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**PRACTICE**

# Requirements Elicitation and Refinement in Collaborative Research Projects

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**Summary**

European Union (EU) projects are means of the European Commission for funding research activities. Such projects address challenging research objectives by involving both academic and industrial partners, from several countries. Information and Communication Technologies related projects often undertake to deliver a software system prototype. In such a context most of the typical issues of global requirements engineering may emerge. Partners can have different background and expertise, needs are not sharply defined, and communication is hampered by linguistic and cultural differences. If these issues are not carefully taken into account from the beginning, problems frequently emerge during project execution. This paper presents the experience of applying a customized elicitation and refinement approach in the context of the Learn PAd EU project, which involved about 50 people. The approach combines collaborative elicitation and wiki-based refinement sessions to come to a set of consolidated requirements. Lessons learnt are discussed as a guidance for researchers dealing with analogous issues in similar contexts. Some of the major observations refer to: the importance of initial face-to-face meetings when combined with asynchronous remote interactions; the role of moderators that have to encourage collaboration and foster a shared understanding; the definition of guidelines to select wiki-based platforms.

## 1 | INTRODUCTION

Global requirements engineering (GRE) is the field of software engineering research that focuses on problems and solutions for the elicitation, negotiation, documentation and management of requirements in globally distributed software projects[5]. Within this field, the literature counts a relevant amount of works describing challenges[6,7,8,9,10,5] and experiences[11,12,13,14,15], and several issues were observed to affect the requirements engineering (RE) activities in global projects. In particular, communication difficulties, knowledge management, physical distance and cultural diversity[15,16,17,8,6], have been regarded as major obstacles for the acquisition of a shared understanding[18] of the problem domain, impacting also on the decision making process. The challenges outlined in these works brought to the definition of techniques for collaborative requirements elicitation[19,20] and distributed RE[7,21,22,23]. Tools have been also developed to support requirements elicitation in global teams[24,25], and, in particular, wiki platforms are regarded as effective solutions to facilitate interaction among the different stakeholders involved in RE activities[17,26,27,28,29,30,31]. One of the major conclusions from previous works is that communication and other requirements issues in GRE can be mitigated by processes foreseeing initial face-to-face meetings[7] combined with the usage of asynchronous wiki interaction[27]. However, despite the large amount of studies on GRE projects[16], limited experience reports are available concerning the lessons learned in collaborative RE supported by wiki platforms[17], and evidence on their actual effectiveness in a real-world context is therefore scarce. Furthermore, published experiences on requirements elicitation, highlighting problems encountered in practice, are also lacking in the RE literature, which mostly focusses on other activities such as modelling and analysis[32].

To address this research gap, this paper presents an experience report concerning requirements elicitation, refinement and consolidation in a globally distributed project, in which face-to-face requirements elicitation workshops are complemented with computer-mediated communication based on wiki. Specifically, our experience concerns a European Union (EU) research project in Information and Communication Technologies (ICT) named Learn PAd (http://www.learnpad.eu), which lasted 40 months and it was recently successfully closed. EU ICT Projects are a particular case of global software projects, in which industrial and academic partners collaborate to address technological and societal challenges. Within these projects, one of the main outcomes is often a software system, normally developed by merging contributions from industrial partners, and enhancing them with advanced features made available by academic partners. In this context, agreeing on a clear set of requirements for the system is particularly complex, and typical communication problems of GRE manifest themselves. In our experience, and that of many colleagues that have participated in EU research projects with whom we had the opportunity to informally discuss about this aspect, when requirements and communication issues are not properly handled since the beginning, the result often is a large project scattered in few small projects with subgroups of partners targetting different objectives. Correspondingly complex integration issues, and a clear waste of resources, will emerge when the complete system will have to be delivered and demonstrated.

To prevent these issues, in Learn PAd, we defined a requirements elicitation and refinement approach based on *physical* and *virtual* communication. Specifically, we conducted a set of requirements elicitation workshops based on the KJ Method[33] and open discussion, in which requirements were first elicited. Then, requirements were loaded into a wiki platform, and the project participants contributed to the refinement of the requirements. Finally, the requirements were consolidated by a designated group. After the design of the system, the coverage of the requirements by the design artifacts was assessed, showing that the majority of the elicited requirements were actually satisfied by specific design solutions. From this experience, and based on previous participation of the authors to several EU Projects with different roles and responsibilities, we derive a set of lessons learnt. Specifically, we confirm the effectiveness of face-to-face initial meetings in improving the degree of shared understanding and aligning the objectives among the different partners[7]. Furthermore, based on the statistics that we derived from the wiki contributions, we show that the usage of a wiki platform stimulates further reasoning and it is actually appropriate for requirements refinement. However, we also observed that the degree of *collaboration* through the wiki between different participants was limited, as well as the *quality* of the requirements produced. This indicates that a wiki moderator is needed to encourage interaction, as well as a centralised control to improve language and uniformity of the produced requirements.

The contribution of this work is manifold:

- we highlight practical requirements elicitation issues in the context of a EU project, which can be considered a special case in the class of global software projects. Readers can refer to the overall discussions both in Section 2, and in Section 8.1. Furthermore, some more specific observations can also be found both in Section 5.4, and in Section 7.1;
- we address the demand for experience reports and lesson learnt in the usage of a wiki-based platform in GRE[17]. Readers can find detailed information about our experience (i.e. set-up, enactment, and outcomes) in Section 4, Section 5, and Section 6. Also relevant considerations about tool support can be found in Section 8.3, and in Section 9.2;
- we present a requirements elicitation and analysis approach, conceived to reduce the risks associated to the highlighted issues, and that combines *virtual* and *physical* communication among stakeholders in a global project. Readers can find the overall approach outline in Section 3, and they can also refer to Section 7 for the ex-post analysis run on the final set of collected requirements.

The suggested approach, and the reported lessons learnt, can in our opinion constitute a useful starting point for stakeholders that need to organize communication related activities within collaborative research and innovation projects, as those financed by the EU.

A preliminary description of the approach, and its application was reported in a previous conference contribution[34]. The current paper details the presentation of the approach, the description of the experience, and the discussion of the collected results. Also, it includes the validation analysis run in order to assess the overall application of the approach. Finally, this paper enhances the presentation of the lessons learnt, aiming at providing exploitable hints on the application of collaborative requirements elicitation in similar contexts.

The remainder of the paper is structured as follows. Section 2 presents some background on EU ICT Projects, complexity dimensions of EU ICT projects in relation to RE activities, and an overview of the Learn PAd project. Section 3 outlines the conceived approach, while the following three sections describe the activities of planning and requirements elicitation (Section 4), collaborative refinement (Section 5), and requirements consolidation (Section 6). Section 7 reports the assessment of the requirements elicited and refined under the referred approach, while Section 8 discusses the lessons learnt from the application of the approach. Finally, Section 9 reports relevant related works in the area of GRE, and Section 10 provides conclusions and final remarks.

## 2 | BACKGROUND

This work addresses practical requirements elicitation issues in the context of a EU project. This section provides a general perspective both on the framework defined by EU commission to finance research projects, and on the specific research project from which we derived the lesson learnt reported here. In addition, the section discusses the typical issues of GRE that affect EU Research Projects in ICT, and why their mitigation has to take into account the distinguishing traits of such a context.

### 2.1 | EU Research Projects

Since 1984 the European Commission (EC) finances research and innovation within the EU through the "*Framework Programmes for Research and Technological Development*" generally referred as FP. The budget of the various FPs continuously increased from one edition to the other to reach 80 Billions euros for the running FP. [1] Generally, with a wide variability depending from the research topic and final objectives, projects are proposed by a mixed consortium of industrial and academic partners coming from different European countries, in general at least three different countries should be represented, often more than five.

The project proposal is constituted by a document (named Description of Work - DoW - that sometimes includes more than 100 pages) which among the others includes a description of the proposed solution, the planned budget, and operative details on how the objectives will be achieved (Workpackages, tasks and Gantt like related diagrams).

On the one hand, there are EU frameworks financing research projects in the area of ICT that gives a strong emphasis to the development of new knowledge. On the other hand, there are also calls that demand for innovative research solutions leveraging on available technologies. Often, in these cases the expected result of the project is a software system that should meet prescribed Technology Readiness Levels (TRL). In these cases, it becomes essential for the consortium to early converge on a shared operative understanding of the project, that can be properly traced, mastered, and adapted during the whole project life-cycle.

### 2.2 | Requirements Complexity Dimensions in Collaborative Research Projects

This section intends to list a set of distinctive characteristics of ICT EU research projects that we considered particularly relevant as strongly impacting on RE related activities.

- **Number/distribution:** EU projects involve a high number of partners physically distributed over Europe (at least): in some case EU projects can even count around 20 partners, but in general not less then 5. The high number of partners could make a plenary discussion on the project needs rather ineffective. The distribution over many different countries may limit the possibility of face-to-face meetings and introduces the need for managing remote requirements elicitation, as further discussed in the next section.

