoperability**
Description			Virtual Enterprise Integration refers to the ability of two or more virtual enterprises to be able to communicate and collaborate in all business levels in a seamless and automated way.
Related Terms/Tags			Virtual Enterprise Interoperability, Virtual Enterprise Collaboration

3.1.3.3 EISB Wiki

The EISB is supported by a Wiki platform in order to maximize the visibility and the collaboration on the development of the EISB, which can be found at: http://www.fines-cluster.eu/fines/mw/.

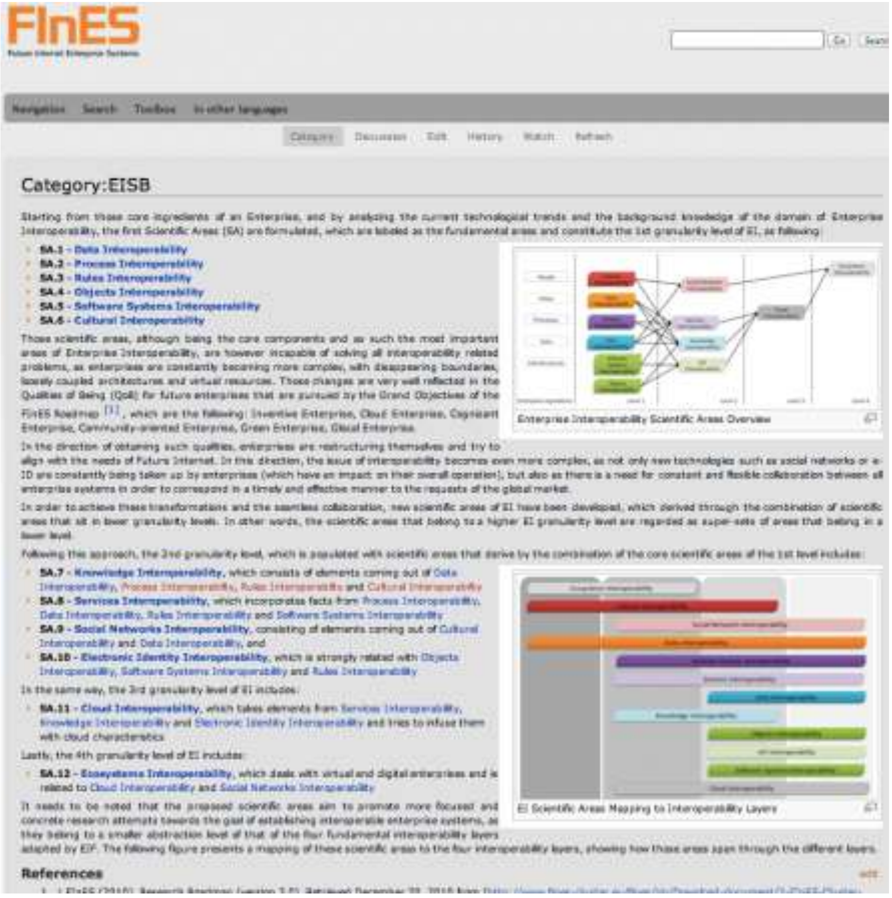

Figure 3-4: EISB Wiki Front Page

At this stage, as the content in the Wiki spans three main themes (the EISB, the Roadmap and the Task Forces) separate templates have been created in order to provide for homogenized presentation of the relevant content in each theme.

To this end, for the EISB, 10 templates have been created:

- **1 template for the Scientific Areas** that includes as Sections: Description, Findings, See Also (with embedded videos from YouTube and presentations from SlideShare), and References (with Key References) together with a Summary table. The Scientific Areas also appear as Categories in the wiki in order to create overview taxonomy in the main page and characterize the contents based on the EI dimension. The pages in the wiki complying with this template were created based on findings of deliverable D2.1 EISB State of Play [35].

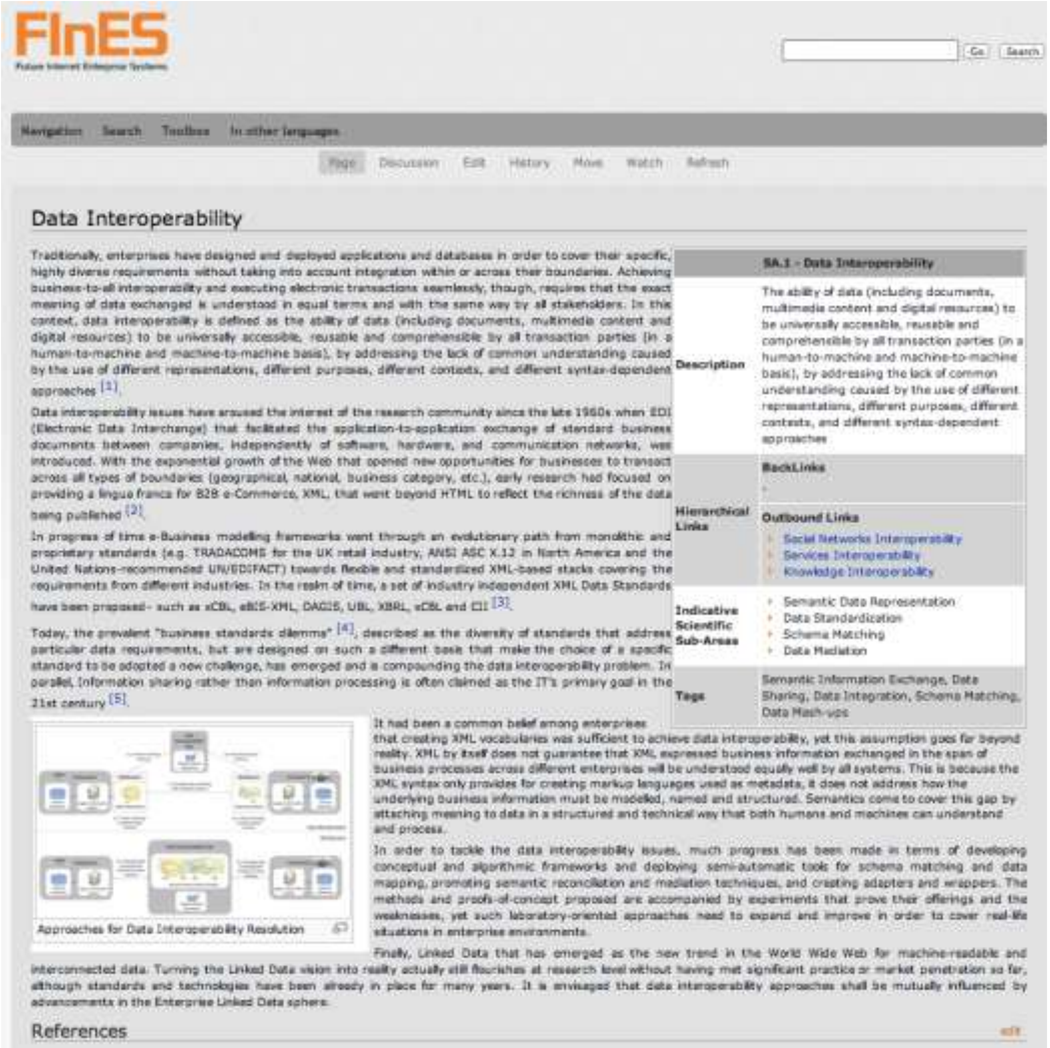

Figure 3-5: EISB Scientific Area Example

- **1 template for the Scientific Sub-Areas** that includes as Sections: Description, Findings, See Also, and References together with a Summary table. The Scientific Sub-Areas also appear as Categories in the wiki in order to create an overview taxonomy in the main page and characterize the contents based on the EI dimension.
- **8 templates for the Science Base dimension** for: Concepts & Positions, Methods, Proof-of-concept, Tools, Experiments, Case Studies, Surveys- Empirical Data, and Standards. Each template includes different Sections that will be populated during the ENSEMBLE Waves. The pages in the wiki complying with these templates will be initially created based on input from D2.3 EISB 1st Wave, D2.4 EISB 2nd Wave, and D2.5 EISB 3rd Wave, but the contribution of the ENSEMBLE Validation Community is also expected to be critical.

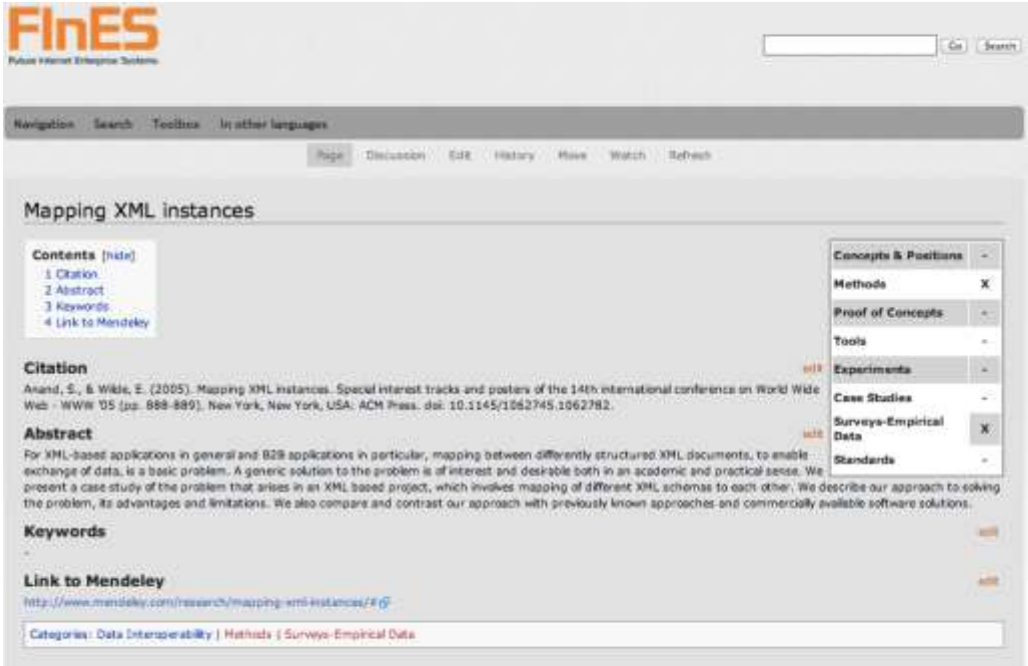

Figure 3-6: EISB Reference Example

3.1.4 EISB Reference Ontology

Ontologies have been recognised as important components of information systems and information processing. The main goal of an ontology should be to easily identify the value of its building and maintenance process effort. Ontologies should be able to explicitly represent a segment of the reality, which would facilitate its knowledge reasoning and consequently its understanding.

The EISB Reference Ontology main goal is to represent all the knowledge related to the EISB domain. However to justify such effort in building such ontology, it is needed to state that such knowledge would facilitate the search of specific information, as for instance papers or methods of a determined EISB area or a specific set of tutorials related to a specific EISB topic, or even a set of expert researchers. To have an advanced EISB service able to provide such specific knowledge with multiple interrelationships, it is needed to have a knowledge base ruled by a reference ontology.

In wave 1, our work will not go further than the taxonomy, but the ontology work will be followed in waves 2 and 3. For this reason, this deliverable only includes an example use-case for the EISB ontology, namely one that will contribute to a particular action in the EISB Action Plan [36] at the end of wave 3, i.e. Syllabus for academic EI post-graduate programmes.

3.1.4.1 The EISB Wiki as a source of knowledge

As explained, the EISB reference ontology can prove to be a valuable asset for the science base itself gathering meta-information relevant to both EI and the neighbouring domains, formal methods, state of the art publications, tools, etc. However, it is also important to note that in ENSEMBLE, the ontology should not overrule the EISB wiki since they are meant for similar, yet different purposes. The Wiki is more focused on the collaborative gathering of information from domain experts, while the ontology is a facilitator for knowledge reasoning, enabling different views of the information gathered from the wiki or directly through an administrator.

As illustrated in Figure 3-7, all EI state of the art research will be maintained directly in the wiki (accessible through the FInES cluster portal), and in order to avoid replication of efforts it will be synchronized automatically with the ontology via a web-services layer. This is only possible due to the common EISB taxonomy adopted by both knowledge repositories.

Also, during the ENSEMBLE life period, knowledge coming directly from the neighbouring domains (green boxes) can be fed directly to the ontology through an administration interface. This enlarges the spectrum of knowledge and, as envisaged in the EISB concept, enables the ontology to use also formal methods from neighbouring scientific domains to describe EI problems and solutions.

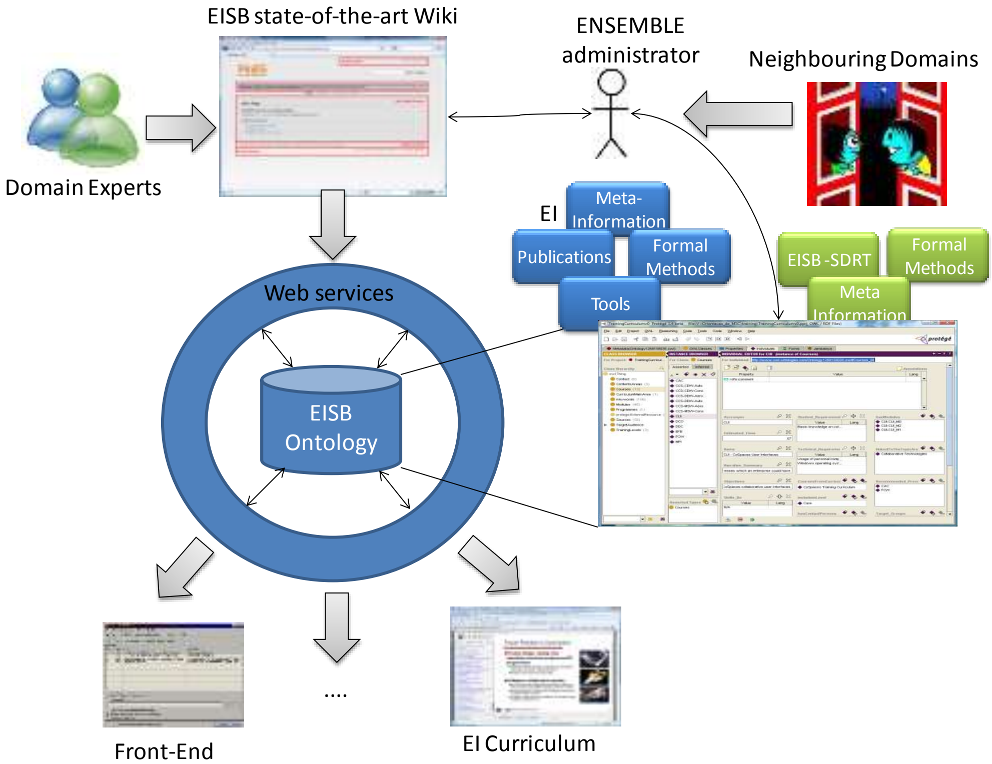

Figure 3-7: EISB Wiki as a source of knowledge

Finally, if sufficient information is available, different front-ends can be made available to access and reason on the EISB, e.g. as explained in the next section it is possible to generate automatically training curriculum and courses for the specific domain of reference. Nevertheless, ENSEMBLE will only run for a limited period of time, and even though we expect to create a significant knowledge base (blue and green boxes) it will still need to be maintained. Due to this, the automatization of the information flows (wiki ⇨ ontology and ontology ⇨ front-ends) will be maximized, leaving a FInES administrator in place of the ENSEMBLE one just to moderate the EISB wiki. The link with the neighbouring domains is expected to be abandoned as soon as the EISB-SDRT is finalised and the major methods of interest to EISB collected.