- **Language/culture:** in a EU project the partners come from different countries with different native speaking languages. As in other distributed projects [21,6], this cultural difference might let emerge different attitudes and personalities, which can be interpreted differently by the partners. Clearly, this is a quite relevant problem since no mediator is foreseen within the consortium.

[1] http://europa.eu/about-eu/funding-grants/index_en.htm

- **Industrial vs academic mindsets:** EU project consortia typically include partners with different working mindsets such as for instance industrial and academic. Industrial partners have daily experience with requirements elicitation for software development. Academic partners are normally more focused on theoretical aspects, and might be less rigorous and effective while performing practical requirements related tasks. However, the combination of the different mindsets can enable the development of novel and interesting ideas[35].

- **Background:** in EU projects partners with different technical backgrounds have to strongly cooperate since the expected innovation or research results could be based on the intermix of their respective competences. These domains imply different backgrounds and vocabularies, and communication might be hampered by both the previous knowledge of the partners, and by the different terminology used.

- **Age/roles:** in EU projects partner representatives have different ages and experiences. Moreover, partners with different roles in the original organization have to act as peers within the project. The issue here is related to the possible uneasiness that a young researcher could have with respect to an older professor or company manager, which they could not personally know in advance.

- **Objectives:** partners can have different objectives and views on the project innovation and research directions to be taken. This is a real issue since requirements could be introduced in order to pursue partner specific interests. This can obviously negatively affect the innovation and research potential of the project and introduce complex effects for requirements management activities.

Interestingly the availability of the DoW does not simplify much the derivation of a common understanding among the project partners. Such a document is in general rather vague in particular with respect to operational aspects, on how the system will actually work, as well as on the relevance of the various functionalities. Obviously this is strictly related to the research and innovation dimensions of any EU project, and the corresponding uncertainty, that asks for the possibility to partially revise project objectives after its start. In our experience the DoW should be mainly considered just as a support to help starting the discussion among the partners, instead of a precise plan to which strictly adhere.

## 2.3 | The Learn PAd Research Project

The requirements elicitation and analysis approach described in this paper has been practically assessed in the context of the Learn PAd EU research project. The overall goal of the project was to improve the sharing of knowledge among civil servants, and as a consequence the perceived quality of services delivered by the Public Administration (PA). The overall idea of Learn PAd is to use the Business Process Modelling Notation (BPMN)[36] to teach civil servants how the procedures shall be implemented in practice, and to complement the models expressed according to the BPMN with wiki documents that give details in natural language about the procedures. The content of the wiki documents is also expected to be incrementally enriched by the civil servants during the learning activities and by designated process experts. Furthermore, an interactive simulation engine is also foreseen to let the civil servants practice with the PA procedures represented as BPMN models. Automated quality assessment of the learning content, i.e., models and wiki documents, as well as automated knowledge assessment for the learners are also supported.

The solution proposed by the project was a *platform* for process-driven, model-based learning. Specifically, the release of the Learn PAd platform was conceived as two major milestones: a reference architecture, and a reference implementation of the platform. The reference architecture aimed at providing a technologically *agnostic* design of the envisioned solution and the definition of conceptual models[37], macro components, APIs, and their interconnection schema were addressed[38]. In addition, the main use case scenarios evidencing components interactions as well as the principal platform functionality have been also covered. The reference implementation aimed instead at providing a technologically dependant proof-of-concept for the platform as defined in the reference architecture. Further details and resources are available on the project website: http://www.learnpad.eu, or on the codebases available on GitHub[2] and on ADOxx[3].

With respect to the complexity dimensions introduced in Section 2.2, the Learn PAd consortium included 9 partners coming from 5 different European countries (Italy, France, Switzerland, Austria, and Lithuania). In particular Learn PAd involved:

[2] see at: https://github.com/learnpad/
[3] see at:https://www.adoxx.org/live/web/learnpad-developer-space/space

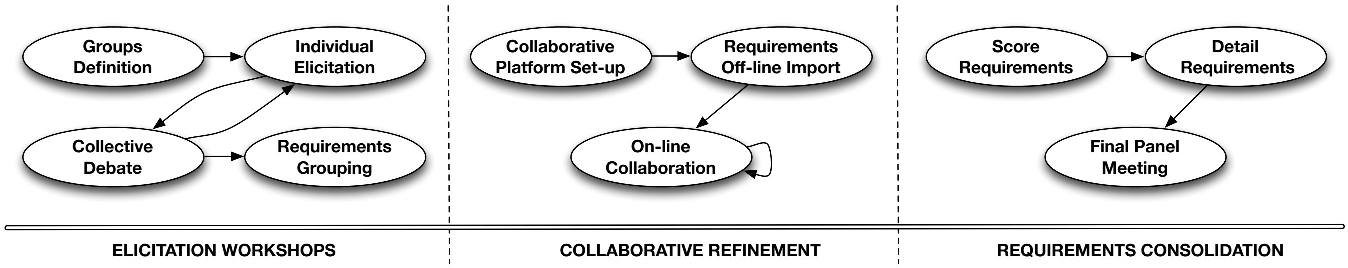


**FIGURE 1** Outline of the Approach

1 national research institution, 2 research universities, 1 applied university, 2 small-medium enterprises (SME) working exclusively with open source licensing schemes, 2 SME adopting strict closed source licensing schemes and business models, and 1 Public Administration (PA).

The partners have strong competences but in different areas, including: Business and Knowledge management, Natural Language Processing, Software Engineering, Collaborative Platforms, Procedures and Regulations. Thus experiences, visions, and jargon form several, and in some cases disjoined, communities had to be properly addressed. Overall more than 50 researchers/developers/modeling experts/civil servants had been actively involved in the projects, and the number of people contemporary working to the project was constantly over 40. In addition 3 external researchers, in the domain of social sciences and learning, provided their consultancy participating to some of the plenary meetings or to remote discussions. Finally plenary meetings were in average attended by around 25 participants.

## 3 | APPROACH OVERVIEW

A running EU project can be usually observed in two different operative states. In the first state all partners, or a subset of them, physically meet to work on the project. In general within a EU project there are three or four plenary meetings per year, lasting around three days, to which all partner representatives should attend. Smaller meetings can be organized as well, in general to clarify specific aspects, typically related to a single work-package. The second state of the project instead is the one in which each partner is working "at home" and communication is obviously much more difficult. Indeed most of the time the project stays in this second state, and people work from remote sporadically communicating using e-mails and VoIP based systems.

The requirements elicitation approach we are proposing considers the two possible operative states of EU projects, and it practically identifies supporting tools and techniques to sketch the requirements, and to successively refine them. The approach has been conceived selecting and reusing already defined techniques among the ones reported in literature. Here, we give a brief overview of how the activities have been conceived and the specific steps for each status of a requirement are reported in Figure 1, while in the following sections the activities are detailed with respect to their specific introduction within the Learn PAd project.

It is worth mentioning that the activities should not be considered as part of a precisely structured software development process. Indeed many EU projects approach the development of the software according to agile techniques, though it is also often the case that a detailed requirements documentation has to be derived as part of one or more project deliverables. In summary the activities can be performed more than once, possibly on the same requirement set.

**Elicitation Workshops** define the first set of collaborative activities needed to define the requirements for the system to be developed (Section 4). The planning tasks for this activity started since the very beginning of the project, and before the official kick-off meeting. Indeed, the earlier the elicitation activity is run, the more shared understanding for the solution is matured so to support a rapid delivery of a first prototype of the system. The core of this activity should be grounded to any collaborative elicitation technique (e.g. KJ-method[33] as we did); specifically we included both individual reflection and collaborative work activities, taking particular care to address the issues highlighted in Section 2.2.

The **Collaborative Refinement** activity (Section 5) has been conceived to permit collaborative reflection on identified requirements/ideas. This permit to put in place a strategy to continue the work on requirements already started during the elicitation workshops, and to enable the cooperation among participants when they will be back to their offices. A natively collaborative infrastructure has been adopted and customized for the purpose. Customizations were considered particularly important in order to let emerge requirements views or aggregations that are considered useful for the collaborative debate within the project. This peer-based collaborative refinement step was also oriented to encourage participation, indeed ice-breaking is normally easier when a computer interface acts as a communication mediator[22].

The last activity performed is **Requirements Consolidation** (see Section 6). This activity has been conceived in order to narrow the collected requirements and to harmonize them with respect to the usage of words and to their syntactical structure. In the first two activities, the requirements elicitation approach outlined in Fig. 1 assigns an important role to the horizontal collaboration among the participants. Nevertheless, for this last activity we considered more effective to involve only a restricted group of key persons in the consortium, and let them analyse the various requirements. The rationale here refers to the fact that a more centralized approach in this case should help the consortium in converging on a more focused definition of the elicited features, with respect to the overall ambition of the project agreed in the DoW. This activity was run by means of a set of conference calls, and all the designated *core team* synchronously joined the discussion on the various requirements.

The following sections provide details on how each activity has been concretely implemented in the Learn PAd research project, and they include a short discussion on the observed effects and results.

Our research is a form of retrospective assessment of a real-world experience on the application of the method, i.e., an *experience report*[39]. In our context, this has allowed us to broadly reflect and discuss on various general aspects of the experience. More structured case studies, with clear research questions and a clear analysis process as prescribed, e.g., by Runeson and Höst[40], can be triggered by this experience.

## 4 | ELICITATION WORKSHOPS

The research and innovation nature of a EU project makes the DoW a quite tricky document that can favor misunderstanding, as consequence of the different mindset and objectives of the included contributions. At the time of the proposal definition it is, in our experience, generally difficult to reach an effective sharing of the project vision among all partners. It is more often the case that the vision is in the mind of the coordinator, and possibly few other partners, that logically and consistently aggregated all contributions in a unique document, to derive a structure that keeps together all the ideas and interests expressed by the partners. As consequence it is clearly important to consider all the plans and descriptions reported in the DoW, but it is certainly more important to include methods and tools to foster direct and indirect communications among the consortium partners.

In the Learn PAd project, it has been decided to devote the first day meeting for project and partners presentations, and to permit to meeting participants to get in touch with each other. In the second day, instead, a couple of workshop sessions, lasting two hours each, were organized to let the partners discuss on the possible project outcomes and to define preliminary requirements.

In the following, we first introduce on how the elicitation group were organized and composed (see Section 4.1). Then, we report on how the rest of the activities in this step have been instantiated and run according to the KJ method (see Section 4.2) in combination with open discussion activities. Finally the Section 4.3 highlights the main observations from our experience.

### 4.1 | Groups Definition

The 25 participants to the first Learn PAd meeting were organized in three different working groups each one focusing on a specific high-level view of the Learn PAd platform, namely “Modelling”, “Quality” and “Learners Evaluation” (**Groups Definition** in Fig. 1). The assignment of people to working groups was carefully planned and took into account expertises, and the possible involvement of the participant to WPs related to the group topic. Clearly the objective was to define groups in which the discussion would have been live and fruitful. For such a reason was also considered useful to have in the same group people that could potentially have different, if not contrasting, opinions. More specifically, the partners were classified according to four categories: partners from academia; industrial partners practicing open-source; closed-source industrial partners; and PA partners bringing their expertises on the demonstrators. Further considerations about the size, and the heterogeneity of the working groups led to the definition of the following criteria (even though it was not always possible to strictly abide by such rules): (a) each group should have counted around eight participants; (b) a project partner should have had representatives in at least two different groups.

## 4.2 | Workshops – KJ Sessions

In organizing the elicitation workshop a project coordinator has to consider all the aspects listed in Section 2.2 that could negatively affect the collaborative emergence of ideas. In particular it is important to initially create a context in which participants do not feel too much exposed, so to favor the inclusion of less experienced or young people.

In Learn PAd the activities of each working group proceeded according to the KJ method[33,41]. This is an exploratory technique[42] fostering creativity, were requirements are first individually written in post-its, possibly anonymously, and then presented to the group and clustered. For each working group one moderator was appointed to drive the discussion and to involve all participants. The choice of the moderators was somehow opportunistic, but also guided by the need to have subjects with (a) a global view of the project, (b) an in-depth view of the specific workshop topic, and (c) the appropriate role and personality to resolve possible conflicts. The scientific and technical leaders of Learn PAd played the role of moderators for 'Modelling" and "Learners Evaluation', since they fulfilled all the criteria, given their central role. The moderator of the "Quality" group was chosen for his experience in the topic of the workshop, and in requirements engineering. All moderators participated to the planning of the workshops.

The method was considered particularly promising considering that at the very beginning of a EU research project participants do not personally know each others. The effects reported in 2.2 could harshly manifest themselves when open discussion based techniques are adopted. In this sense a method, permitting anonymity and individual work, seemed to be the right choice to foster the involvement of all participants, at this stage.

In the first workshop session, according to the guidelines reported in[41], each moderator illustrated to the group members how the activity of the group had to proceed and the expected outcomes. In particular the moderator clarified the specific functionality to which the group should devote the focus. For instance the "Modeling" group was asked to "clarify which modeling related functionality/aspects has to be considered relevant to facilitate training of civil servants?". At this stage it is important that each participant get a clear understanding of the specific aspects of the system to which the session is devoted. The next activity then did not start until all the participants had the impression of having quite clear in mind how to proceed. Clearly the focus of this initial discussion should be kept as much as possible abstract and aim at clarifying the general objective without suggesting possible concrete requirements. This first step did not take more than twenty minutes in each group.

Successively, each participant had the opportunity to write in post-its the requirements that he/she considered relevant for the subject of his/her group (one requirement for each post-it). This activity appears in Fig. 1 with the name **Individual Elicitation** and it lasted around 20 minutes. Each participant had the opportunity to decide where to perform the activity. Being the rooms rather wide group members had the opportunity to move a bit from the other members, so to avoid possible influencing factors.

Successively all the post-its were collected by the moderator, and then read one by one to the group. For each post-it a short collective discussion followed to understand the relevance of the specified requirement, and to possibly elicit novel ideas (**Collective Debate**). In case a new requirement emerged it was written by the moderator using an additional post-it. No post-it was discarded at this stage. The collective debate is not generally foreseen by a pure KJ method, nevertheless it can be useful to introduce the typical benefits of brainstorming related techniques. Indeed these are particularly suitable, differently from the KJ method, to share and identify novel ideas[41].

In the second session, participants were asked to provide additional requirements in the post-its, according to the discussion performed in the first workshop. Again the members had to individually work for around 15 minuts. Then, the moderator collected all the post-its, and briefly asked for further discussions on the added requirements, and then all post-its were put on a blackboard. With the support of the participants, the requirements were grouped (**Requirements Grouping**) according to their topics, and specific labels were used (e.g., "Meta-modelling", "Models Quality", "Cooperation") so to permit to derive sets with non empty intersections, i.e. the same post-it could be classified using multiple labels. The labels were decided along the discussion, and were later used as semantics tags (see Section 5.2). At this stage, differently from the general guidelines for the KJ method as reported in[41], some of the post-its were discarded in case they were judged not much informative by the whole group, or because the content was already covered by other post-its. In doubt the post-it was kept. At the end of the second workshop session a wrap-up activity was included in the agenda. During the wrap-up session the vision of each group was presented to the other groups. The activities on requirements carried on during the first meeting permitted to identify 249 preliminary requirements (78 for the "Modelling" group, 81 for "Quality", 90 for "Learners Evaluation"), which would have been the starting point for the successive collaborative activities. Notably each group defined a similar number of requirements confirming somehow the good splitting and relevance of the three aspects.

### 4.3 | Observations

In general, all the sessions were successful and all group members were quite involved in the activity, permitting to suppose that the negative effects of some heterogeneity issue were rather limited. Besides the careful grouping of the participants, the success of the experience was mainly due to two factors: (1) the design of the workshops; (2) the moderators. Starting the workshops with an individual activity (i.e., post-it writing) and letting each participant present his/her point of view before the brainstorming was paramount in limiting age/role effects and mitigating objective discrepancies. Then, the partitioning in two workshop sessions let the participants have the time to re-think about their views. Indeed, in the second sessions, the participants experienced a sort of "second chance" to align the terminology with the others, and smooth out cultural and background differences. The smoothing of these aspects was also enabled by the choice of the moderators, and by their attitude. The moderators of the "Modelling" and "Learners Evaluation" groups were the scientific and technical leaders of the project, respectively, and were familiar with almost all the participants. Therefore, they knew how to deal with them, and they could leverage their role to resolve conflicts. Conversely, the moderator of the "Quality" group, was unknown to most of the participants, and acted as an independent facilitator with the task of reducing relational problems thanks to his independent profile[43].

## 5 | COLLABORATIVE REFINEMENT

At the end of the elicitation activity, a preliminary version of the requirements is available and grouped according to one or more topics. The objective of the following activity is to refine these preliminary requirements by continuing the collaborative discussion and elicitation process in a virtual, distributed space, after that all partners went back to their offices. To this end, within Learn PAd, a collaborative infrastructure for requirements management was set using a wiki-based platform.

The section is structured as follow: Section 5.1 presents the collaborative platform adopted during this experience, and how its feature were exploited. Section 5.2 details the steps followed in order to import into the collaborative platform the initial set of requirement obtained from the workshops; while Section 5.3 reports on the methodology followed in order to improve such specifications. Finally, Section 5.4 discusses the observations and the practical issues emerged from all these three activities.