3.1.4.2 EISB Ontology Use-Case: Automatic Generation of Training Courses

According to the action plan presented in ENSEMBLE deliverable 2.2 [36], one of the objectives of wave 3 of EISB formulation is the announcement of the findings to a broader scientific community, while embodying of the scientific approaches to university and vocational training programmes. If prepared to that, the EISB ontology can assist in this activity since it can be used to represent a training knowledge base, facilitating the categorization of its elements and subsequently reasoning over it. Below is presented an illustration of a training system model that can be adapted to ENSEMBLE. It was built in Protégé in the scope of an ICT project that targeted the collaboration aspects of interoperability [27].

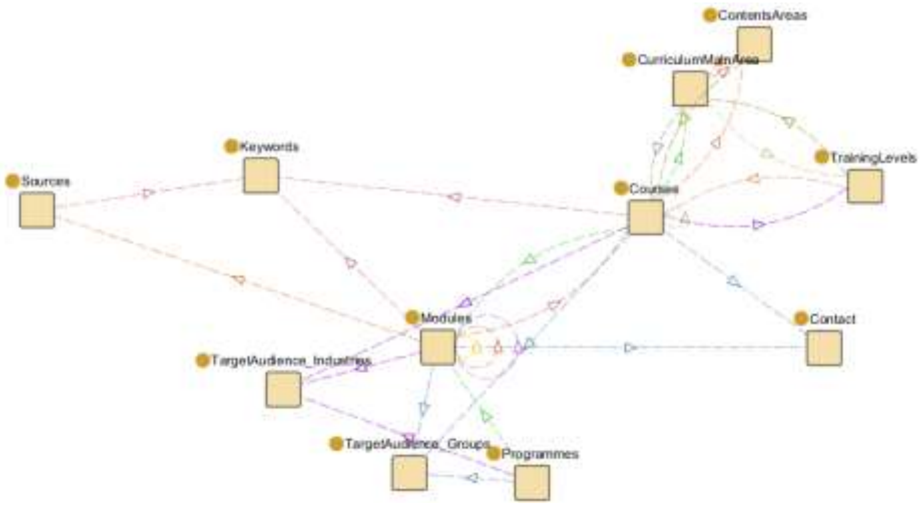

Figure 3-8: Relationship structure of the Training System Knowledge Base

In such model (Figure 3-8) each training Module has several concepts associated. The Sources concept contains information about the sources referred in the Module, Contact includes the contact information of the author of a Module or Course and Keywords that contain a list of all relevant keywords needed for describing the contents of the Module. A Course, apart from Contacts and Modules that contain the course also includes Keywords (that include Keywords inherited from its Modules) and belongs to a Curriculum Main Area that is divided by Content Areas and Training Levels. Each Module and Course has a Target Audience Group and a Target Audience Industry, for defining the profile of the user. Finally, a Programme is defined for a specific profile, e.g. Target Audience Industry and Target Audience Group as has a set of modules.

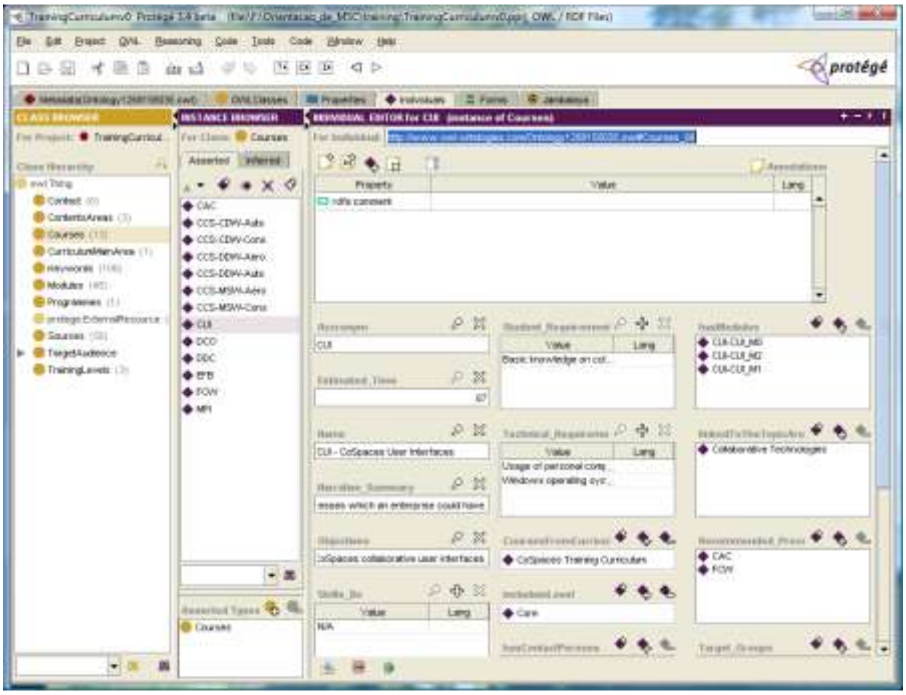

Figure 3-9: Training System Knowledge Base in Protégé

The model provides an easy comprehension and management of the whole system by adopting a visual knowledge modelling approach for reasoning and inspection based on Protégé. The figure above presents the knowledge related to one of the modelled courses – the CUI (CoSpaces User Interfaces) course. It is shown that the CUI course has 3 modules, and it is linked to the curriculum topic area Collaborative Technologies. The recommended precedence's and the level of training on which the CUI course belongs are also in the model, among other relevant concepts.

The implementation generates adaptable courses with content originally developed for static courses. By having a training curriculum matrix, it was possible reasoning over it to generate a set of modules ordered in a sense to define a specific course related to a given topic of interest. Recommended precedence's property of modules and courses are used to generate such ordered set of modules, whose are considered relevant for the better understanding of the topics of interest.

In additional such automatic orchestration uses also information related to a specific profile of target audience, choosing in this way the modules relevant for each of the identified profiles.

In order to create the implementation, a simple architecture was developed using mainly protégé and web services technology. The architecture is depicted in the Figure 3-10, which is composed by three different parts:

- The Training Orchestration Server
- The JSP files used for interface
- Server with the flash videos

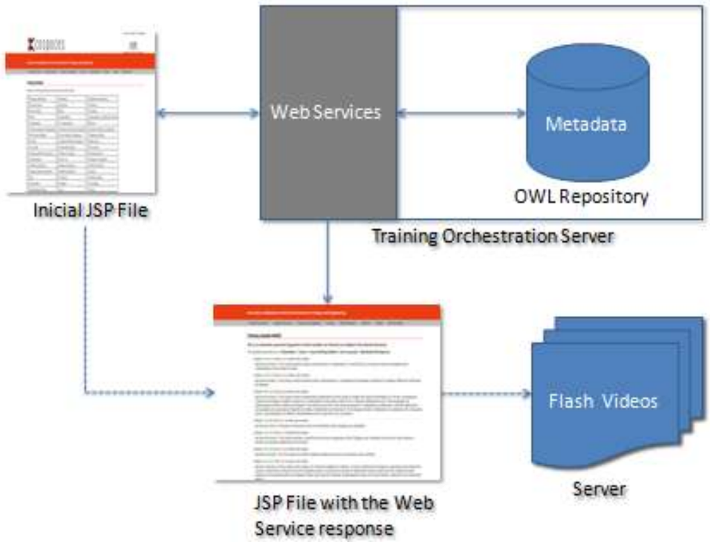

Figure 3-10: Implementation Architecture

With this architecture a user is able to retrieve an automatic orchestrated course that is built according to his/her needs. After connecting to the web service of the Training Orchestration Server in order to fetch the available keywords and target audiences, the user selects and sends to the web service the intended fields of search. By reasoning over the Metadata of the Training Systems Modelling existing in the OWL Repository, it is generated a list of modules suggested to be followed and the answer replied and presented in the final JSP file. The response includes all the links to the modules suggested, that can be consulted in another server.

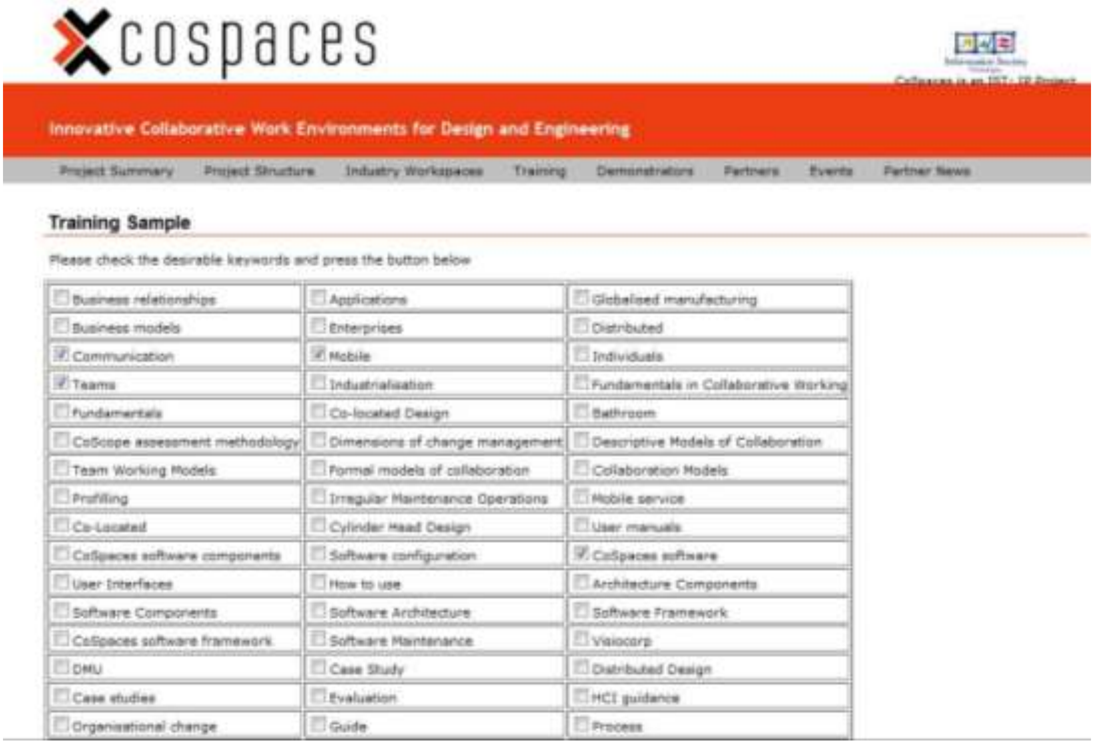

Figure 3-11: CoSpaces Training Keywords List

This implementation was tested with real courses contents from the project CoSpaces[19] . As stated before, such functionality is available in JSP technology, thus from a browser. Such JSP GUI firstly presents to the user a list of all the available keywords. The user can select the ones that he/she could be interested in. After a submission, a training course is prompted on the fly, adapted to the choice. A list of training modules is then presented. With such a list, the trainee could follow a training programme adapted to his/her interests.

Figure 3-11 illustrates the first step where the user selects the 'Communication'; 'Teams', Mobile and 'CoSpaces Software' concepts. After pressing the generation button, a suggested training programme is displayed. It is composed by all the modules that contain the selected keywords and the recommended precedence's of them. This suggested training programme presents the modules ordered accordingly to a pre-determined sequence, resulting from the position of the modules in its course and the course in the curriculum. Thus, the trainee can start with the more basic training modules and progress to the more advanced ones. The result is displayed in the Figure 3-12.

On this sample, the trainee will follow respectively the modules: FCW_M1; FCW_M2; MPI_M1; CUI_M0; CUI_M2; EFB_M0 and EFB_M1. All the modules are presented with their short description. These modules are possible to be followed through the browser since they were developed in a flash based format.

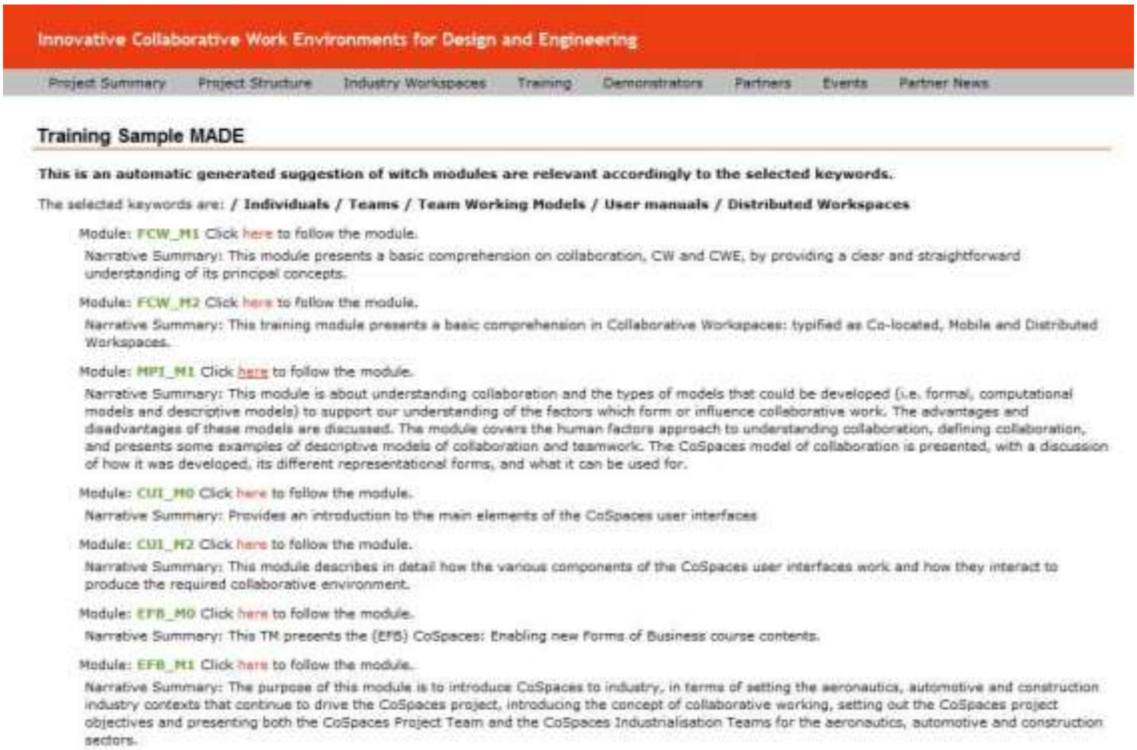

Figure 3-12: Example of an adaptable training programme composition

[19] http:// www.cospaces.org

3.2 Formal and Other Descriptive Methods for EI Problems and Solutions Definition

This section focuses on the investigation of basic ideas and concepts and possible formal methods to describe problems and solutions, patterns identification, critical research questions.

As argued by Suppes [102], putting aside the positive argument from the tradition that begins with Archimedes and that includes Newton, and also the negative argument that points out the low level of formalization current in much of contemporary science, it is still pertinent to ask what are the reasons for a concern with formalization in science. Formalization will not answer all questions nor solve all problems, but nearly everyone would agree that formal methods play a central role in assessing the intuitive correctness of a solution to a conceptual problem or the construction of an explicit foundation. Also according to Suppes [102], there are a number of reasons why the formalization of a scientific theory is desirable, namely:

- **Explicitness**: formalize a connected family of concepts is one way of bringing out their meaning in an explicit fashion;
- **Standardization**: One broad aim of formalization is to make communication easier across scientific disciplines through standardization of terminology and methods of conceptual analysis;
- **Generality**: Another virtue of formalization is that it often provides a means of seeing a wider picture eliminating non-essential features out of the way;
- **Objectivity**: Formalization provides a degree of objectivity that is impossible in theories that are not stated in such fashion. In areas of science where great controversy exists about even the most elementary concepts, the value of such formalization can be substantial;
- **Self-contained assumptions**: Formalization is a way of setting off implicit assumptions that if added informally as needed, there would be always doubt whether a genuine explanation of empirical phenomena had been found. For example, physicists are fond of ruling out on "physical grounds" solutions to fundamental equations which they find unacceptable. However, unless the assumptions required for the elimination of such solutions are stated in advance, the selection of solutions is left to untutored intuition. To drive for assumptions that are self-contained is also a way of assuring scientific objectivity;
- **Minimal assumptions**: Formalization of a theory makes possible an objective analysis of what are the minimal assumptions necessary for statement of the theory.

Formal methods in the IT domain are mathematically based techniques for the specification, development and verification of software and hardware system [19]. As it is stated in Monin [75], they are best described as the application of a variety of theoretical computer science fundamentals (like logic calculi, formal languages, automata theory, and program semantics), but also type systems and algebraic data types to problems in software and hardware specification and verification. In more detail, formal approaches in the area of computer science include a collection of methods stemming from mathematical formulation, such as First Order Logic, Category Theory, Pattern Theory. Another set of formalization attempts includes management and information technology systemic approaches, such as Model Driven Architecture (MDA), Business Process Management (BPM) or even Service Oriented Architecture (SOA) elements. Nevertheless, it has to be noted that formal methods can be used at a number of levels [106]:

- Level 0: Formal specification may be undertaken and then a program or system developed from this informally. This has been dubbed formal methods "lite". This may be the most cost-effective option in many cases.
- Level 1: Formal development and formal verification may be used to produce a program in a more formal manner. For example, proofs of properties or refinement from the specification to a program may be undertaken. This may be most appropriate in high-integrity systems involving safety or security.
- Level 2: Theorem provers may be used to undertake fully formal machine-checked proofs. This can be very expensive and is only practically worthwhile if the cost of mistakes is extremely high (e.g., in critical parts of microprocessor design).

Despite that many mathematical topics support sciences formalisation and it is neither possible nor desirable to avoid these topics when pursuing formal methods; as in Fleck [44], for the EISB we will not take the approach that applying discrete mathematics to everything assures relevant formal methods. While mathematically rigorous descriptions promise to improve system reliability, design time and comprehensibility, they do so at the cost of an increased learning curve. In addition, the meta-models used by most formal methods are often limited in order to enhance provability which proves that many times there is a notable trade-off between the need for rigor and the ability to model all behaviours [26].

Specific methodologies are probably needed for each interoperability facet that generates the need for diversified formal methods for technical, semantic, organisational, legal and policy issues. The following sections investigate the evidence of formal methods in EI and in other, neighbouring scientific domains and discuss the applicability of formal methods towards EI.

3.2.1 From EI Research Community

As Butler [19] mentions, "the value of formal methods is that they provide a means to symbolically examine the entire state space of a digital design (whether hardware or software) and establish a correctness or safety property that is true for all possible inputs. However, this is rarely done in practice today (except for the critical components of safety critical systems) because of the enormous complexity of real systems". This statement is true for EI as practise has shown that efforts until now for bridging enterprise systems and for solving interoperability problems did not consider and was not based on formal methods.

The complexity of the domain of EI, which is a direct outcome of EI scientific areas stack (see ENSEMBLE Deliverable D2.1 – State of Play) [35], makes it very difficult to identify formal methods that can be applied to EI. Moreover, the fact that Enterprise Interoperability is an applied and practical scientific field and not a theoretical one (that is based on axioms, theorems and formal methods to describe problems and solutions of abstract elements) makes it even more difficult to identify existing formal methods, as most problems and solutions are described today using more direct and practical methods. However, this does not imply that formal methods cannot be applied in the EI domain.

There is a strong debate whether formal methods for EI are required as per ce, or whether EI can be based on formal methods from neighbouring domains that seem to solve specific problems, which can be matched to the issues that are included in the EI domain. The reason behind this argumentation derives from the fact that EI problems are quite complex and are not easy to be described in a formal way, as the different scientific areas that are touched by a problem and their structure in layers makes it quite impossible to classify and fully describe such a problem using formalisms.

In more detail, a specialised workshop session has been organised during the Samos Summit 2011[20] aiming to bring together researchers and scientist of Interoperability to identify formal methods that are currently being employed in the domain and identify the need to design and implement such methods towards the goal of building the scientific groundings of Enterprise Interoperability. The main objectives of this workshop were:

- To outline the boundaries and interrelations of the EI problems and solutions space;
- To investigate the need of defining a formal method for the description of EI problems and solutions;
- To elaborate on existing formal methods that may be applied in the context of EI;
- To identify the main characteristics that such formal methods should contain.

As the experts participating in the Samos Summit 2011 stressed out, "It is difficult to identify a formal method for the whole stack of EI problems and we cannot be sure that they even exist". Moreover, methods should focus on generic problems and solutions and not be too specific.

In a debate for the need to have such formal methods for describing and solving issues, answers in favour have been noted, but also some stated against the need for formal methods in this scientific domain (Table 3-47).

Table 3-47: Summary of debate concerning the need to have such formal methods for describing and solving EI issues

Positions in favour formal methods in EI	Positions against formal methods in EI
• Formal Methods offer a more rigorous definition and precise understanding of issues amongst researchers; • They allow automation in order to tackle issues more easier and precisely; • There seem to exist some standards, which could be easily transformed to formal methods (for example the POWDER[21] standard for describing web resources); • Formal methods are in position to provide a shared definition of reality; • Formal methods allow stratification of knowledge, a fact aligned with the concept of the existence of the various layers of EI; • Formal methods are a precondition for hypothesis testing; • Formal methods allow reusability and expressiveness.	• There is a high number of sciences, most of them applied ones, that exist since centuries without having formal methods of their own. • Enterprise Interoperability issues are too complex to be handled by formal methods • Enterprise Interoperability problems incorporate in a huge degree human nature related issues which cannot be address with the application of formal methods

[20] http://www.fines-cluster.eu/fines/jm/Publications/Download-document/204-Samos-2011-Summit-Proceedings.html
[21] http://www.w3.org/2001/sw/wiki/POWDER

Although the debate for the need of designing specific formal methods (and employing them in order to solve the major interoperability problems) is still on-going amongst experts, all agree that there is a need to be able to describe problems and solutions in a more structured way, even if this is not in the exclusive and strict format of a formal methods. Such methods should include the following characteristics:

- They should be quite descriptive, able to present various aspects and dimensions of issues and solutions (What? Where? Who? How? When?);
- They should be systematic, easy to apply and should be supported by IT systems;
- They should be visual and easy to understand;
- They should be based on natural languages in order to be comprehensible by as much people as possible;
- They should take into account dependencies with other issues/methods and be flexible to address complex problems;
- They should follow specific guidelines resulting in a common description framework for both problems and solutions.

Having in mind all the above, one can claim that today there exist some methods applied in the EI domain which are quite close to answering the requirements set above. For example:

- **Ontologies**, which can be used to describe the problem domain, business semantics and a number of interoperability problems - an E/R ontology description can be used for expressing interoperability problems between enterprises. In fact, an ontology produces a common language for sharing and reusing knowledge about phenomena in a particular domain [51].
- **System Dynamics, Agent based models and Social Network Analysis**, which can be used for identifying the value flows between entities and the various barriers that exist.
- **Organisational Management methods** (like organisational charts) to identify different organisation structures.
- **Enterprise Architectures and Enterprise Models**, which are organized in a way that supports reasoning about the structure, properties and behaviour of the system [21], thus defining its components and providing a blueprint of the enterprise that enable the definition of interoperable relationships.
- **Information Models**, either being used in the form of traditional Entity-Relationship databases, architectural models, or domain ontologies, models can be described on multiple formats, languages, expressiveness levels, and for different purposes, e.g. interoperability [60].
- **Standards** are of major importance in enterprise communication. Enterprise interoperability is concerned with communication and cooperation between software components, processes, organization units and humans, thus to make interoperability happen, the exchange of concepts is key. Terminology must be agreed and standardization is a must [22].
- **Model-Driven Development (MDD) and Model-Driven Architectures (MDA)** to specify an information system at three different levels of abstraction (CIM – computation independent model, PIM – platform independent model, PSM – platform specific model), thus enabling to observe an analyse it from different perspectives and unifying every step of the development of an application or integrated suite from its start as the application's business functionality and behaviour, through one or more PSMs, to generated code and a deployable application [80], [60].

- **Model-Driven Interoperability (MDI)**, a methodological framework, which provides a conceptual and technical support to make interoperable enterprises using ontologies and semantic annotations, following the Model-Driven Architectures (MDD) principles [62].
- **Model-Based Systems Engineering (MBSE)**, which applies modelling to support an interoperable systems engineering processes, namely requirements, design, analysis, verification and validation activities, beginning at the conceptual design phase and continuing throughout development and later LC stages.
- **Model Morphism (MoMo)**, which is the application to systems interoperability and information models of the mathematical morphism method, i.e. an abstraction of a structure-preserving map between two structures (see [61] and [3]).

The list of EI methods is neither extensive nor final and will be subject to debate amongst the ENSEMBLE Scientific Community that will contribute for further development/amendment during the next waves of the project, in order to formulate a solid and globally accepted list of formal and other descriptive methods.

3.2.2 Formal Methods from Neighbouring Sciences

As stressed before, formal methods are techniques used to model/design complex systems rigorously so that it becomes possible to verify the system's properties in a more thorough fashion than empirical testing [26].

Table 3-48 indicates an initial list of some of the formal methods that probably are of most interest to the EISB. Not all neighbouring scientific domains from the EISB-SDRT of section 2.1.1 are included nor all of the ones included will necessarily be considered for ENSEMBLE's Wave 2 descriptions of EI problems and solution. This is due to the fact that this deliverable reports an initial analysis based on the contributions provided by experts participating on the Samos 2011 Summit. Also, as explained in section 2, the taxonomy of scientific domains closest to EI (EISB-SDRT) is not yet closed. In fact, the neighbourhood recognition process is iterative, and reaching the envisaged final short list of neighbouring domains, further iterations on the methodology for recognizing neighbouring scientific domains and their relationship with EISB (see Figure 2-1) are needed.

Theories are foreseen as integral to EI practice, promotion, and research. The choice of theory, although often unacknowledged, shapes the way practitioners and researchers collect and interpret evidence. Thus, theories range from explicit hypotheses to working models and frameworks of thinking about reality, which is important, scientifically and practically, to recognise implicit theories: they powerfully influence understandings of EI problems and solutions spaces.