### 5.1 | Collaborative Infrastructure

Wikis are a lightweight approach to produce documentation more powerful than plain office suites or collaborative tools, and easier to use and tailor than proprietary RE tools[27]. Moreover, wikis are regarded as promising tools for requirements elicitation/negotiation in distributed environments (see, e.g.[29,17]). The adoption of a wiki in RE enables the various members of the project to contribute by adding, modifying, or deleting contents. In addition, a wiki platform natively supports the versioning of the handled documents. In this sense, contributors can always access to the history a requirement had, and they can trace its evolution. In our context, we have decided to use XWiki (http://www.xwiki.org/), an open-source and general-purpose collaborative platform (embedding a wiki). The platform, besides the collaborative editing capabilities typical of wikis, exposes a flexible data model (i.e., Classes, Properties, and Objects), which can be both queried and extended by the users. Indeed, though wikis facilitate collaborative work, customization is required to address RE-specific needs: a template requirements structure has to be defined, and requirements views have to be enabled to ease navigation. To this end, XWiki has been extended with a model of requirements that is based on the widely used VOLERE[44] template (**Collaborative Platform Set-up** in Fig. 1). In practice, each requirement was associated to a XWiki page with several VOLERE-like predefined fields such as type (e.g., Functional, Non-Functional), status (e.g. Proposed, Accepted, Discarded), description, justification, relations to other requirements (e.g. dependency, refinement and conflicts among requirements), semantic tags, *etc.* Other widely used requirements specification templates are available, such as the one reported in the ISO/IEC/IEEE 29148:2011(E) Standard[45], which provides a template along with recommended practices for software requirements specification. Furthermore, the ECSS-E-ST-10-06C Standard[46] provides requirements specification guidelines specific to the aerospace domain. In our case, our preference went to the VOLERE template, given (a) the high degree of internal structuring provided for the requirements, and (b) the ease of adaptation to the XWiki format.

Dynamic views for the requirements have been also defined. Each view focuses on a specific aspect, for example: supporting the navigation of the requirements by some field (e.g. the initiator, the type, etc.); or showing the semantic dependencies among requirements tagged with the same meta-information. In addition, we provided views to query the data model and return analytics about the collaborative activities performed on each requirement.

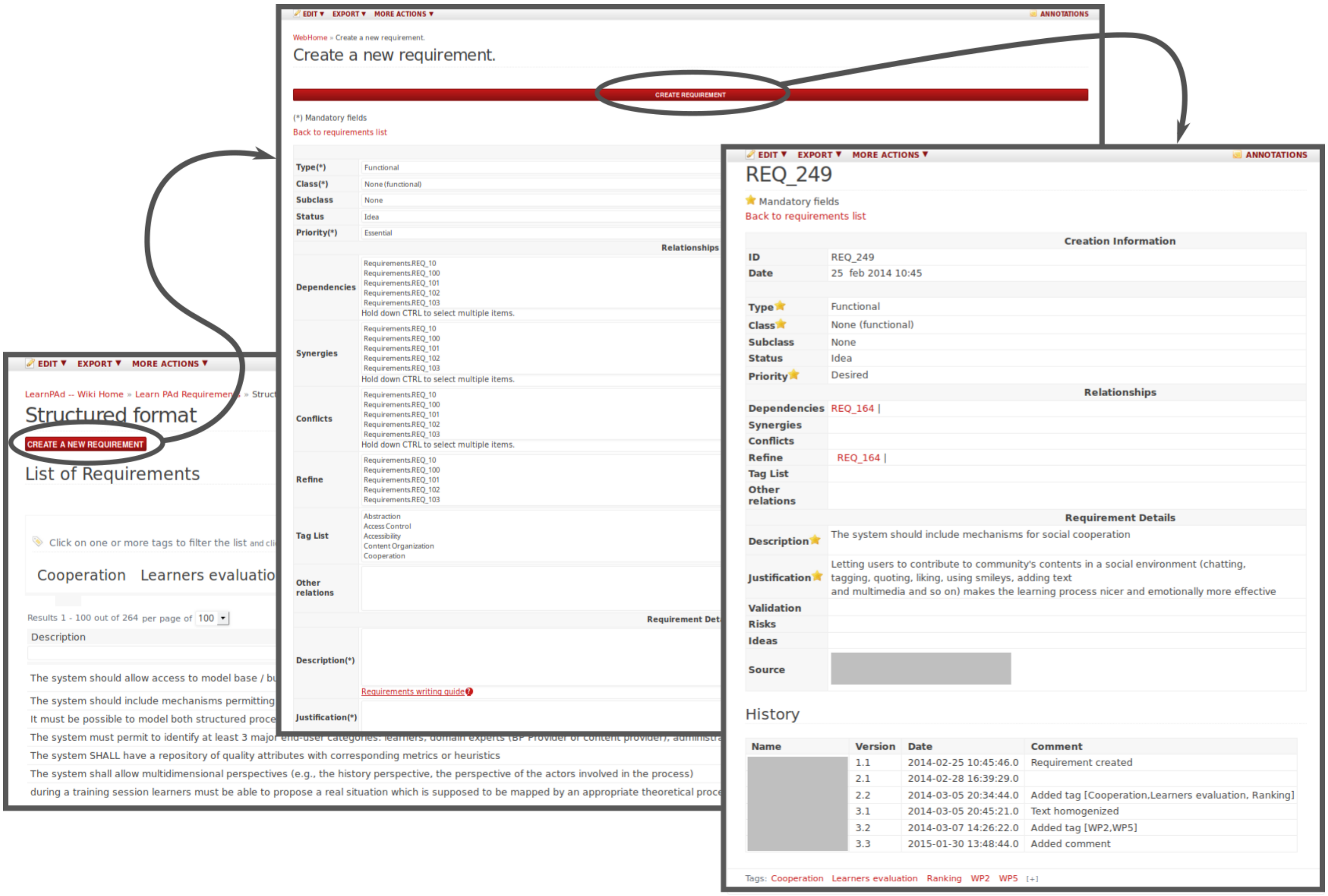


**FIGURE 2** Collaborative refinement of requirements within XWiki

Fig. **??** composes several screenshots of the developed XWiki extension, and it highlights: the main steps for creating a new requirement within the collaborative platform, and part of the adopted VOLERE-like structure.

## 5.2 | Requirements Off-line Import

The results of the elicitation process pursued by means of the workshops was imported into the collaborative platform (**Requirements Off-line Import**). During this step, the moderators took care of uploading the preliminary requirements of the post-its into the platform, associating each requirement to the topic that was chosen during the KJ-sessions. The topic was stored as a semantic tag in the VOLERE-like template. Moreover, to enable a uniform tagging, the moderators met to tag the requirements elicited by each thematic group with the categorizations proposed by the other groups. Requirements that could not be semantically categorised with a single tag were tagged with multiple tags of the set. This work permitted to all the other contributors to more easily search and compare requirements on the base of semantic categorizations.

In addition, for each requirement, the moderators evaluated which work-packages of the project could be affected by that specific concern. This information was codified in the structured template in XWiki by adding the names of the WPs as items in the tags list field of the template.

Fig. 2 shows the number of requirements associated to each WP (WP not concerning the software - e.g., Dissemination and Project Management - had zero requirements, and are not reported); while Fig. 3 plots the number of requirements associated to each tag. These visualisations have been useful as a preliminary *informal assessment* of the project plan. Indeed, we see that most of the requirements are apportioned to WP2 and WP3, which are also the dominant WPs in terms of person-month effort (58 and 51, respectively). Though the effort associated to each single requirement cannot be evaluated in this phase, this coarse-grained alignment between the number of requirements and the planned effort can at least tell us that we did not underestimate

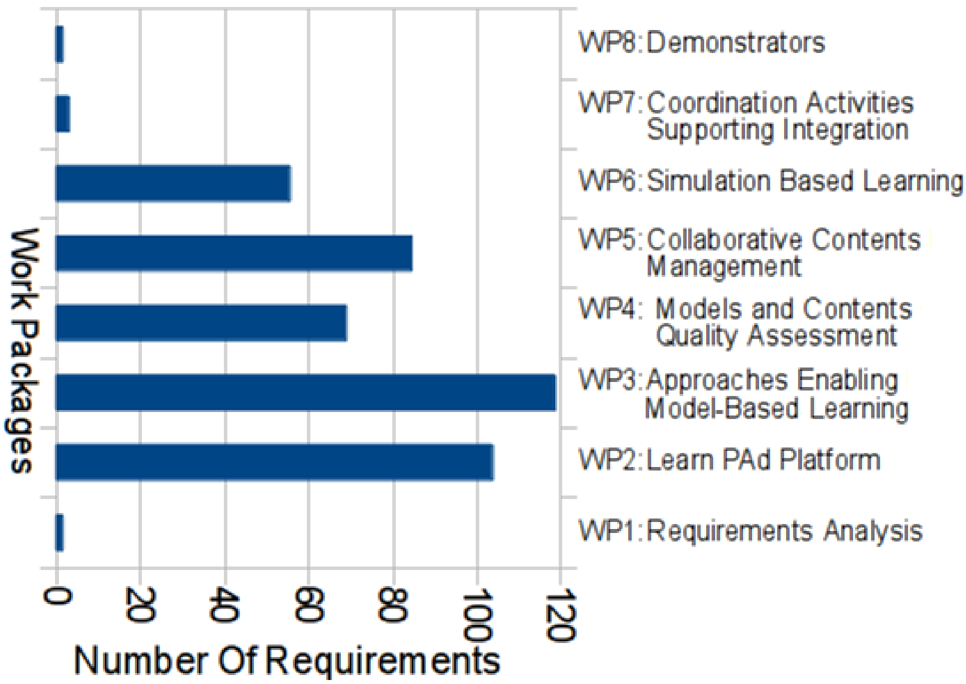


**FIGURE 3** Number of requirements for each WP

the relevance of the WPs that are associated to a higher number of needs to be addressed. On the other hand, Fig. 3 suggests that there are aspects of the project to be delved more. Indeed, we see that for a project aiming at enabling model-based learning, the tags related to pedagogical aspects of learning (i.e., Learning Styles and Goals) are far to be a common topic in the requirements. This already showed a weakness of the project: pedagogical expert did not participate in the KJ sessions, and few learning-related requirements emerged. This aspect was taken into account by the consortium that contacted experts in the learning field, asking them for consultancy on the specific topic. In particular they successively participated both to project plenary meetings, as well as to restricted meetings.