Table 3-48: Wave 1 Analysis on Formal Methods from Neighbouring Sciences

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	Benefits and contributions for EISB
Mathematics	• Logic • Set Theory • Graph Theory • Category Theory • Calculus and Analysis • Number Theory • Fractal Theory • Petri Nets • Queuing Theory • Stochastic Processes • Bayesian Networks • Markov Chains • Catastrophe Theory	Mathematical methods provide a body of definitions, axioms, theorems and examples that are essential for the development of EISB. They provide mathematical techniques and embrace mathematical methods that have been typically used, or identified of relevance to be used, in the EI domain. These methods are vitally connected with the applied research and engineering of EI systems and applications, which are used to assist in the investigation and in the development of solutions for EI problems.
Computer Science	• Concept-Knowledge C-K • General Design Theory • Software Science • Programming • Information Theory • Database Theory • Cryptography and Data Encryption • Meta-Modelling • Algorithms and Data structures • Artificial Intelligence • Pattern Recognition • Simulation • Program verification • Automata theory • Event systems • Multi-Agent Systems • Lambda calculus	Enterprise systems are implemented by computer systems and applications. Thus, computer science provides the fundamental source of theories and methods valuable for the development of the EISB. From the large list of established computer science methods, these identified have higher relevance for EI, considering the specifications and functionalities applied in the EI framework layers. From Computer Science, EISB can get the theoretical foundations on information and computation. Also, it gets the methods for the implementations of EI computational systems and applications. This includes for example algorithmic processes that create, describe, and transform information and formulate suitable abstractions to model interoperable enterprise complex systems.
Interdisciplinary	• Cybernetics • Complexity Theory • Systems of Systems Theory • Complex Adaptive Systems • Systems Thinking • Cybernetics • Chaos Theory	By its nature, EI has been developed through applied research and engineering addressing two or more disciplines, taking approaches from multiple traditional theories and methods, combining and modifying them so that they are better suited to address the EI problem at

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	Benefits and contributions for EISB
	• Edge of Chaos • Cognitive Science • Network Theory • Axiomatic Design Theory • Services Science • Web Science • Information Science	hand. Addressing interdisciplinary methods, EISB is seeking to synthesize broad perspectives, knowledge, skills, interconnections, and epistemology in an integrated complementary setting. With such, it may be founded in order to facilitate the study of subjects which have some coherence, but which cannot be adequately understood from a single disciplinary perspective (for example, the complexity of the networked enterprise systems).
Economics	• Coordination Theory • Decision Theory • Game Theory • Innovation Economics • Behavioural Economics • New institutional economics	EI should not be addressed exclusively from a technical point of view. The economic and business aspects related with EI are of relevance for the organizations and also for the environment where they are integrated. Examples are theories and methods concerning the impact of interoperability in the business of the enterprises, and the creation of value proposition.
Communication Sciences	• Universal Theory • Constructivist Theory • Action Assembly Theory • Likelihood Model • Inoculation theory • Coordinated Management of Meaning • Uncertainty Reduction Theory • Social Penetration Theory • Predicted Outcome Value Theory • Relational Systems Theory • Relational Dialectics • Structuration Theory • Unobtrusive and Concertive Control Theory • Functional Theory • Symbolic Convergence Theory • Social Cognitive Theory • Communication Codes Theory • Face-saving Theory	These theories provide insights in the aspects of Enterprise interoperability concerning universal communication, message production and processing, and the interaction between systems and individuals. They address at individual and organizational level, concerning aspects like those of culture, small and large groups, social worlds and networks.

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	Benefits and contributions for EISB
	• Symbolic Interactionism • Linguistics	
Sociology	• Intercultural communication theory • Critical Theory • Phonetic social science • Rational choice theory • Social Network Analytics	EI is an enabler for networked enterprise systems, and its integration in the society in general. This, EI should account for the origin, growth, structure, and activities of society by the operation of physical, vital, and psychical causes when making interoperable enterprise systems and applications. These methods address the impact of EI in the society, its relationship and interactions.
Psychology and Philosophical Sciences	• Activity Theory • Applied Performance Psychology and physiology • Actor-Network Theory • Phenomenology • Epistemology	These methods provide the basis for the reasoning and philosophical development of EISB.
Healthcare Sciences	• Medicine • Pharmacology	Healthcare sciences address strong problems of interoperability. Their theories and methods can be used as examples for the studies of application in EI. Examples are within the theories related with compatibility of medicaments, blood and organs, e.g., blood transfusion, transplantation of organs, and efficacy of medicaments.

The following table presents an initial thought of how those identified formal methods could be matched to the 12 EI Scientific Areas. As it has been done for the neighbouring domains and the EI scientific areas, this classifications will be extensively validated and improved with the discussions and workshops joining experts from the several areas.

Table 3-49: Initial distribution of identified formal methods to the EI Scientific Areas

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
Mathematics	Logic	X	X	X	X	X		X					
	Set Theory	X			X	X		X			X	X	
	Graph Theory	X				X		X	X	X			
	Category Theory	X	X	X								X	X
	Calculus and Analysis	X	X	X		X		X	X		X		
	Number Theory	X				X		X					
	Fractal Theory											X	X
	Petri Nets		X						X	X			
	Queuing Theory		X						X				
	Stochastic Processes		X					X	X				
	Bayesian Networks		X						X	X			
	Markov Chains		X	X					X				
	Catastrophe Theory											X	X
Computer Science	Concept-Knowledge C-K				X							X	X
	General Design Theory				X							X	X

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
	Software Science	X	X	X	X	X			X			X	
	Programming	X	X	X	X	X			X			X	
	Information Theory	X			X	X		X	X				
	Database Theory	X		X	X	X	X	X	X	X	X	X	X
	Cryptography and Data Encryption										X		
	Meta-Modelling	X	X	X									X
	Algorithms and Data structures	X						X				X	
	Artificial Intelligence	X	X		X	X		X	X				
	Pattern Recognition	X	X	X				X	X				
	Simulation		X	X		X			X				
	Program verification								X				
	Automata theory		X						X				X
	Event systems		X						X				X
	Multi-Agent Systems		X						X				X
	Lambda calculus		X						X				
Interdisciplinary	Cybernetics		X		X				X				X

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
	Complexity Theory		X			X			X	X		X	X
	Systems of Systems Theory					X			X			X	X
	Complex Adaptive Systems					X						X	X
	Systems Thinking						X	X		X		X	X
	Chaos Theory												X
	Edge of Chaos						X						X
	Cognitive Science							X					
	Network Theory							X		X		X	X
	Axiomatic Design Theory												X
	Services Science		X			X			X				
	Web Science								X	X	X	X	
	Information Science	X				X		X					X
Economics	Coordination Theory												X
	Decision Theory									X			X
	Game Theory							X					X

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
	Innovation Economics												X
	Behavioural Economics												X
	New institutional economics												X
Communication Sciences	Universal Theory						X						
	Action Assembly Theory						X						
	Likelihood Model						X						
	Constructivist Theory						X						
	Coordinated Management of Meaning						X						
	Uncertainty Reduction Theory						X						
	Social Penetration Theory						X			X			
	Predicted Outcome Value Theory						X						

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
	Relational Systems Theory						X						
	Relational Dialectics						X						
	Structuration Theory						X						
	Unobtrusive and Concertive Control Theory						X						
	Inoculation theory						X						
	Communication Codes Theory						X						
	Face-saving Theory						X						
	Symbolic Interactionism						X						
	Linguistics						X						
	Functional Theory						X						
	Symbolic Convergence Theory						X						
	Social Cognitive Theory						X			X			

Neighbouring domain (EISB-SDRT level 2)	Formal Methods / Systemic Approaches (Leaves of the EISB-SDRT)	SA.1 - Data Interoperability	SA.2 - Process Interoperability	SA.3 - Rules Interoperability	SA.4 - Objects Interoperability	SA.5 - Software Interoperability	SA.6 - Cultural Interoperability	SA.7 - Knowledge Interoperability	SA.8 - Service Interoperability	SA.9 - Social Networks Interoperability	SA.10 - eID Interoperability	SA.11 - Cloud Interoperability	SA.12 - Ecosystems Interoperability
Sociology	Intercultural communication theory						X	X		X			
	Critical Theory						X	X		X			
	Phonetic social science						X	X		X			
	Rational choice theory						X	X		X			
	Social Network Analytics									X			
Psychology and Philosophical Sciences	Activity Theory		X			X	X		X				
	Applied Performance Psychology and physiology						X			X			
	Actor-Network Theory		X				X		X	X			
	Phenomenology						X						X
	Epistemology	X	X	X	X	X	X	X	X	X	X	X	X
Healthcare Sciences	Medicine	X		X	X			X					X
	Pharmacology	X		X	X			X					X

4 EISB Concept Formulation

The vast and deep "knowledge mining" performed in relation to the requirements of interoperability within the 12 scientific areas that have been defined in D2.1 [35], converges to the identification of a list of macro-issues, that can be considered coincident with the sub-areas.

Even a rapid analysis of the documents referenced testifies of a large number of initiatives and studies in each sub-area (with some preferences) with a large prevalence of "local" analyses, hypotheses, experiments, while attempts at holistic views and syntheses are less popular.

In no sub-area we can say that all the specific issues have been adequately satisfied by existing methods, tools, standards, for two main reasons:

- The accelerated pace of technology, in terms of digitalized management of an ever increasing number of aspects of our every-day life, requires a continuous adjournment of standards and tools. The landscape is evolving.
- The increasing "globalization of everything" highlights even new requirements for transparent and effective interoperability, at all levels of the "research chain" from conceptualization to the provision of operating tools. The landscape keeps extending.

Beside these issues already identified in relation to interoperability, we deem important to consider complementary issues that require some specific research efforts in relation to the use of theories and methods coming from neighbouring scientific areas, particularly as a unifying approach.

In facts methods like graph analysis or meme spreading analysis (that in many cases are already considered across different interoperability requirements) can provide cross-areas methodologies and the holistic approach, that are rather scarce in the EISB landscape.

4.1 Problem Space

The general list that follows analyzes the problem space articulated by each scientific area, and for each two issues lists are defined:

- The first one is relevant to the specific problems identified already in deliverable D2.1, that require additional research exercises within the scientific area itself, or in other interoperability areas.
- The second one indicates issues that require basic research efforts performed tapping into the domains of natural formal sciences (like Mathematics, Statistics, Complexity) or social ones (Psychology, Sociology). This second group highlights research tracks that can promote solutions to interoperability problems coming from neighbouring sciences.

4.1.1 Data Interoperability

In order to address the identified research issues about Data Interoperability (Table 4-1), we consider the topics of Table 4-2 relevant, and might need input coming from neighbouring sciences.

Table 4-1: Data Interoperability research issues

Issue	Comments
Semantic data representation	The Semantic Web implies the comprehensive use of the main semiotic postulates on the Web, such as syntagm and paradigm, in the context of logical understanding and knowledge representation on the Web.
Data standardization	The main problem in this case concerns particular harmonization of standard and standard translation.
Schema matching	The goal of schema matching is to find semantic correspondences between the elements of two schemas. Since Schema matching still remains largely a manual, labour-intensive, and expensive process, automatic methods and tools are required to support this task.
Data mediation	Data mediation, or data transformation, converts data from a source data format into destination data. Mapping is generally complicated by different standards, by polisemic expressions, and the like.

Table 4-2: Data Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Semantic annotation	Requires the solution of problems in logic. Efficient similarity reasoning algorithms must be studied in order to produce automatic tools for adding semantic annotation to data.
Conceptual schema analysis	A schema can be always described as a graph and the problem of verifying if two schemata are identical or contained or have a common intersection can be formulated as a problem of Graph Isomorphism (GI), or as a problem of Graph Matching, a more relaxed version of GI. In addition semantic aspects require investigation on methods and tools for similarity reasoning.
Data modelling	Transformation languages and grammars are research topics crucial for data mediation, whose extension to interoperable and semantic environment requires further investigation.

4.1.2 Process Interoperability

In order to address the identified research issues about Process Interoperability (Table 4-3), we consider the topics of Table 4-4 relevant, and might need input coming from neighbouring sciences.

Table 4-3: Process Interoperability research issues

Issue	Comments
Process Modelling	Formalization of the process in a specific language, generally integrating graphic, text, numerical values.
Process Reengineering	Activity performed generally in order to increase the efficiency of existing processes, using techniques like elimination of unnecessary steps, parallelization of activities, and so on. The reengineering has to relate also

	to the management of semi-structured an unstructured interactions.
Process Standardisation	Part of (and pre-requisite to) reengineering.
Process Alignment	Degree of consistency of business processes to the enterprise strategy.
Automated Process Execution	Generally this is the last step of Business Process Modelling tools, which takes a process model and is capable of instancing it as a running process.

Table 4-4: Process Interoperability research problems tapping into neighbouring sciences

Problem domain	**Comments**
Process model transformation and equivalence verification	In the context of Model Driven Engineering models are the main development artifacts and model transformations are among the most important operations applied to models. A number of transformation languages are being developed for this task, for different meta-models (i.e. modelling environments). Since models can be generally considered a particular kind of graphs, a natural way to address model transformation in a rule-based way, is reusing existing graph transformation languages. Examples of solutions can be found in [66], [83], [29]. Equivalence verification is part of the transformation, and the techniques are dependent on the modelling environment. Research is active in this field, and the relevant solutions can be applied in process modelling for interoperability.
Rewriting systems	In this category fall, in the scopes of mathematical logic and theoretical computer science, theories like Abstract Reduction System, Confluence, Divergence, Word Problem, etc. Transfer of these research methods to our field can provide fruitful solutions.
Program transformation	Program transformation techniques are used in a many areas of software engineering. Methods coming from formal logic are Pattern Matching, Lexical Analysis, etc. These methods can be applied to process models, considered as programs.
Program verification	Also the logic and mathematical techniques used in the verification of programs can be extended to the verification of business processes.
Standard harmonisation/translation	Standardization Agencies are pushed, by the market and by Public organizations, to harmonize and streamline standards in all sectors. Anyway this is a continuous task, as new standards are being defined. For this reason standard translation techniques are required when processes relevant to Enterprises that adhere to different standards have to interoperate. The relevant issues are similar to those of model transformation.
Process Synchronization	This issue is mainly related to Operating Systems engineering, but can be translated into business processes interoperations. In mathematics and computer science, a history monoid is a way of representing the histories of concurrently running computer processes as a collection of strings, each string representing the individual history of a process. The history

	monoid provides a set of synchronization primitives (such as locks, mutexes or thread joins) for providing rendezvous points between a set of independently executing processes or threads. The related solutions can be explored for similar problems in business processes that interoperate and need to be synchronized within distributed enterprises.

4.1.3 Rules Interoperability

In order to address the identified research issues about Rules Interoperability (Table 4-5), we consider the topics of Table 4-6 relevant, and might need input coming from neighbouring sciences.