## 5.3 | On-line Collaboration

Once the offline import activity was completed, we asked the whole consortium to access the XWiki platform in order to improve the specification of the requirements as originally proposed (**On-line Collaboration**). Indeed, the granularity of the information collected was minimal with respect to the VOLERE-like structure adopted for the requirements, and the sentences provided in the post-its were often unclear and with a free-form structure that made them hardly usable in an official requirements document. The moderators also provided a *glossary* to be followed by the contributors when modifying their requirements.

In a first iteration, we asked the members of the consortium to improve and detail the information associated to each requirement. In particular, we asked to revise the text of the requirement according to a set of basic requirements editing guidelines, such as: use the verbs “shall” or “should” to indicate mandatory and optional requirements, respectively; use active sentences; the subject of the requirement should be the system, part of it, or an actor; *etc.* Successively, the consortium collaboratively revised again the whole set of requirements. The goal of this second iteration was editing the “justification” field in order to provide detailed information about the rationale of each specific requirement. The final iteration foreseen aimed at identifying some existing relations among the requirements. Specifically, the members of the consortium were asked again to access the views given by the XWiki platform, and browse the requirements looking for dependencies, conflicts, or refinements.

It is important to remark that, at any iteration, any member of the consortium had the possibility of both accessing, and modifying *any* of the collected requirements. During each iteration, members were also encouraged to add requirements. At the end of the collaborative refinement activity, the set of requirements increased from 249 to 337.

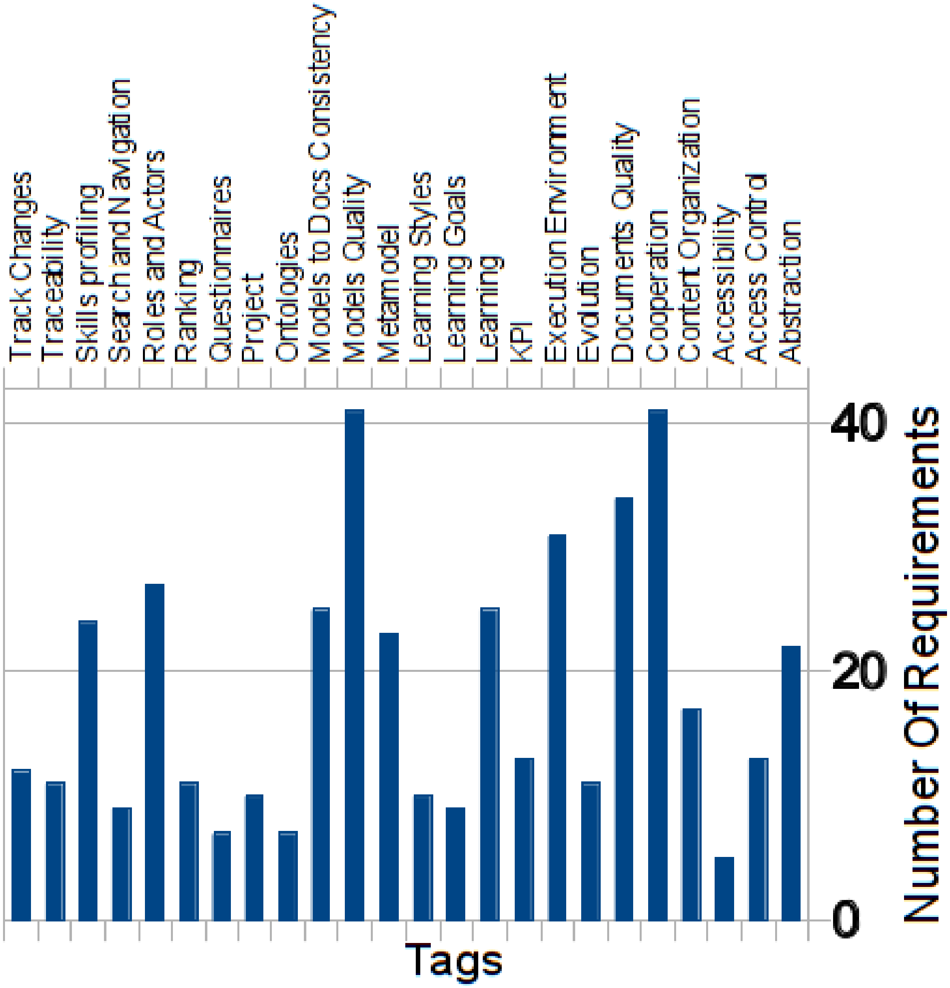


**FIGURE 4** Number of requirements for each semantic tag

## 5.4 | Observations

A set of specific views has been developed in order to get analytic data about the behaviour of the different editors during the collaborative refinement process. Among the others, a view provided the total number of modifications each requirement experienced. The result of this indicator showed that the average number of changes on a given requirement is 5.14 (variance 3.01). Another view aimed at counting the number of different contributors who edited each requirement. In this case, we have an average of 2.58 editors per requirement (variance 0.39). Fig. 4 plots the number of versions, and the number of different contributors for each requirement.

From these data emerges that in average a requirement has been modified more than the number of iterations planned by the process. The participants to the RE process actually perceived some need in order to progressively evolve the set of requirements, for example by aligning the ideas expressed in a requirement according to the current status of the whole set. This observation becomes even more evident if we analyze only those requirements having a number of modifications greater than the number of iterations we requested. In this case, the average of changes applied on a requirement rises to more than 6. It is worth noticing that this sub-set counts more than the 70% of the collected requirements. Thus, the collaborative refinement approach can be considered successful at least in stimulating *further reasoning* on the requirements. The remaining 30% includes both requirements that have been modified only according to the instructions given (i.e., almost the 7.5%), and requirements resulted with less modifications than the number of planned iterations (22.5%).

A further comment about the data from Fig. 4 concerns the number of contributors per requirement (dark line in the plot). In this case, although having 2.58 editors per requirement in average might show a rather good degree of collaboration, from a more fine-grained analysis we saw that only four out of 25 participants edited the majority of the requirements. It is worth

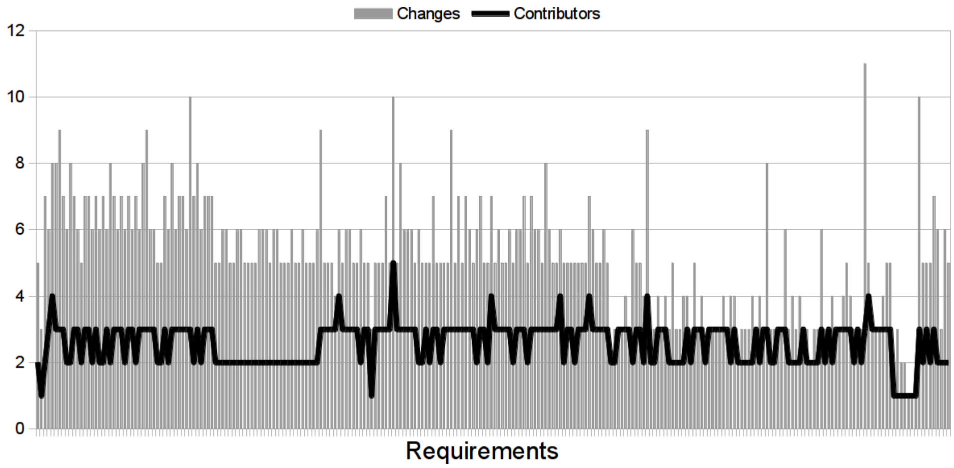


**FIGURE 5** Analytics on the set of requirements after collaborative refinement

| ACCEPT | PROV. ACCEPT | DETAILS REQ. | REJECT | Total | Total (ACCEPT) |
|---|---|---|---|---|---|
| 110 | 144 | 55 | 28 | 337 | **191** |

**TABLE 1** Requirements per score given by the RE manager.

noting that three of these participants are the moderators of the KJ sessions. If we exclude these four major collaborators – and the requirements touched solely by them, namely the 39, 3% over the whole requirements set – the average number of editors per requirement decreases to 1.04. This result suggests that the largest majority of the editors tended not to modify the requirements initially promoted by other participants. Our interpretation of this result comes from the fact that research projects are mainly organized as peer-based projects with a clear separation of competences. Thus, while the initial promoter of a requirement is keen to reconsider and to let evolve his/her conception about some aspects of the project (i.e. expressed by a requirement), at the same time he/she may be feel *uncomfortable* in a direct modification of the contribution of some other promoter.