Table 4-5: Rules Interoperability research issues

Issue	Comments
Rules Modelling [81]	Formalization of business or legal rules into a model. Research has been mostly devoted in the first place to business rules, while legal rules constraints have been considered more recently. For example SWRL is a proposal for Semantic Web rules-language, combining sublanguages of the OWL Web Ontology Language (OWL DL and Lite) with those of the Rule Markup Language (Unary/Binary Datalog). SWRL has turned out insufficiently expressive to capture some of the essential peculiarities of legal reasoning. For that reason, a partly novel rule formalism, called LKIF rules, has been developed and incorporated in SWRL. Further research has lead to an extension of the LKIF-rules syntax enabling the addition of temporal arguments.
Legislation Homogenisation/Alignment	Alignment of processes to legal rules can be considered a specific application of business process alignment, considered in the previous issue. An example of specific research is the framework for checking if a software program is compliant with existing legislation in terms of security, proposed by [63].
Rules Execution	Tools coming from the expert systems area, able to decide on a specific case on the base of the constraining rules.

Table 4-6: Rules Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Rules Transformation [8], [74]	The documentation retrievable on the Web for rule transformation issues is not abundant. In any case, the research on the use of rule sets for decision support systems is active, and the solutions proposed can be explored in order to solve the problem of matching different sets in interoperable contexts. The possible way, in case neither set can be modified, is to converge to a common set that translates adequately both.
Rules consistency checking	This is a complementary issue of that of rules transformation: Having to interoperate in presence of two different sets, it is important the use of tools able to check the consistency of the translated common set.

Knowledge representation	This specific problem is caused by the compound issues of interoperate with sets of rules formalized with different frames and interpreted with different semantics. In this case the integration of methods and tools coming from knowledge management and expert systems area needs to be explored.
Automated theorem proving	The mathematical theory of theorem proving has a long history, and research is very active for the production of tools, a long list of which can be found in Wikipedia. Many of these tools are dedicated to graphic representations of the logic to be proved, and can be useful for the rules transformation and consistency checking tasks.

4.1.4 Objects Interoperability

Object interoperability regards both sensors and actuators for different application or RFID devices networks. All these object are or can be networked, giving rise to a complex system of information that could be used in yet unknown way. However there are technological and formal issues that arise from this complex world. The technological issues are addressed in the deliverable D2.1 [35] and are those listed in Table 4-7.

Table 4-7: Objects Interoperability research issues

Issue	Comments
RFID interoperability	Seamless communications between RFID tags and readers. The global nature of logistic operations requires global standards. These standards are being defined for different industry sectors (for stance ISO 28560-1, -2, and -3 for the use of RFID in Libraries) and evolution is still on-going.
Internet-connected objects	The integration of a myriad of embedded and personal wireless objects, capable of supporting the interaction between users' social, physical and virtual activities.
Networked media	Refers to media mainly used in computer networks such as the Internet; implies the bi-directional communication capability, and distributed content creation.
Factory-of-Things	Also referred to as "smart factory". Automation technology complemented by an adequate software architecture promoting the developments of mechatronic functionality integration and intelligent field devices.
Smart Objects / Devices	Devices that are digital, active, computer networked, are user reconfigurable and that can operate to some extent autonomously.

In order to address the identified research issues about Objects Interoperability, we consider the topics of Table 4-8 relevant, and might need input coming from neighbouring sciences.

Table 4-8: Objects Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
RFID identification	RFID identification and authorisation also in case of different standard

	requires the study of new architectures capable of supporting the reading and translation of huge quantity of devices. Other research issues concern the problem of read rates that are less than 100% even in the most favourable RF environments, low read ranges, security problems, localization of tags and lack of efficient simulators.
Self-organization of smarts objects	These objects (like Networked media components, Factory-of-Things devices, Smart Objects / Devices) require a complex system of communication and distributed intelligence, hence protocols, synchronization and the study of new computational models.

4.1.5 Software Interoperability

According to ENSEMBLE deliverable D2.1, Software Interoperability (SI) refers to the ability of an enterprise system or a product to work with other enterprise systems or products. In order to address the identified research issues about SI (Table 4-9), we consider the topics of Table 4-10 relevant, and might need input coming from neighbouring sciences.

Table 4-9: Software Interoperability research issues

Issue	Comments
Requirements engineering for interoperable enterprises	Refers to the capability of identifying and analysing software with the aim of developing systems able to interoperate both within a given enterprise (e.g., software systems supporting different company departments), and between enterprises.
Component-based software engineering	A branch of software engineering which emphasizes the separation of concerns in respect of the wide-ranging functionality available throughout a given software system [83].
Monitoring and Evaluation	In this context refers to the capability of controlling and assessing the degree of interoperability (in terms for instance of semantics and syntaxes) among interacting software systems.

Table 4-10: Software Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Components compatibility checking	Referring to the above issues, component-based software engineering needs strong support of *compatibility checking* methods [24], in order to assess the capability of software components to be interoperable. Such methods mainly leverage on the use of formal languages for components interfaces description and performance evaluation.

4.1.6 Cultural Interoperability

In order to address the identified research issues about Cultural Interoperability (Table 4-11), we consider the topics of Table 4-12 relevant, and might need input coming from neighbouring sciences.

Table 4-11: Cultural Interoperability research issues

Issue	Comments
Language interoperability	Multilingualism can be the source of issues, and of solutions, when the difference of cultures stems from the difference of nationality. Research in natural language interpretation and formalization, semantic analysis of speech, emotion mining, is abundant, even if many issues are still standing. Once formalized, the interoperability issue is that of cross-mapping.
Regional aspects compatibility	An aspect of intercultural exchanges is represented by the association of people to the major cultural plexes of their region. A cultural plex is the complex integration of language, habits, religion, all the cultural models that drive a person's behaviour. Beyond language barriers, enterprise interoperability on a global scale requires more subtle cultural barriers to be overcome. A small example is the amount of care that car makers have always applied to the choice of model names, in order not to offend any cultural group.
Alignment in traditions, religions and ethics	The considerations are the same as for the interoperability across different regions, i.e., across different cultural plexes.

Table 4-12: Cultural Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Resistance to change	Psychology is certainly a discipline that can provide useful methodologies to cultural interoperability. For instance the degree of acceptance of the introduction of a new product or service in a given region or for an ethnic group can be eased by adopting specific messages that help in "tuning" the product characteristics to specific habits.
Group dynamics	Sociology researches the interactions of people in every situation of their life: many aspects of enterprise interoperability involve the interaction with people seen as groups. Group dynamics, that are a research topic of Psychology and Sociology, can provide hints and solutions for cultural interoperability issues, for instance in the case of the evolution of the acceptance of a given service in a specific group.
Competition vs. Cooperation	In a field characterized by limited resources there are two basic ways of exploiting them. Individuals and groups can: • Compete in efficiency in order to produce maximum value with minimal use of the resources, • Cooperate with individuals/groups in neighbouring fields in order to find ways of using in a different way the same resources, or use new untapped ones.

	• Psychology and Sociology can provide useful methods for exploring these different approaches.

4.1.7 Knowledge Interoperability

According to [35], Knowledge Interoperability is defined as "the ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilise it, and to further extend them through cooperation". In this context, the following two tables describe some research issues that are considered relevant to Knowledge Interoperability (Table 4-13), and related basic research problems for addressing them (Table 4-14).

Table 4-13: Knowledge Interoperability research issues

Issue	Comments
Knowledge Sharing & Knowledge Repositories	Knowledge sharing refers to the capability to access, exchange and transfer knowledge (e.g., information, skills) among actors within a given community. This capability still represents a very challenging issue in the field of knowledge interoperability and management because individuals often tend to resist in sharing their knowledge with the rest of the organization they work in. For this reason, it does not appear only as a technological problem. However, the support of enhanced repositories of knowledge, with a strong support of semantic technologies appears very crucial.
Business Units Alignment	This problem refers to the capability of getting the business units pulling together into a company with a unified strategy, and as a basic requisite, with the capability of talking and understanding each other. As such, this problem is strongly affected by sharing and transfer of knowledge among the different actors.
Transportation of Knowledge	The capability of transfer knowledge (that is information + references to semantic models capable of resolving implicit information) between knowledge management systems. This issue relates also to knowledge sharing between communities having different "languages" (in term of cultural models).
Smart Infrastructures	Future Internet will require technological infrastructures capable of ensuring the expected growth, in the coming years, of an order of magnitude increase in services, in the interconnection of smart objects and items (Internet of Things) and its integration with enterprise applications.
Knowledge Embedded Systems	Systems whose behaviour is based on knowledge that is formalized and interpretable.
Context-aware Systems	General class of mobile systems that can sense their physical environment, and adapt their behaviour accordingly.

Table 4-14: Knowledge Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Knowledge sharing	As reported in the previous section, knowledge sharing, and knowledge management at large, can be really improved by applying semantic technologies. In particular, *semantic annotation* is needed for semantically enriching knowledge resources, in order to allow, for instance, classification of documents, profiling of people and organization, semantic description of services and products. Furthermore, knowledge sharing needs powerful *semantic search engines* which are enabled by semantic annotation techniques and represent a relevant aspect in the problem of accessing knowledge resources.
Ontology matching	As a basic issue in the application of semantic technologies is the problem of *ontology matching*, which represents a fundamental aspect to allow knowledge and semantics driven applications to communicate each other. Ontology matching refers to logic theory and in particular to a specific class of logics which is the description logic.
Natural language processing (NLP)	Research on *natural language processing* (NLP) techniques appear very relevant to knowledge interoperability, since they help in analysing and understanding human-oriented knowledge resources (e.g., textual documents) and create valid support for automatic semantic annotation.
Effective remote human interaction	A significant part of knowledge will be transferred and generated through advanced video conferencing, such as tele-presence. Researches on interpreting emotional content from voice tones or body expressions would be beneficial for enriching the semantics of these interactions.

4.1.8 Service Interoperability

According to D2.1 "Services interoperability" refers to the ability of an enterprise to dynamically register, aggregate and consume composite services of an external source, such as a business partner or an internet-based service provider, in seamless manner. This way in order to address the identified research issues about Service Interoperability (Table 4-15), we consider the topics of Table 4-16 relevant, and might need input coming from neighbouring sciences.

Table 4-15: Service Interoperability research issues

Issue	Comments
Automatic service description [12]	This problem refers to the need of describing a web service with additional pieces of information (i.e., semantic annotation), about what it does and how it behaves, by using automatic techniques.
Automatic service discovery [69]	Is the process of finding a suitable web service for a given task, without the human intervention. This implies the capability of formulating a request in a certain language, and resolving it against previously described services, by using inference mechanisms.
Automatic service composition and	It refers to the capability of creating new web applications by combining existing web resources utilizing data and web APIs. This process could end

mash-up	up as an exercise of co-design and co-creation between different actors, through a feed-back of "assemblers" to component creators.
Automatic service negotiation	Negotiation mechanisms between web services refer to the capability of them to reach agreements such as for service provision.
Service Mediation [58]	This issue refers to the capability of intercepting and modifying messages that are passed between existing services (providers) and clients (requesters), in order to allow them to interact in a proper way.

Table 4-16: Service Interoperability research problems tapping into neighbouring sciences

Problem domain	Comments
Semantic annotation / similarity	*Semantic annotation*, and consequently *semantic similarity*, are strongly required to improve the automatic capability of service description.
Semantic reasoning / search	*Semantic reasoning* at large and *semantic search* are crucial for supporting service discovery and mash-up. Furthermore, *grid computing* and *multi-agent systems* can be very helpful in addressing service negotiation, since both aim to achieve "large-scale open distributed systems, capable of being able to effectively and dynamically deploy and redeploy computational (and other) resources as required, to solve computationally complex problems" [45].

4.1.9 Social Networks Interoperability

In order to address the identified research issues about Social Networks Interoperability (Table 4-17), we consider the topics of Table 4-18 relevant, and might need input coming from neighbouring sciences.

Table 4-17: Social Networks Interoperability research issues

Issue	Comments
Social Network Integration	Social networks are pushing enterprises, acting in many markets, to an ever-stronger commitment to the exploitation of their unpredicted impact on people. The issue here is that most enterprises are not yet prepared to enter this arena. An example is that many companies prohibit the access to these functions from company intranets, despite the business advantages that could arise from this use. A first issue is the capability of an enterprise of building a community out of its human resources, and this is particularly important for distributed, virtual enterprises. The building of a community means the establishing of a specific "culture", that has always been considered a very precious asset of an enterprise. In the dynamics of today markets (and in presence of a widespread sense of precariousness particularly among young employees) culture can be the only permanent feature of a Company. A second issue is acquiring the capability of exploiting the impact of social

	networks to increase the value produced by an enterprise. What is needed is the conversion of procedures like customer care or commercial promotions to the use of these new channels.
Heterogeneity of nodes and networks	The heterogeneity of a social network in terms of nodes (data sources) and of interoperable networks poses specific issues in terms of management of heterogeneous and potentially redundant data.
Social Analytics & Social Cross-Networks Analysis	Together with the integration of social networks with the procedures of an enterprise, another issue is the acquisition of the capability of mining the traffic data on these networks as an additional source of knowledge related to the business of interest.
Social Business Models	Some kind of business are considered "social" (the definition is not univocal), and some of these rely principally on a distributed network of stakeholders and/or customers. For these the interaction with social networks is natural, and so the related interoperability issues. There are a number of models being proposed, and surely more will be in the near future, as the specific territory is very much in ferment. It is important for enterprises to maintain an observatory on these activities, in order to be able to adopt, in case of opportunity, the one best suited to them.

Table 4-18: Social Networks Interoperability research problems tapping into neighbouring sciences

Problems	Comments
Integration of enterprise knowledge with crowd wisdom	Crowd wisdom is the main value produced by a social network, and it is its tapping that enterprises look for. The main issue for this interaction is the need to interoperate the existing knowledge system of an enterprise (SW application systems, strategy, processes, etc.) with this new knowledge. One typical difference between the two is that crowd wisdom is a continuous stratification of beliefs, trends, fashions, while enterprise knowledge tends to be more stable and static. Here research items typical of Sociology and Psychology can help.
Data mining & information retrieval	The methods and tools available from knowledge management are a sure support for these issues, particularly the frontier research exercises, in terms for instance of "emotion mining" [76]
Ethical issues	A theory that crosses the boundary between Psychology and Sociology is Memetics. Its definition can be the following (presented by [55]): *Memetics* is the theoretical and empirical science that studies the replication, spread and evolution of memes. *Meme* is an information pattern, [a part of the conceptual model] held in an individual's memory, which is capable of being copied to another individual's memory. Memetics is important for the ethical issues of social networks because its basic research exercises explore the ways that a new "piece of knowledge" can spread in a community and change the common behaviours. The mechanisms propagation of fashions is an example of Memetics interest.

4.1.10 Electronic Identity Interoperability

In order to address the identified research issues about eID Interoperability (Table 4-19), we consider the topics of Table 4-20 relevant, and might need input coming from neighbouring sciences.

Table 4-19: eID Interoperability research issues

Issue	Comments
Digital Signatures Interoperability	Capacity of transferring digital signatures across different control systems
Federated Identity Management Systems Interoperability	Capability of interoperating Identity Management Systems to exchange sensible data in a transparent (to the User) and secure way. The issue arises from the different systems being provided by industry.
Electronic Identity Security	All the issues of privacy and security need to be addressed both at the technical level and at the legal one. Interoperable entities create a potential risk of security breakage at the interfaces, requiring additional control mechanisms.
Electronics ID Cards Infrastructures & Services	Many Countries have adopted Electronic ID Cards, and of course the mobility of people requires that these can be transparently managed by any system anywhere.
Single Sign On Architectures	As more and more services are offered to users, there is the need to control access privileges to these across all services. The issue lies in the need to share identity data in a controlled and secure way.

Table 4-20: eID Interoperability research problems tapping into neighbouring sciences

Problems	Comments
Privacy	Privacy issues require specific platforms and tools developed in computing science.
Ethical issues	For these issues the considerations made for Social Interoperability apply as well.
Cryptography	Mathematics in involved in the cryptography problem: 100% security against breakage is theoretically impossible, and researches in quantum computing promise to extend this security level nearer to 100 than with current technology.

4.1.11 Cloud Interoperability

According to D2.1 [35], Cloud Interoperability is the ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud dependant. The essence of the problem, though, is that each vendor's cloud environment supports one or more operating systems and databases. Each cloud contains hypervisors, processes, security, a storage model, a networking model, a cloud API, licensing models and more. Rarely, if ever, do two providers implement their clouds in exactly the same way, with all the same moving pieces [97]. However, Cloud Interoperability requires not just standards compliance today, but a unified approach to evolving those standards and for coping with incompatibilities as they occur in the future [25].

Table 4-21: Cloud Interoperability research issues

Issue	Comments
Cloud Orchestration	Thousands of companies are trying to simplify the speed and adoption of their products and services by transforming them into cloud services [1]. There will not be just one cloud but numerous types -- private and public clouds. These will further get divided into general purpose and specialized ones. All these clouds will be full of applications and services. It will not be possible to use these without some type of orchestration.
Unified Cloud Interfaces	Is the need of unifying various cloud APIs and abstract it behind an open and standardized cloud interface. A key driver of the unified cloud interface is to create an API about other APIs [82]. A different approach is based on a cloud broker in charge to serve as a common interface for the interaction between remote platforms, networks, systems, applications, services, identity and data. An interesting initiative is given by the Open Cloud Computing Interface (OCCI, http://occi-wg.org/)
Cloud Federation	Intercloud is a term introduced by Cisco, that refers to a mesh of clouds that are interconnected based on open standards to provide a universal environment for cloud computing. Like the name suggests, it's similar to the Internet model, where everything is federated in a ubiquitous, multiple-provider infrastructure [88].

In order to address the identified research issues about Cloud Interoperability (Table 4-21), we consider the topics of Table 4-22 relevant, and might need input coming from neighbouring sciences.

Even if the concept of cloud refers to a new way of computing, research activities for addressing cloud development and interoperability problems, could certainly benefit from research on *operating systems*, *scheduling* of computing resources, *optimization* of such resources, and *parallelism* of computation.

Table 4-22: Cloud Interoperability research problems tapping into neighbouring sciences

Problems	Comments
Operating systems interoperability	Since a standard among providers of cloud platforms does not exist, issues that have interested, and still interest, interoperability among different operating systems could be used for supporting interoperability among cloud platforms.
Scheduling of computing resources	The need of delivering high quality of services in cloud environments is a very crucial issue. To this end, primary means for obtaining this goal are given by planning the schedule of allocation of resources and adapting the schedule to unforeseen events.
Optimization of computing resources	In a scenario of federated clouds, such as private, public, general purpose and specialized ones, in the so called InterCloud optimization of

	computing resources to support cloud orchestration will be a key issue.
Parallelism of computation	As cloud computing concepts become reality, the need for systems to operate in a highly dynamic grid environment will require parallel processing techniques to be incorporated into some mainstream programs. This is particularly true for analytical tasks that incorporate large data sets.

4.1.12 Ecosystems Interoperability

In order to address the identified research issues about Ecosystems Interoperability (Table 4-23), we consider the topics of Table 4-24 relevant, and might need input coming from neighbouring sciences.

Table 4-23: Ecosystems Interoperability research issues

Issue	Comments
Distributed Systems and Agents	An Ecosystem is a distributed adaptive open socio-technical system. Its peculiar issues are those typical of complex systems, the principal of which is probably the difficulty in forecasting its evolution: impacts of local events are proportional to the event magnitude only up to given limits, and often the consequences of a disturbance are felt in the entire system (the famous butterfly effect). The scale-free characteristic comes from the interoperations of "nodes" of every size, from a single SW Agent to a Country-level System. The Web is a perfect epitome of this ecosystem. This characteristic requires the ability of interfacing communications from "partners" of any size and sophistication.
Business Ecosystems Interoperation	Interoperation of different ecosystems requires the organization of specific communication channels: if the same "anarchical" interfacing capabilities that operate within a single ecosystem would be required across two or more, these would become a single ecosystem. These organizations constitute an additional issue to all the ones examined up to now, and needs to be addressed.
Virtual Enterprise Integration	Virtual Enterprises are a variety of ecosystems, with their peculiar information and knowledge sharing requirements. The issues to be solved are the same commented for ecosystems in general.

Table 4-24: Ecosystems Interoperability research problems tapping into neighbouring sciences

Problems	Comments
Complexity science	The single most important source of solutions for the Ecosystems Interoperability is the science of complexity. Here all the characteristics of a complex environment, like the self-organization capability, the scale-free structure, the punctuated evolution feature, are objects of research. Ecosystems are Complex Adaptive Systems, i.e., they evolve, adapting to changes coming from the context. In our case the context is represented by society, technology, the natural environment. Complexity science in facts borrows methods and tools from formal, applied, social sciences,

	and provides original theories stemming from its holistic approach. An example of methodology coming from complexity is that of simulating the impacts of events using a model of the system: it comes from the exponential time involved in applying non-linear algorithms to the model. For instance in the situation of unpredictability of impacts, the performance of simulations of different patterns of disturbances can give useful hints on the probable outcomes of a real-life event.

4.2 Solution Space

As already mentioned, the solutions being provided by the large number of research exercises tend to be local, while interoperability, by its nature, requires cross-solutions.

The main problem of interoperability seems to be not the lack of specific solutions, but rather the abundance of them. And this multiplicity of solutions will probably increase mainly because of the complexity of the territory. The presence of different standards competing in some areas, for instance, is a typical consequence of this complexity. In many documents the authors report the necessity of adding some ad-hoc solution to an established method or standard selected as the backbone of the exercise, in order to cover all the stated requirements.

Another example of unavoidable divergence is provided by the use of application software from the part of enterprises: we can find many different solutions for each business sector, and no matter how large is the spectrum of functionality that each package offers, you always find some specific requirement of YOUR business that is not covered. Competing packages differ by some little function missing here and there, and one can rarely find a solution that covers all his or her requirements.

Diversity of rules, behaviours, habits, is un-eliminable, and luckily so, as it is the fuel of evolution. In any case there will never (probably) be a unique language and a unique way of doing business: interoperability will have to live with an ever-increasing complexity.

It is important to note that, since interoperability is an articulated cross-sector discipline, its peculiarity is represented by the fact that there exist plenty of useful solutions; however these are not ready to be used as such. In fact they need to be selected and connected in a synergic way in order to achieve the required objectives. In this respect we find three order of problems: the first is how to select and integrate the available specific solutions; the second is how to assess which are the specific solutions, pertaining to the specific domain of interoperability, that need to be developed by the dedicated research teams; the third is how to decide that a required solution is so specific that it has to be defined a-hoc.

The solution elements that are highlighted for each issue in the following matrix are just a first indication of priorities that at this date look important in terms of research efforts. The increasing complexity of the landscape will require a constant revision (planned for Waves 2 and 3 of the Project) of these considerations, together with a deeper dive into the relevant topics.

The elements are suggested on the base of a survey of the documentation related to the Scientific Themes of Enterprise Interoperability (bibliography in ENSEMBLE D2.1), on web searches on specific topics, and on the relevant comments associated to the EISB Lexicon in Section 3.1.3 of the present Document.

Note that in the "tools" column, it is provided a first indication of the kind of tools required (the word "tool" is skipped for brevity, e.g. instead of automatic matching tools, it is written only automatic matching).

4.2.1 Indicative Solution elements matrix

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
Data Interoperability	Semantic Data Representation		X			X			
	Data Standardization				Unified data schemas				X
	Schema matching				Automatic matching				
	Data Mediation		X		Enterprise service bus		X		
	Semantic annotation		X			X			
	Conceptual schema analysis		X		Graph matching				
	Data modelling		X		Event driven architecture		X		
Process Interoperability	Process Modelling				Integration of structured and unstructured operations		X		
	Process Reengineering		X		Business network platforms		X		

[22] First indication of the kind of tools required (the word "tool" is skipped for brevity, e.g. instead of automatic matching tools, it is written only automatic matching)

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
	Process Standardisation				Process commonalities		X		X
	Process Alignment		X		Process commonalities				
	Automated Process Execution				Business network platforms		X		
	Process model transformation and equivalence verification		X		Graph transformation				
	Rewriting systems		X						
	Program transformation		X						
	Program verification		X		Logic & mathematical tools				
	Standard harmonisation/translation				Model transformation	X			
	Process Synchronization				history monoid mgmt				
Rules Interoperability	Rules Modelling				Rules-languages		X		
	Legislation Homogenisation/Alignment	X					X	X	

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
	Rules Execution				Specific inference engines		X		
	Rules Transformation		X		Decision Support Systems				
	Rules consistency checking				Decision Support Systems				
	Knowledge representation				Knowledge mgmt				
	Automated theorem proving		X		Problem solving				
Objects Interoperability	RFID interoperability		X				X		X
	Internet-connected objects		X		Interfaces		X		X
	Networked media				bi-directional communication				X
	Factory-of-Things				Mechatronic engineering				X
	Smart Objects / Devices								X
	RFID identification				Architectures				
	Self organization of smarts objects		X			X			

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
Software Systems Interoperability	Requirements engineering for interoperable enterprises		X		User centered design		X		
	Component-based software engineering		X		Model driven software engineering		X		X
	Monitoring and Evaluation		X						
	Components compatibility checking		X		Formal language definition		X		
Cultural Interoperability	Language interoperability		X		Language interpretation		X	X	
	Regional aspects compatibility						X	X	
	Alignment in traditions, religions and ethics		X				X		
	Resistance to change	X	X	X					
	Group dynamics	X	X	X					
	Competition vs Cooperation	X	X	X					

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
[redacted]									
Knowledge Interoperability	Knowledge Sharing & Knowledge Repositories			X			X		
	Business Units alignment			X			X		
	Transportation of Knowledge		X	X					
	Smart Infrastructures	X	X		Knowledge mining, Knowledge discovery, Semantic mapping, meta data repository mgmt				
	Knowledge embedded systems		X		Knowledge sharing	X			
	Context-aware systems	X			Semantic mapping,	X			
	Knowledge sharing	X	X						
	Ontology matching		X						
	Natural language processing (NLP)		X	X		X			
	Effective remote human interaction	X	X		Effective video conferencing				
[redacted]									
Inte rop era bilit	Automatic service description		X		Semantic				

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
					representation				
	Automatic service discovery		X		Semantic representation		X		
	Automatic service composition and mash-up		X		API's		X		
	Automatic service negotiation		X		Inference engines		X		
	Service Mediation				API's		X		
	Semantic annotation / similarity	X	X						
	Semantic reasoning / search	X	X						
Social Networks Interoperability	Social Network Integration				Data/IP protection		X		
	Heterogeneity of nodes and networks		X		Heterogeneous data mgmt		X		
	Social Analytics & Social Cross-Networks Analysis				Central Data management for personal data		X		
	Social Business Models	X					X		
	Integration of enterprise		X	X			X		

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
	knowledge with crowd wisdom								
	Data mining & information retrieval		X		Emotion mining				
	Ethical issues	X		X			X		
Electronic Identity Interoperability	Digital Signatures Interoperability						X		X
	Federated Identity Management Systems Interoperability				Central Data management for personal data, Identity Federation, Global identity management		X		X
	Electronic Identity Security		X				X		
	Electronics ID Cards Infrastructures & Services				Data/IP protection		X		
	Single Sign On Architectures				Open APIs				
	Privacy				Data/IP protection				
	Ethical issues						X		
	Cryptography				Mathematical				X

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
Cloud Interoperability	Cloud Orchestration					X	X		
	Unified Cloud Interfaces				Advanced virtualization Standardized API's, Migration				X
	Cloud Federation		X			X	X		
	Operating systems interoperability				OS interoperability				X
	Scheduling of computing resources		X			X			
	Optimization of computing resources		X			X			
	Parallelism of computation				Monitoring	X			
Ecosystems Interoperability	Distributed Systems and Agents		X			X			
	Business Ecosystems Interoperation		X	X		X			
	Virtual Enterprise Integration		X	X			X		

Scientific Area	Sub-area Issues/Problems	Concepts & positions	Methods	Proof-of-concept	Tools[22]	Experiments	Case studies	Surveys-empirical data	Standards
	Complexity science	X	X			X			

5 Synthesizing the EISB Community

5.1 EISB community groups

The Enterprise Interoperability Science Base community is closely interrelated with the FInES community. This relationship is outlined in Figure 5-1. A full analysis of the content and structure of these groups was presented in ENSEMBLE Deliverable D1.2.1: Community Synthesis-1st Version. In summary:

- The primary constituents of the FInES Cluster are the related FP7 funded projects, Working Groups which support long term or recurring actions of the Cluster and Task Forces formed as necessary to undertake specific Cluster tasks, and usually having a finite lifespan.
- A number of external domain stakeholders are represented to the Cluster through its members. These have related interests, but are not primarily addressing the issue of EI. Conversely, the FInES community has an interest in the activities of these stakeholders, as their activities impact on future development of Enterprise Interoperability.
- Independent legal entities currently embrace both the INTEROP-VLab and individuals who contribute to the activities of the FInES community.