## 6 | REQUIREMENTS CONSOLIDATION

After the refinement task, a core team of key partners led by the coordinator of the requirements activities (referred in the following as "RE coordinator") performed a manual analysis of the requirements in the collaborative platform. The goal of this task was to come to a final set of consolidated requirements. Indeed, though the collaborative refinement experience was rather lively, many requirements still needed both syntactic adjustments – to adhere to the guidelines provided – and semantic refinements – to clarify their content. The analysis started with a requirements scoring activity, in which each requirement was associated to a score by the RE coordinator (**Score Requirements** in Fig. 1): (a) ACCEPT, in case the requirement is clear and the RE coordinator evaluates the implementation effort as acceptable; (b) PROVISIONALLY ACCEPT, in case the RE coordinator cannot evaluate the implementation effort; (c) DETAILS REQUIRED, in case the requirement is unclear; (d) REJECT in case the implementation effort is not acceptable or the requirement is equivalent to others. Then, each requirement that was scored with (c) was sent back to the stakeholder who originally produced the requirement to provide further details (**Detail Requirements**). In a **Final Panel Meeting**, the core team discussed each requirement and marked it as (a) or (d). The set of consolidated and accepted requirements consists of 191 unique elements. A dedicated and public deliverable of the Learn PAd project[?] reports about the final set of requirements as resulted from the application of the presented approach (see http://www.learnpad.eu/pubs.php?filter=del).

### 6.1 | Observations

Table 1 shows the number of requirements associated to each score, and the final number of accepted requirements. We see that, among the requirements marked with (c) and (b), only 81 (i.e., 41%) have been finally accepted. This implies that, for many requirements, the implementation effort was considered not acceptable. This result is however tolerable. Indeed, KJ sessions are a creative space that can naturally lead to a large number of ideas that are hardly applicable. However, such ideas were part of the creative atmosphere of the KJ sessions, and we conjecture that limiting such ideas would hamper also the emerging of those solutions that, in the end, result to be more interesting.

## 7 | REQUIREMENTS COVERAGE

This section reports the results of the analysis performed during the Learn PAd project in order to assess the coverage of the requirements elicited and refined using the process introduced in Section 3. The analysis was run after 12 months since the first elicitation workshop. The intent was to evaluate the realization status of each requirement with respect to the architectural design of the platform, the detailed use case specifications, and the prototypes developed within the first year of the project. In the context of this paper, this analysis gives an indication of the feasibility and project relevance of the elicited requirements.

As reported in detail in[1], the analysis followed a bottom-up and decentralized process. First a common evaluation template was agreed. The template distinguished each requirement as:

- Targeted: if some detailed use case, specific architectural interfaces, or prototype implementation was available at the time of the assessment;
- Partially Targeted: if a concept of use case was available, and if the architectural components responsible for its realization were already identified but some additional/planned effort was required at the time of the assessment;
- Not Targeted: a requirement had this status when it was not addressed at any level during within the first 12 Month-Period, and no further activities were planned for the next project period.

Then, the WP leaders were asked to evaluate and to justify the realisation status of the requirements within their responsibility. Finally, a project-wide team processed the individual reports from each WP leader in plenary meeting sessions with the intent to review, and to meld the numerous justification comments.

The result of the assessment revealed that after the first year of the project the 36% of the consolidated and accepted requirements were completely targeted, while a consistent number (i.e. 60%) were actually considered by the consortium so that it was possible to trace them to some design artefact or specification. Only the remaining 4% of requirements were not targeted and sorted out as ignored by the consortium.

We do not provide requirements coverage on the actual artifacts finally implemented, because this requirements-to-code tracing activity was not performed within the project. Furthermore, we argue that the implementation may be subject to several disturbing factors that are not necessarily related to the feasibility or relevance of the requirements – i.e., some requirements may not be implemented due to issues emerging in the development process. Examples of these issues are (a) the actual expertise of researchers in developing high-quality code, (b) obligations to select technologies according to the licensing schemas, (c) corporate constraints for the industrial partners in sharing actual services/data with third parties even if within the consortium, etc. We therefore argue that the architectural artifacts considered in the current analysis are therefore more appropriate to assess the value of the requirements.

### 7.1 | Observations

The current results show that the majority of the requirements were taken into account in the actual design of the system. This result, which may appear obvious in an industrial project, is not obvious in the context of a EU research project such as Learn PAd. Indeed, the partners were not committed to strictly abide to the requirements initially defined. The fact that most of the requirements resulted to be covered by design artifacts indicates that the process of requirements definition was successful, in that the different partners considered the requirements feasible and relevant, designing solutions to satisfy them. In this sense the problem of delivering heterogeneous and independent components from a set of sub-projects was actually prevented. Some other factors may have influenced this positive result, e.g., the maturity of the partners, or their interest in the general idea of

Learn PAd. However, we argue that a strong contribution to this result was given by the RE activities presented in this work, which allowed to reach a shared understanding and, hence, a homogeneous system. Although we cannot provide requirements coverage on the actual artifacts finally implemented, we argue that the current results are an indication of the effectiveness of the elicitation and refinement process adopted.

## 8 | LESSONS LEARNT

Overall requirement related activities were judged quite successful by the consortium partners. In the following we report our perception on what really worked or did not work in the applied approach to GRE, trying to identify the rationale behind the observed results, and providing suggestions for possible improvements. We organized the discussion according to the following three aspects that are quite relevant in GRE and in particular in EU projects:

- Partners Heterogeneity
- Motivation and Collaboration
- Tool Support

For each item, we highlight some relevant lessons learnt in our experience, and we discuss point in favor of the applied approach (✓) and issues that we had to face (✗).

### 8.1 | Partners Heterogeneity

Learn PAd, as many others EU projects, involves three types of associates, namely industrial, academic and public administration partners (case study providers). In our experience, closed-source industrial partners normally push to include their product *as-is* in the project. They are reluctant to change their platforms for the needs of the consortium, and in general less keen to innovation. Open-source industrial partners have the opposite tendency, and are in line with the academic partners: they tend to encourage *experimentation*, and changes to their products are seen as a way to explore new market scenarios. These differences in approach have become evident in later stages of the project, but at requirements elicitation stage the issue was mitigated by the peer-based KJ sessions, where the pressure of the interests of closed-source industrial partners was reduced by the heterogeneity of the groups.

Instead, a significant difference between industrial and academic partners emerged in the initial phase of the KJ method, where the participants were asked to write requirements in the post-its. Industrial partners – closed and open-source SME –, more in use with this kind of creative requirements elicitation approaches, started to write as soon as the session begun, and produced a large set of post-its. For example, in the Modelling group, two participants from the industry produced 43 out of the 78 preliminary requirements (55%). Instead, academic partners perceived the task as a sort of "homework" and they appeared less comfortable with the technique, and then edited relatively few post-its. However, when the discussion started, we could not distinguish between the two types of partners, as the degree of participation was more influenced by the personal attitude than by the affiliation.

In all the requirements elicitation stages, a manifest difference in attitude and behaviour with respect to the other participants was shown by the PA partners. PA associates had to play the role of customers but had visible difficulties in defining requirements for the platform. In fact, we were expecting the PA participants to contribute to the requirements about the demonstrators, since they are the domain experts who can provide practical needs. However the expectations did not match the outcome. The reason is manifold. Non-research projects are normally customer driven, while, in research projects, the real-world customers (i.e., the PA, in our case) are not the primary trigger of the project, and are generally included *after* the idea is conceived in order to permit the validation of possible project results. Therefore, they may not have a clear vision of the project, and mapping the general idea with their daily needs may be hard to them. Moreover, in our experience, the participation of PA partners was also hampered by their limited confidence with an international, English speaking environment. We argue that these limitations can be addressed by organizing meetings with PA participants only, possibly using other techniques such as interviews and questionnaires, to reduce the perspective gap, and reproduce a customer-developer environment that can be more effective to elicit user-level requirements.

In summary partner heterogeneity introduces quite complex challenges for global projects and EU projects in particular. In our approach we could observe the following results:

✓ the mix of KJ-method and open discussion during the workshops resulted an effective technique for eliciting a good number of good requirements;
✓ the involvment of all partners during the workshops permitted to reach a good coverage of the different aspects of the platform;
✓ the informal nature of KJ-method and the open discussion contributed to create a cooperative atmosphere in the consortium among all partners;
✗ heterogeneity creates some issues in reference to the used vocabulary, and also in the way requirements are written. A quite relevant effort could be needed to homogenize the requirements text;
✗ partners providing case studies should be interviewed and involved also in different ways. In particular, they can have difficulties in approaching group-based requirements elicitation techniques involving subjects with diverse background. Moreover, in some cases, they do not have clear in mind what can be realistically achieved, and some technical preparation is needed before reaching a shared understanding.

## 8.2 | Motivation and Collaboration

In a collaborative environment, motivation of the participants is a key aspect. In our experience, we saw that during the KJ sessions the people were naturally motivated by their physical participation, their natural involvement due to the need to let emerge their objectives, or simply by the fact that it was a new experience. Moreover, while running collaborative refinement activities, our statistics have shown that the participants actively contributed to the refinement of their requirements (see Section 5.3). Therefore, the motivation did not decrease, even though the participation space was now virtual. On the other hand, the degree of collaboration – rather high in the KJ discussions – was lower, since few comments and changes were provided on the requirements of the other participants. Moreover, the quality of the requirements did not increase much, since people tended not to follow the editing guidelines provided. The lack of collaboration and quality contributions identified during the wiki-based collaborative sessions makes us reflect on the need for a web moderator/leader who is in charge of directly asking the people to contribute to the requirements of the other participants according to their competences, and who checks the quality of the requirements. Moreover, the remote web-moderator could successfully act as facilitator[11], to encourage collaboration and resolve conflicts.

Indeed, while the collaborative refinement task was peer-based, a hierarchical management of the requirements activity was enforced in the requirements consolidation task. Responsible persons were identified in each institution to form a requirements task-force under the guidance of the RE coordinator (see Section 6). The responsible persons directly motivated the people in their institutions, and checked their work. Hence, the shift towards a *hierarchical management* of the activities was the key to come to a set of consolidated requirements. Though this aspect might appear obvious in an industrial requirements process, it is not straightforward in a process that lives within a research project. Indeed, such projects normally show a weak hierarchy among participants. In this context, enforcing leadership is not easy and might hamper the spirit of the project. However, it appeared as an effective solution, and we argue that such choice should have been applied already during the collaborative refinement sessions.

The relevance of motivational aspects in global projects cannot be obviously neglected. Similarly, collaboration aspects have to be carefully considered:
✓ the lively atmosphere of the small elicitation groups facilitates motivation. In running the refinement activity, hiding behind the peer-based wiki motivates everyone to contribute and reduces age/role effects;
✗ remote asyncronous collaboration does not emerge *per se*. For several reasons people tend to work remotely on requirements defined by themselves. Moderators should foster indirect interactions on requirements proactively asking comments and revisions to partners;
✗ quality of requirements does not improve as expected after some iteration. People tend to use similar way of writing requirements even if they try to make them more precise and more consistent with the rest. We conjecture that an introductory sessions on expected requirements formulation from the beginning could save time for the final refinement activities. Otherwise, tool support as in[26] shall be provided.

## 8.3 | Tool Support

Though an exhaustive comparison with other RE wiki tools is beyond the scope of this paper, it is worth mentioning that the capabilities of XWiki are not common in other RE approaches adopting wikis[27,47]. In particular, well-known weaknesses of RE wikis are[47,17]: the absence of features for restructuring the content, particularly for classifying/reclassifying the information; the absence of flexible navigation means; a limited support in capturing the semantics of the links between the requirements. These issues are addressed by XWiki through a flexible data model that supports the organization of the information as structured objects conforming to a given meta-structure. This information (i.e., the requirements in our case) can be searched and manipulated (e.g., classified/reclassified) automatically by means of a script and a query language, which enables also the possibility to define views, identify the history of a requirement and provide analytic data. Moreover, the semantic of a given object can be inferred both by its type, and by means of the dynamic relations it has with the other objects rather than the mere page where it is displayed. This allows identifying refinement and other relational links among requirements.

In practice, the flexibility of the XWiki-based collaborative platform demonstrated its effectiveness especially in providing analytic data and views on the requirements. This helped in spotting out missing stakeholders (i.e., the pedagogical experts), and reduced participation of part of the stakeholders (i.e., the PA partners). Moreover, the active participation of the partners during the refinement sessions gives us confidence on the usability of the platform. Usability has to be carefully assessed since many partners could have experience in RE using other tools within their company and could find difficult to adapt to a different tool.

On the other hand, in running requirements consolidation activities, the feeling of the RE coordinator was that collaborative platform was not giving sufficient tool support to manipulate the requirements together, and decided to export the requirements in a spreadsheet. Then, requirements were manually re-imported in the collaborative platform to enable proper versioning. We argue that providing a spreadsheet-like view in the collaborative platform could have helped in the requirements consolidation activities. Moreover, to reduce the effort of the manual import from post-its to the collaborative platform, also computer-based support for the KJ method (as, e.g., in[48]) shall be foreseen.

Clearly remote interactions in global projects need specific support. Our experience with the wiki platform was quite successful thanks also to the specific characteristics of the platform we adopted. In summary, aspects worth highlighting are:

✓ the possibility to perform tagging and data analytics through the wiki enables greater control over the set of requirements, and over the refinement process itself. In particular, the possibility to monitor single contributions helps in adjusting the process of requirements refinement during its execution;

✓ the content of the wiki is accessible to all the participants. This enables a better understanding of the needs of all the stakeholders involved in the requirements refinement, and can help eliciting novel ideas;

✓ the possibility of defining requirements templates (VOLERE templates in our project) allows structuring the requirements in a uniform manner. On the other hand, we have seen that, to have a uniform structure also at the level of the natural language requirements, different tools are needed;

✓ wikis are easy to use for all the stakeholders, since they do not require any installation, and the actions that the user can perform are limited;

✗ wikis tend to grow in an unstructured manner, and tend to be chaotic and hard to navigate. If one wishes to have an abstract view of the content, this is hard to achieve in current wikis. This issue has been addressed by providing views in XWiki, which have helped both the requirements contributors and the requirements managers to have a clear understanding.

## 9 | RELATED WORKS

The literature counts several papers describing observed problems[6,7,8,9] and associated countermeasures[24,25,49,17,27,50] in the field of GRE. In the following, we briefly summarise the main research works regarding challenges in GRE, and some of the solutions proposed – for a survey on challenges and solutions, the interested reader can refer to Schmid[16]. Then, we discuss more in depth the works that specifically focus on the usage of wiki-based platforms to support RE tasks in globally distributed teams.

### 9.1 | Challenges and Solutions

Cheng and Atlee[9] pointed out globalisation and global team distribution as one the major challenges in RE research. The specific issues that global teams have to face in dealing with requirements communications and management were pointed out, among others, by Daniela Damian and co-authors[12,6,11,7] based on field-studies and practical experiences. The issues identified in these works include problems in integrating knowledge from distributed sources, process and vocabulary mismatches, and cultural differences, which tend to have a negative impact on the achievement of a shared understanding among stakeholders[51]. More recently, given the raising interest on agile practices in the last decade, Inayat *et al.*[14] have studied GRE in distributed agile teams, highlighting the paramount role of product owners as hubs to facilitate communications among teams. In an empirical study on the distributed development of Windows Vista, Bird *et al.*[13] have shown that the communication problems observed in previous studies may not have a tangible impact on the actual products delivered, in case there is organisational homogeneity between different sites. However, as pointed out, e.g., by Herbsleb[8] process-level countermeasures have to be taken for the project to succeed.

Among the countermeasures, in an early role-playing work, Lloyd *et al.*[21] propose to use a combination of groupware collaborative software tools, i.e. tools for virtual meetings and document sharing, to facilitate communication. In an empirical study, Calefato *et al.*[22] have shown that, in computer-mediated, synchronous communication, rich-media tools that allows face-to-face communication provide more opportunity to familiarize with others, and allow the expression of complex ideas, while textual communication is more effective for discussing conflicting issues. Laurent and Cleland-Huang[23] study the usage of online forums for requirements gathering and prioritization, based on the input from different stakeholders. The authors suggest to facilitate stakeholders' grouping based on their topics of interest, to improve the online discussion. To this end, they recommend the usage of data-mining methods for the creation of discussion groups, and to have a moderator who creates a pre-defined structure of topics to organise the different discussions. The usage of data mining techniques for the creation of stakeholders' discussion groups is further studied by Castro *et al.*[24]. Similarly, Lim *et al.*[25] propose a web-based tool called StakeSource 2.0, which uses social networks and collaborative filtering to identify stakeholders and requirements, and also to support prioritisation. On top of StakeSource, StakeRare[52] was developed and applied on a study involving 87 distributed stakeholders. Social networks have been also exploited by Seyff *et al.*[3], who used Facebook to support requirements elicitation and negotiation between stakeholders.