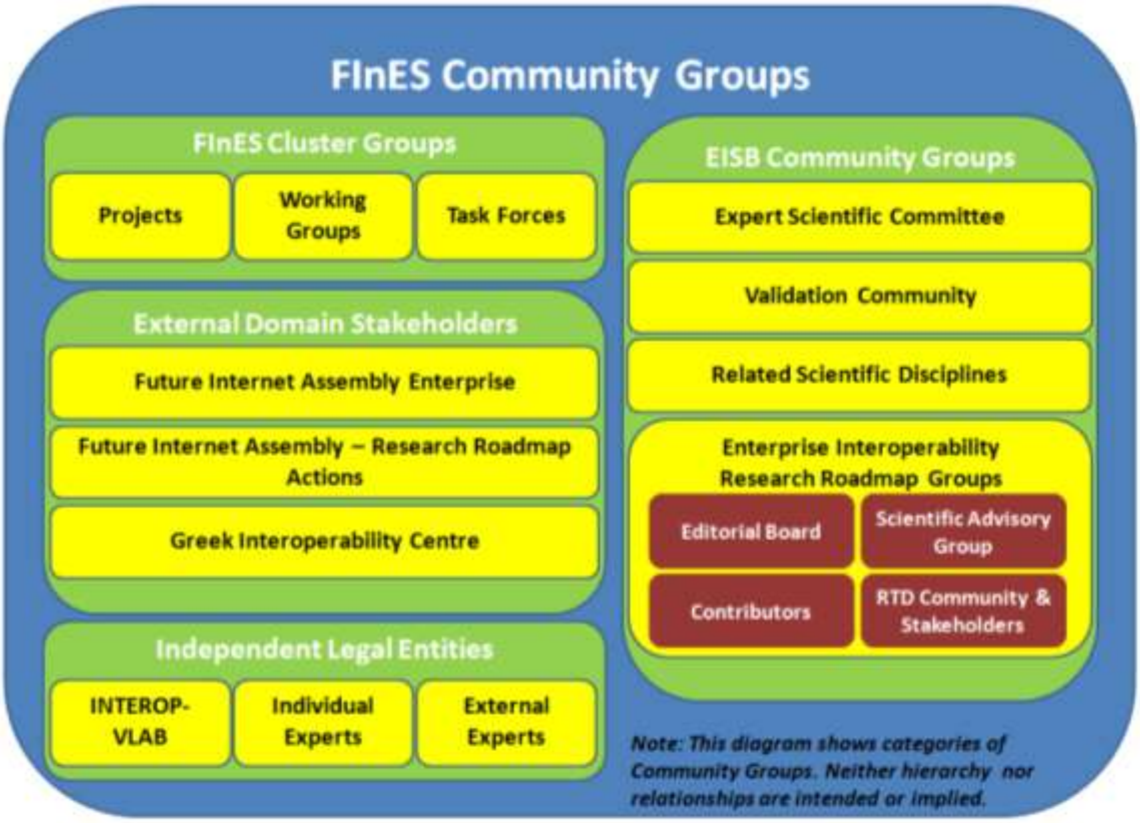

Figure 5-1: FInES Community Groups

- With the expansion of activity on the Enterprise Interoperability Science Base supported by ENSEMBLE a set of community groups specifically addressing the development of an EISB have also been established.

- The Expert Scientific Committee and Validation Community have been described in some detail in ENSEMBLE Deliverable D1.2.1.
- The Enterprise Interoperability Research Roadmap Groups have been established since publication of D1.2.1, and strictly speaking address the roadmap issue. However this is closely related to Science Base, and so these groups are shown as they are in the figure.

Whilst Deliverable D1.2.1 described the current status of the other groups, the EISB Community Groups were proposed at that stage. Here we review the current status of these EISB Community Groups.

5.1.1 Experts Scientific Committee

The ESC has been established through two ENSEMBLE actions, described in detail in D1.2.1, summarised as:

- A Call for Contributions was published in late September 2011, and in December the resulting contributions were reviewed by the ENSEMBLE team and 6 were selected as the best contributions. Their contributors were invited to join the ESC, and all agreed to do so. They are listed in Table 5-1 below.
- The ENSEMBLE team identified a number of experts from both within and beyond the existing FInES community, whom it was felt would be able to make a significant contribution to the ESC. These too were invited to join, and also appear in Table 5-2 below.

Table 5-1: ESC members selected through Call for Contributions

ESC Member	Location	Domain of Interest
Antonio Manzalini	Italy	Future Networks architectures and business models, Autonomic Computing and Networking, Cognitive Networking, Computational Neuroscience
Antonio Grilo	Portugal	Interoperability, Public Procurement, Building Information Modeling, Project Management, Information Systems, Strategic Management, and Appraisal Systems
David Chen	France	Networked Enterprises; Enterprise interoperability
Lars Taxén	Sweden	PLM support based on Matrix, engineering management. Coordination of large, complex projects based on an integration centric development approach
Nenad Ivezic	USA	Systems integration, semantic technologies, standardization, and testing
Norbert Koppenhagen	Germany	eCommerce, Internet and intranet and workflow technologies

Table 5-2: ESC invited members

ESC Member	Location	Domain of Interest
Weiming Shen	Canada	Agents and Multi-Agent Systems; Concurrent Engineering; Collaborative Design and Manufacturing; Facilities Management and Maintenance; Virtual Design and Manufacturing; Virtual Enterprises and Supply Chain Management; e-Commerce / e-Businesses; Knowledge-Based Systems
Stephen Bishop	UK	Mathematics, Non-linear dynamics, chaos
Petra Ahrweiler	Ireland	Collaborative knowledge networks and innovation processes in knowledge-intensive industry sectors; innovation networks.
Jonathan Cave	UK	Economics
Ted Goranson	US	Business systems
Sergio Gusmeroli	Italy	EI/FInES
Arne Berre	Norway	Migration towards the Service Cloudand Future Internet service platforms and service engineering, based on a model driven approach with semantics and models@runtime and migration towards SaaS/ServiceCloud, including use of an extensions to SoaML. Application focus on mobile systems, sensor networks, location-based services/GIS, Enterprise systems and eGovernment
Robert Constable	New Zealand	Music: composition, piano, interaction of musical structure in other domains (eg. Architecture)

It was considered essential that the ESC interests should not be limited to experts in the EI or even FInES domain, but should be extended to related disciplines such as economics, and even to apparently unrelated domains such as music. The research domains represented are outlined in the tables, as are the experts' working locations, which show wide international representation.

The establishment of the ESC has been highly successful. ESC members are making a valuable contribution both to workshops, where most attended the Samos 2011 Summit on Future Internet, organised by ENSEMBLE, and to the online consultation on deliverables, which has been very substantial.

5.1.2 Validation Community

The Validation Community embraces the FInES Cluster Groups, External Domain Stakeholders and Independent Legal Entities represented in Figure 5-1: FInES Community Groups. These were of course established before the inception of the ENSEMBLE project, and ENSEMBLE support in respect of these has been to support already vigorous communication and consultation in the community.

The set of groups has been expanded by ENSEMBLE to include the EISB Community Groups also represented in the Figure, as described elsewhere in this chapter. It must be recalled that significant membership of these groups overlaps that of the previously established groups, but nevertheless the overall FInES community has been successfully expanded to include contributions from a wider range of disciplines and geographical distribution than heretofore. A significant aspect of the enhanced support provided by ENSEMBLE is the Collaboration Environment which has been extensively used in consultation of the Validation Community on ENSEMBLE deliverables on the EISB and the Research Roadmap. Additionally, the LinkedIn group provides a communication and discussion base for the Validation Community.

Support for the validation now includes:

- A FInES Cluster Collaboration Environment to support management of Cluster events and workshops, consultation on Cluster reports including both ENSEMBLE deliverables and other documents such as for example, future orientation papers, and task force activities and dissemination.
- Promotion of the use of social media through the establishment of a FInES presence in Facebook, Twitter, LinkedIn, Flickr, Delicious, YouTube and SlideShare. It will be appropriate over the remaining year of ENSEMBLE to review the use made of these services by the FInES community, so as to establish which offer real value to the community, and how to employ these to greatest effect.
- Promotion of the EISB development activity and FInES interests more generally through presence in workshops and conferences. To date this has included:
    - The highly successful Samos 2011 Summit on Future Internet, organised by ENSEMBLE, reported in detail elsewhere;
    - Presentation of a dedicated EISB invited session at CENT 2011 in Orlando, Florida. This was highly successful with significant worldwide (including US, Australasia and Europe) interest evident from beyond the community;
    - Presentation of a dedicated EISB workshop at ICE 2011 in Aachen, Germany.
    - Presentation of the EISB and knowledge cafes during the ICT 2010 networking session on "FInES in Networked SMEs", in Brussels, Belgium.

  Future workshops are planned:

    - Participation in the I-ESA 2012 Conference in Valencia, Spain, in March 2012, with an EISB dedicated workshop
    - Final ENSEMBLE Workshop in Brussels, Belgium in Summer 2012
- Promotion of collaboration between Cluster projects remains problematic in some respects. Project consortia are naturally defensive of their results, especially where potentially exploitable IPR is at issue. We suggest that this is a problem which must be addressed by the FInES community as a whole, perhaps as the sole subject of a Cluster meeting in the near future, once again allowing the Cluster to lead the development of concertation of research activity funded by the EC, as it is unlikely that the problem is peculiar to this community. Aggregation of project results into the FInES Cluster wiki would be particularly beneficial for increasing the EISB impact.

5.2 Evidences of Interoperability in Neighbouring Domains in terms of EI community

ENSEMBLE deliverable D2.2: EISB Action Plan identifies three main neighbouring scientific domains relevant to the science of Enterprise Interoperability:

- Computer Science
- Software Science
- Complexity Science

In Table 5-3 we identify the overlapping interests of EI Science Base groups with these domains. This is further detailed in Table 5-4 where we identify the members of the ENSEMBLE Expert Scientific Committee with interests and contacts in these domains. Finally in Table 5-5 we outline the coincidence of interests of FInES Cluster projects with the neighbouring domains.

Table 5-3: EI Science Base Group Coincident Interests in Neighbouring Domains

EISB Community Group	Computer Science	Software Science	Complexity Science	Other
Expert Scientific Committee	X	X	X	Economics Business Systems Design & Manufacture Music
Validation Community	X	X	X	Open

Table 5-4: ESC Member Coincident Interests in Neighbouring Domains

ESC Member	Computer Science	Software Science	Complexity Science	Other
A. Manzalini	X			
D. Chen	X			
A. Berre	X			
A. Grillo	X			
M. Leyton	X			
N. Ivezic		X		
S. Gusmeroli		X		
N. Koppenhagen		X		
L. Taxén			X	
S. Bishop			X	
J. Cave				Economics
E. Goranson				Business Systems

W. Shen				Design & Manufacture
R. Constable				Music
P. Ahrweiler				Epistemology

Table 5-5: FInES Cluster Projects Coincident Interests in Neighbouring Domains

Project Acronym	**Computer Science**	**Software Science**	**Complexity Science**	**Other**
ACESS-ICT				**ICT Investment**
COIN & COIN-EEU	**X**	**X**		
COMMIUS	**X**	**X**		
EBBITS	**X**	**X**		
ENSEMBLE				**Coordinating Action**
iSURF	**X**			
K-NET	**X**	**X**		
NEFFICS	**X**	**X**		
NiSB	**X**	**X**		
SPIKE	**X**	**X**		
SYNERGY	**X**	**X**		
UNITE				**Strengthening research cooperation**
VENTUREGATE				**ICT Investment**
YMIR				**ICT Investment**

Another analysis concerning evidences of interoperability in neighbouring domains will, according to the methodology presented in section 2 of this document, be obtained after the realization of the "extensibility" step within this and other groups of experts. As explained before that will supersede the results presented in ENSEMBLE deliverable 2.1 [35].

5.3 EI Special Issues

It was considered the preparation of a special issue in a scientific journal indexed in the Web of Science with significant Impact Factor. This special issue would address subjects in the area of FInES, aiming to bring sound contribution at scientific level for the foundations of EISB.

"Computers in Industry" was the one selected. After more than one year working and negotiating with the respective editor-in-chief and editorial board, we got approved the launch of the Call for Papers (CFPs). The special issue in preparation has the call for papers opened in March 2011, and expected to be published in May 2012. All the FInES community has been encouraged to provide significant contributions submitting papers to the special issue.

5.3.1 Computers in Industry, Special Issue on Science foundations for sustainable interoperability in future internet based industrial enterprises (ongoing)

Guest editors:

- Prof. Ricardo Jardim-Goncalves (UNINOVA, Universidade Nova de Lisboa – Portugal),
- Prof. Keith Popplewell (University of Coventry, UK).

Computers in Industry aims to publish original, high-quality, application-oriented research papers that: Show new trends in and options for the use of Information and Communication Technology in industry; Link or integrate different technology fields in the broad area of computer-applications for industry; Link or integrate different application areas of ICT in industry.

Computers in Industry: ISSN: 0166-3615, Imprint: ELSEVIER

Impact Factor: 1.524 (Journal Citations Report® published by Thomas Reuters 2010)

http://www.elsevier.com/wps/find/journaldescription.cws_home/505646/description#

6 Conclusions and Next Steps

The purpose of this document has been to report on the activities the 1st EISB "Wave" following the objectives (W1.O.x) as initially envisaged in the EISB action plan [36].