Recently, with the advent of mobile applications, crowd-sourcing requirements from software reviews provided by the users has become a hot research topic in RE[53,54]. Although, in a sense, these works can be regarded as belonging to GRE, they are not mainly focused on communication issues faced by global teams, as our work. Therefore, we do not discuss them in the context of this paper. A general account of crowd-sourcing methods applied to software engineering is provided by the recent survey of Mao *et al.*[4].

## 9.2 | Wiki-based Support for RE

One of the main contributions of this paper resides in the usage of a collaborative/wiki-based tool to support RE activities in a GRE context. A complete review of existing wiki techniques for RE can be found in[17]. Here, we briefly present the most relevant technologies, and we discuss them in relation with their core objectives.

Among the available technologies, the SOP-Wiki[31,27] tool focuses on the importance of the document structure of the wiki pages and inter-document relationships, to enforce navigability and shared understanding. With a similar objective, the tool WikiReq[30] structures the wiki pages according to viewpoints and arguments, to facilitate participation of stakeholders with different skills to the RE process. This goal is also addressed by OntoWiki/SoftWiki[28], which leverages semantic data links among requirements instead of document templates. A different motivation drives the WikiWinWin[29] platform, which is specifically focused in supporting the *negotiation* of requirements among the different stakeholders, to come to a mutually satisfactory set of requirements by means of the Win-Win approach. The core goal of SmartWiki[26] is to provide high-quality requirements, by automatically sending feedbacks to those stakeholders who provide poor specifications. As in our approach, a VOLERE-based template is used to enforce requirements quality. Finally in[50] the authors investigates the usage of a collaborative platform also for prioritization activities exploiting gamification techniques.

As SOP-Wiki[31,27], WikiReq[30], and Softwiki[28], our wiki-based approach relies on semantic links among requirements. Moreover, our approach structures the requirements according to an object-oriented data model which does not reflect the page structure of the wiki (i.e., the data presentation layer). The consequence is a more flexible approach in elaborating groups and views over the collected requirements. This feature contributes to the final goal of achieving a shared understanding and improve structured participation, besides easing data analysis and control. We remark that the negotiation issues addressed in WikiWinWin[29], and the requirements quality issues considered in SmartWiki[26], are secondary objectives in our work.

With respect to the previous papers concerning wiki-based approaches for RE, the main contribution of the current work resides in the *evidence* provided regarding the usage of a wiki in requirements elicitation and refinement. Indeed, as highlighted in[17], very little contribution exists in the literature concerning practical experiences associated to the usage of such wikis.

Another central contribution of this paper is the description of a practical experience in employing a workshop technique[55], i.e., the KJ method[33], for collaborative requirements elicitation[56]. Several approaches have been presented in the literature concerning group-based requirements elicitation, such as Joint Application Design (JAD)[57], Quality Function Deployment (QFD)[58], Cooperative Requirements Capture (CRC)[59]. Creativity-based collective elicitation has been addressed in[60], where an approach is presented which employs user stories as a basis to collectively elicit user requirements. Still on creativity approaches, Mich *et al.*[61] introduces a step-by-step technique that is based on a model of the pragmatics of communication. More recently, collaborative process design[62] has been shown to be an effective structured technique to achieve collaboration while enforcing rigor. Our approach provides only slight adaptation of the canonical KJ-method[33], and it would be beyond our scope to compare such method with other approaches presented in the literature (e.g.[60 61]). However, it is worth highlighting that, with respect to other elicitation techniques, the main advantage of the KJ method resides in its *simplicity*, which drove our choice of applying it for collaborative requirements elicitation.

A final contribution of this paper is the accurate description of a methodology where an established face-to-face elicitation technique (i.e., requirements workshops[55]) is combined with computer-mediated communication[63] based on wiki. From our experience, we argue that the process-level integration of *physical* and *virtual* interaction among stakeholders is a key element for enabling collaborative requirements elicitation and refinement in a global project.

## 10 | CONCLUSIONS

In this paper, we presented an experience report concerning the application of an approach that combines a face-to-face requirements elicitation technique (i.e., the KJ method) with a collaborative approach for distributed requirements refinement and consolidation. The approach has been defined in order to mitigate the risks related to communication issues during requirements elicitation in the context of a ICT EU research project.

Specifically, in the first part of the paper, we reported why EU research projects in ICT show issues that are common to GRE (e.g., communication difficulties, knowledge management, see[6,7]) and that can be addressed with tools that are suggested by previous experiences (i.e., initial face-to-face meetings[7] combined with asynchronous wiki interaction[27]). Then, we have also seen specific characteristics that demand for proper solutions: among them, the need to enforce the role of moderators also during on-line activities in order to foster collaboration, and the need to define a preliminary glossary already during the face-to-face meetings in order to improve the uniformity of the future requirements. Advanced techniques to distributed requirements clarification (e.g.,[64]) are also foreseen to increase the quality of the elicited requirements.

Some of the results and the lessons we learnt form this experience can be summarized according to the following perspectives:

**Shared understanding:** the content of the wiki is accessible to all the participants. This enables a better understanding of the needs of all the stakeholders involved in requirements refinement. Indeed, as observed in Section 5.4, refinements were often provided to align the initial ideas to the status of the whole project, taking into account the requirements of other stakeholders.

**Motivation:** the lively atmosphere of the small elicitation groups facilitates motivation. In running the refinement activity, hiding behind the peer-based wiki motivates everyone to contribute and provide novel ideas. Indeed, as shown in Section 5.3, during on-line collaboration, the number of requirements increased consistently (about 35% additional requirements).

**Collaboration:** collaboration was effective during the face-to-face meetings, where people were called to discuss the requirements of the others, but collaboration was less effective during refinement. Moderators had a key role in the face-to-face meetings. Therefore, we argue that the role of the moderators as *facilitators*[11] have to be enforced also during the refinement activities, to foster collaboration and also to improve the quality of the requirements.

**Uniformity:** the possibility of defining requirements templates (VOLERE templates in our project) allows structuring the requirements in a uniform manner. On the other hand, we have seen that, to have a uniform structure at the level of the natural language requirements, different tools are needed. In particular, defining a glossary already at requirements elicitation stage can help having fixed reference concepts and a shared vocabulary.

**Control:** the possibility to perform tagging and data analytics through the wiki enables greater control over the set of requirements, and over the refinement process itself. In particular, the possibility to monitor single contributions helps in adjusting the process of requirements refinement during its execution. The following observations highlight the peculiar aspects of our wiki infrastructure, which enable greater control on the requirements process.

**Semantics Links:** the navigation across the requirements is enabled by a collection of tags implemented using the data model of the XWiki platform. Each tag is intended to classify a collection of similar requirements. A set of predefined tags was given, but users were able to formulate new ones. The flexibility of the XWiki platform supports the definition of scripts that can dynamically query the set of requirements in order to classify/reclassify the information. For example, in such a way contributors do not have to remember to explicitly cross-link the pages were requirements are displayed. It is worth noting that requirements relationships such as dependency, refinement and conflicts were elements of the VOLERE template, and could be navigated like

the other semantic links.
**Traceability:** given the flexibility of the XWiki platform, different views can be implemented as queries over the set of requirements. For example, we inspected the requirements by type, tags, contributors, modifications, as well as we elaborated statistics on them. Also the data model of XWiki supports the dynamic modification on the requirements templates. In this sense new fields can be added, for example in order to express emerging links with other specifications. In this case, views can implement traces of the requirements on such specifications.
**History:** wikis support pages versioning. In our experience each requirement is attached to a page for its display. Each modification to a requirement results as a modification on a page that the wiki will store as a passed revision. In this sense, the wiki automatically supports to trace the evolution of a requirement.
**Navigation:** wikis tend to grow in an unstructured manner, and tend to be chaotic and hard to navigate. If one wishes to have an abstract view of the content, this is hard to achieve in current wikis. This issue has been addressed by providing views in XWiki, which have helped both the requirements contributors and the requirements managers to have a clear understanding.

The observations reported in this paper stem from a retrospective analysis on a single project. Our elicitation technique needs further evaluation and refinement, and additional, structured cases studies, with an improving and then confirmatory nature[40], are needed to assess our observations. Although general claims cannot be made about the external validity of these observations, the principles of case-based generalisation proposed by Wieringa and Daneva[2] can be considered to identify the salient architectural aspects that make our case generalisable to other context. Specifically, Learn PAd is a medium-sized ICT project, with a large majority of partners coming from computer science areas, a balance between industry and academia, and the involvement of five non-native English speaking countries (see Sect. 2.3 for further details). Hence, we argue that our observations may be applicable to similar culturally heterogeneous contexts in EU Projects, when these involve a majority of computer scientists/engineers.

Part of our observations stem from quantitative analyses performed through XWiki based collaborative platform. However, our lesson learnt are mainly qualitative, and based on our perception of the strength and weaknesses of the approach, compared to our experiences in other EU projects in ICT, where requirements were defined by a selected group of participants. In depth quantitative analysis and comparison with these previous projects are foreseen as future research.

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