To tackle the first objective (W1.O.1: To consolidate the EISB structure and terminology), ENSEMBLE defined a methodology for the EISB ontology building which envisaged defining 3 knowledge representation elements, namely a glossary, taxonomy, and the ontology itself. During Wave 1, we have worked towards the first two, gathering a number of relevant (more than 50 in the first phase) terms and proposing and initial draft on the taxonomy. As envisaged, it will be subject to debate amongst the ENSEMBLE Scientific Community and will be further developed / amended during the next waves of the project, in order to formulate a solid and globally accepted taxonomy for EISB.

Nevertheless, according to the deliverable strategy, presented in the beginning of the document (section 1.3), the initial activities have been directed exactly towards the second objective (W1.O.2).

Social sciences, applied sciences and natural sciences have been recognized in the high-level general classification of scientific domains. In all of them, characteristics of interoperability are identified and ENSEMBLE acknowledged a number of sub-domains of each of them that are neighbours to EI, either by providing a set of formal methods that can be reused to describe EI problems and solutions, or by proving themselves to be closely benefiting from EI practices. The strategy for recognizing neighbouring scientific domains and their relationship with EISB (presented in Figure 2-1) has suffered a number of updates considering what had been originally presented in the EISB state of play (v1.00).

With this redefinition, W1.O.2: "To identify evidences of interoperability in neighbouring domains" could not be fully achieved. Indeed, up to now this objective has been "tricky" since people coming from EI had trouble to fully understand the need for the relationship with the neighbouring domains, as well as practitioners from those domains did not fully understand the EI phenomena. Results have been mostly constricted to the EISB community, and a dialogue and a dialectic approach is needed with people out of the box (with EI scientists as mediators), to maximize the efficiency and the quality of results. As part of the strategy, and in order not to lose results due lack of time to put them on paper, a template is available for guidance and traceability in the collection of results.

In section 3 of the document, formalisation has been recognized as necessary in order to achieve objective representation of knowledge and resolution of misunderstandings. There is no other general means of resolving conceptual conflict in science. Moreover, in a wide variety of experimental situations, the way to resolve disputes about the interpretation of data objectively is through careful and explicit use of the formal methods. The proposition of the EISB ontology provides a technical knowledge base to capture tacit and explicit knowledge about the EI domain, as well as the formal methods identified capable of describing EI problems and solution. This activity tackles W1.O.3 "To set up the theoretical foundations of enterprise interoperability".

Step 4 of the deliverable methodology, also reported in section 4, is related to the first formulation of the EISB concept and contributed towards W1.O.4 and W1.O.5 since it delimits the EI problem and solution spaces based on a vast and deep "knowledge mining" performed on the inputs gathered in the EISB state of play and action plan. These objectives, as W1.O.3 are ongoing since they have proved too large for completion in wave 1, and as envisaged in the step 6 of the methodology of

Figure 2-1, need several iterations. Formal methods from EI and neighbouring domains, as well as EI problems and solutions have only begun to be enumerated.

Thanks to the EISB Community (W1.O.6) establishment, the ENSEMBLE dissemination activities and public participation in events such as the Samos 2011 Summit, or the invited session "Science Base for Enterprise Interoperability in the Advent of the Future of Internet" within the CENT 2011 conference, we managed to get valuable inputs and feedback considering the methodologies adopted and activities conducted. EISB community groups have been established. Its members, as well as participants to these public events are recognized as EISB interested communities and have been participating in the consolidation and validation of the fundamental elements (W1.O.7).

In summary, wave 1 has been conducted following the plan, and most of the objectives have been tackled in the envisaged period. However, as predicted, ENSEMBLE will not be able to close all the wave activities and will serve as kick-off concerning the EISB formulation.

6.1 Adherence to Action Plan

Table 6-1: EISB Wave 1 Milestone Accomplishments

No	Milestone	Time	ENSEMBLE Wave 1 Planned Elements	Adherence		Wave 1 Accomplishments
W1.M.1	Consolidating the EISB structure and terminology	M9	• Definition of the EISB glossary (~25 terms) • Definition of the EISB taxonomy (12 scientific areas, ~100 nodes)	✓ ✓	Yes	• Initial version of the EISB glossary (more than 50 terms) • Initial version of the EISB taxonomy (about 60 nodes) • Definition of a methodology to define the EISB ontology
W1.M.2	Identifying evidences of interoperability in neighbouring domains	M10	• Elaboration of the EISB-SRDT in relation to the EISB taxonomy • Recognition of shared content and research communities among EI and neighbouring domains	Postpo-ned for wave2 ✓	Partial	• Redefinition of the neighbouring domains strategy • Elaboration of version 2 of the EISB-SDRT, following the validation community suggestions and incorporating formal methods • Recognition of shared content and research communities among EI and neighbouring domains • Initial distribution of identified formal methods to the EI Scientific Areas
W1.M.3	Setting up the theoretical foundations of enterprise interoperability	M11	• Establishment of the EISB problem and solution description framework	✓	Yes	• Delimitation of the EISB problem and solution spaces for the EISB concept formulation
W1.M.4	Advancing the EISB Wave 1 Elements by: • Synthesizing the EI community • Consolidating and validating the fundamental elements	M12	• Identification of 3 specific problems per scientific area • Open call for solutions (methods, tools, proof-of-concept, case studies) to Enterprise Interoperability	✓ Postpo-ned for wave2	Partial	• Identification of 50 research issues to the EISB problem space (average of 4 issues per EI scientific area) • Identification of 36 problems and problem domains to the EISB problem space (average of 3 problems per EI scientific area) • Elaboration of a solution elements matrix cross-matching the EI scientific areas and problem spaces with solution

No	Milestone	Time	ENSEMBLE Wave 1 Planned Elements	Adherence		Wave 1 Accomplishments
			• Identification of solution elements (methods, tools, proof-of-concept, case studies) covering all scientific areas • Identification / Initialisation of 3 community groups for the EISB development • Planning / Contracting of 1 special issue regarding the EISB developments in Wave 1 • Population of all EISB findings in the FInES Cluster Wiki • Organization of 1 online validation workshop in the FInES Collaboration Environment • Organization of at least 1 face-to-face validation workshop • Investment on social media (especially twitter and LinkedIn) to further promote results	✓ ✓ ✓ Partial Postpo-ned for wave2 ✓ ✓		elements (methods, tools, proof-of-concept, case studies) • Identification / Initialisation of the Expert Scientific Committee, the Validation Community, and the Enterprise Interoperability Research Roadmap Groups as the 3 community groups contributing for the EISB development • Special Issue approved on Science foundations for sustainable interoperability in future internet based industrial enterprises (Computers in Industry journal) • Population of the main EISB findings of this wave (glossary sub areas) in the FInES Cluster Wiki. The rest of the EISB elements of the work performed under ENSEMBLE's EISB Wave 1 will be published after the deliberation of the present deliverable in the FInES Collaboration Environment (and already published elements will be revised accordingly) • Realization of two experts events (Samos Summit and CENT conference invited session) for the gathering of solutions (methods, tools, proof-of-concept, case studies) to Enterprise Interoperability and validation of results • Publication of news on social media
W1.M.5	Monitoring progress of the EISB establishment and further planning of the waves	M12	• Update of the EISB Action Plan	✓	Yes	• Update of the EISB Action Plan

6.2 Next Steps: Wave 2 - Hypothesis and Experimentation

The following table presents the revised timeplan for the 2nd ENSEMBLE EISB Wave (this superseded the timeplan reported on deliverable D2.2 [36]). As explained during this document, wave 2 will carry also the iterating activities of wave 1.

Table 6-2: Revised ENSEMBLE EISB Wave 2 Timeplan

<table>
<tr><th>EISB Wave</th><th>No</th><th>Milestone</th><th>Time</th><th>ENSEMBLE Actions</th></tr>
<tr><td>1</td><td>W1.M.1</td><td>Consolidating the EISB structure and terminology</td><td>November 2011</td><td>Consultation on the initial versions of the
EISB glossary
EISB taxonomy
Final draft versions of both knowledge representation elements</td></tr>
<tr><td>1</td><td>W1.M.2</td><td>Identifying evidences of interoperability in neighbouring domains</td><td>December 2011</td><td>Consultation on the EISB-SRDT
Consultation and completion of the initial distribution of identified formal methods to the EI Scientific Areas
Execution of the "Extensibility" assessment</td></tr>
<tr><td>1</td><td>W1.M.3</td><td>Setting up the theoretical foundations of enterprise interoperability</td><td>February 2011 (but anticipated to continue during the ENSEMBLE EISB Wave 3, as well)</td><td>Formalization of at least 3 EI problems and solutions using the methods identified</td></tr>
<tr><td>1</td><td>W1.M.4</td><td>Advancing the EISB Wave 1 Elements by:
Consolidating and validating the fundamental elements</td><td>December 2011</td><td>Consultation and completion of the:
Specific problems per scientific area identified
Identified solution elements (methods, tools, proof-of-concept, case studies) covering all scientific areas
solution elements matrix cross-matching the EI scientific areas and problem spaces with solution elements (methods, tools, proof-of-concept, case studies)
Further Population of all EISB findings in the FInES Cluster Wiki
Publish Open call for solutions (methods, tools, proof-of-concept, case studies) to Enterprise Interoperability
Execution of the "Learning" assessment
Investment on social media (especially twitter and LinkedIn) to further promote results</td></tr>
</table>

EISB Wave	No	Milestone	Time	ENSEMBLE Actions
2	W2.M.1	Formalizing hypothesis for the EISB	February 2012	• Creation of at least 12 hypothesis covering all scientific areas (1 per area)
2	W2.M.2	Setting up the theoretical foundations for assessing enterprise interoperability	January 2012	• EISB Assessment Framework (for the enterprise maturity and impact assessment of proposed solutions)
2	W2.M.3	Matching the enterprise interoperability problems and solution space	January 2012	• A matrix / graph matching identified solutions to identified problems and denoting problems / solution paths (continuation of the matrix already presented in D2.3)
2	W2.M.4	Advancing the EISB Wave 2 Elements by: • Applying hypothesis to vertical domains • Assessing solutions of the EISB • Extending the existing EISB • Shaping academic directions for enterprise interoperability research	February 2012	• Population of the Assessment Framework with cases (from enterprises of various sizes and sectors)[23] • Testing of specific hypothesis and problem-solution paths in the specific cases[23] • Enriching the solution space with result-oriented practices[23] • Generalization of at least 3 solutions covering as many scientific areas as possible • Population of all EISB findings in the FInES Cluster Wiki • Initial version of the EISB ontology (avoid possible duplication of efforts with the knowledge repository of the FInES RR) • Organization of 1 online validation workshop in the FInES Collaboration Environment • Organization of at least 1 face-to-face validation workshop[24] • Investment on social media (especially twitter and LinkedIn) to further promote and validate results
2	W2.M.5	Monitoring progress of the EISB establishment and further planning of the waves	February 2012	• Update of the EISB Action Plan

[23] Originally planned for ENSEMBLE's EISB Wave 2, but depending on the contributions received and collaboration established may be shifted to ENSEMBLE's EISB Wave 3
[24] Tentative date: March 2012

Finally, the following figure provides a high-level overview of the ENSEMBLE EISB 1st Wave activities, as well as the anticipated key actions for the 2nd Wave and towards the 3rd Wave (that are further analyzed in D2.2 Action Plan[25]).

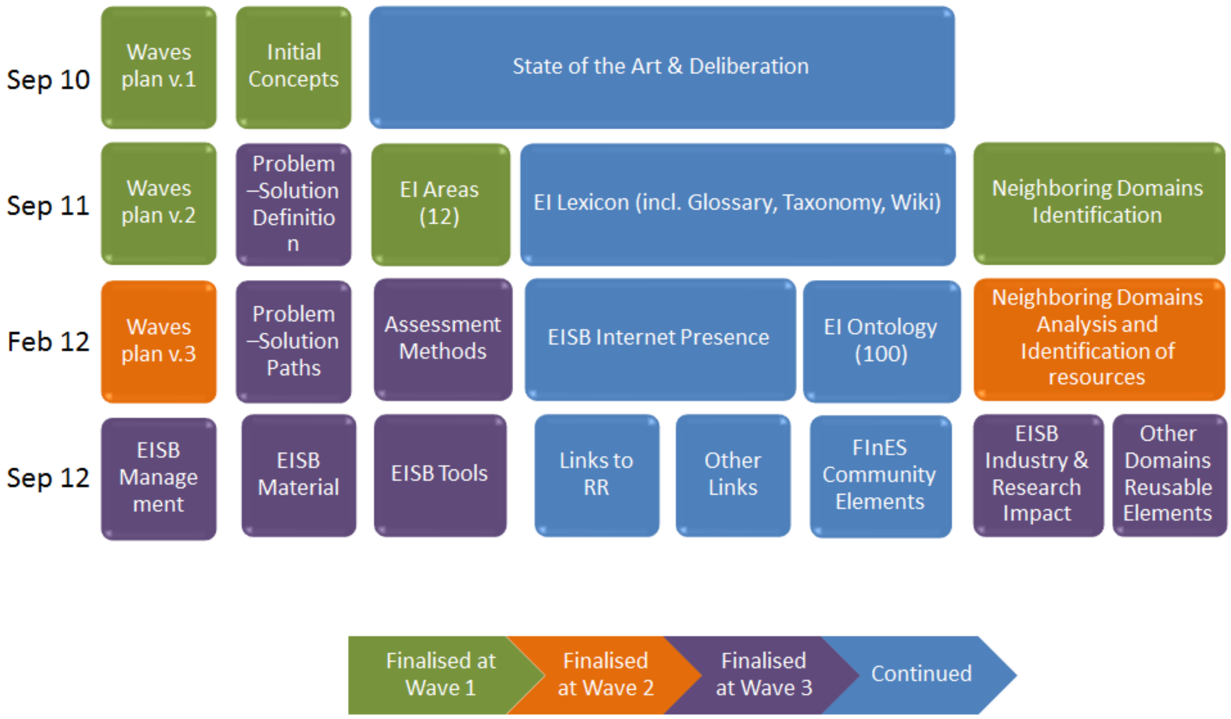

Figure 6-1: ENSEMBLE EISB Key Actions across the Waves

[25] Especially in the revised version of D2.2 that addresses the comments received after the online deliberation and the debate in Samos 2011 Summit.

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