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Using Wikis to Simulate Distributed Requirements Development in a Software Engineering Course*

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Software development activities are increasingly being conducted collaboratively across multiple time zones and multiple teams. This creates challenges in building shared values and trust, and in coping with asynchronous collaboration and communication. In response to these trends, tools such as wikis, blogs, web portals and groupware are being integrated in development processes to enhance the productivity and effectiveness of teams. To enable students to meet these challenges, there is a need to use technology in software engineering education to simulate authentic structures of work practices. Use of collaborative and discourse tools will provide students with the experiences of communicating and negotiating with diverse stakeholders with different views and backgrounds. It will also enable the development of transferable skills for working with community tools in the industry. As with most software design and development processes, Requirements Engineering (RE) is increasingly being conducted in distributed environments. Wikis are being used to provide a platform for asynchronous collaboration for participative requirements development. In a post-graduate RE part-time distance-learning course at the Open University in the UK, we have introduced wiki activities in the course to provide students with the opportunity to engage in small-group collaboration to emulate RE practice. In this paper, we discuss the nature of the RE process, the usage of wikis in RE practice, and the challenges of introducing collaborative-work and wikis on the RE course at the Open University and our solutions. We will draw on empirical evidence to discuss effectiveness of wiki in collaborative learning of the RE processes.

Keywords: wiki; collaborative learning; requirements engineering; software engineering education; virtual teams

INTRODUCTION

A SOFTWARE ENGINEER must possess a wide range of skills and talents. We, the educators, face the challenge of preparing these engineers—especially when the technologies and requirements of the industry are changing rapidly with time [1]. In addition to preparing the students for the new realities [2] of off-shoring and managing off-shored and outsourced projects, distributed computing, pervasive computing, information security management, and the proliferation of new tools and technologies to support the software engineering processes [3], there are two key non-technical skills that are essential to the success of software engineer—*communication* and the *ability to work in a team*. These skills are specifically important in requirements engineering (RE) where communication problems with stakeholders are a major source of requirements problems (e.g. missing, incomplete and misinterpreted requirements) and these can cause significant project re-work costs. Software engineering (SE) projects are conducted in teams and although good communication skills can help one to be a better team player, working in a team requires negotiating, making compromises, accepting others' perspectives, and working towards the common goal of developing a software system that will meet the customers' requirements.

Software development activities are increasingly being conducted collaboratively across multiple time zones and multiple teams. This creates challenges in building shared values and trust, and in coping with asynchronous collaboration and communication [4]. In response to this trend of global software engineering (GSE), tools such as wikis, blogs, web portals and groupware are being integrated in software development processes to enhance the productivity and effectiveness of teams ([5]; also *see* [6]). RE is increasingly being conducted in distributed environments and wikis are being used to provide a platform for asynchronous collaboration for participative requirements development [7]. Software engineers are expected to interact and communicate with colleagues from different countries, disciplines, backgrounds, cultures and technical abilities, and thus it is even

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more important than ever before to impart the skills of team-working and communication to our students, and to give them the transferable skills of working with collaborative and communication tools in the industry. There is a need to use technology and asynchronous collaborative activities (projects) in SE education for the simulation of authentic structures of work practices.

In a post-graduate RE part-time distance-learning course at the Open University (OU) in the UK that involves teaching systematic elicitation, recording, and communication of requirements of software systems, we have introduced wiki activities into the course to provide students with the opportunity to engage in small-group collaboration to emulate RE practice.

The Requirements Engineering discipline

The primary measure of success of a software system is the degree to which it meets the purpose for which it was intended. *Requirements engineering* (RE) is an early phase in the software engineering lifecycle that involves discovering that purpose, by identifying stakeholders, eliciting, validating and verifying stakeholders' requirements and presenting them to the rest of the development team (e.g. designers, developers and testers) in a document known as *requirements specification*. Stakeholders are individuals and organisations that are actively involved in a software project or whose interests the project affects [8]. These include customers, users, project managers, analysts, developers, senior management and quality assurance staff.

The requirements specification is written in a form that it is amenable to analysis, communication, and subsequent implementation [8]. Any shortcomings in the requirements specification can lead to excessive re-work on software projects and yield software systems that fail to achieve full customer satisfaction. RE is a communication-intensive activity involving various stakeholders of the software system. An ongoing collaboration with the stakeholders ensures that the requirements are interpreted properly, fluctuating requirements are dealt with, and communication breakdowns are avoided. RE process involves going through recurrent cycles of exploring the perceived problem, proposing improved specifications, and validating and verifying these specifications with the stakeholders.

Also, requirements engineers on a project need to communicate with one another during the RE process to ensure that the requirements collected by them, either individually or in pairs/groups from different stakeholders are not conflicting or ambiguous, are complete, and the dependencies amongst various requirements have been identified. In addition, there are other links in the requirements communication chain, for example, with the designers, developers and testers of the software system being developed. A breakdown in any of these links leads to significant problems. For example, if a requirements engineer misunderstands stakeholder input about requirements, if important requirements information does not surface, or if a requirements engineer and developer do not share the same understanding about requirements, the resulting software system will not satisfy customers. The inevitable outcome of requirements errors is time consuming and costly rework. Multiple studies have indicated that roughly 50 percent of the defects identified on software projects can be traced back to errors in the requirements [9]. One analysis of the potential return on investment from better requirements suggests that requirements errors can consume between 70 and 85 percent of all project rework costs [9].

For effective communication of requirements engineers with the stakeholders, or within the software development team, and with one another during the RE phase, requirements engineers should possess skills of communication and team-working. Also, tools for communication, collaboration, and requirements management may be required to support the requirements engineers in the requirements development process.

Furthermore, in response to the trends of distributed software development, and to overcome the significant cultural, time zone and organisational challenges in global RE, requirements engineers and other stakeholders need effective practices, processes and tools for knowledge acquisition and sharing as well as for relationship building. Tools such as CASE tools, wikis, blogs, web portals and other groupware are being integrated in development processes by organisations such as Nokia, Sun Microsystems, IBM and Motorola to enhance the productivity and effectiveness of teams (e.g., [5, 10, 11]).

For distributed RE, wikis are being used to provide a platform for participative requirements development ([7]; also see [12]). A *wiki* is an asynchronous collaborative authoring environment—a readable and writeable website in which potentially all the visitors to the site can create new pages or modify existing ones, with optional access control to set limits on authorship. Ward Cunningham and Bo Leuf, in the book *The Wiki Way*, define wiki as a 'freely expandable collection of interlinked web 'pages', a hypertext system for storing and modifying information—a database where each page is easily editable by any user with a forms-capable Web browser client' [13]. It is a server-based collaborative tool that allows any authorised user to edit pages and create new pages without learning any programming language. Wikis, therefore, allow distributed teams to write and edit documents collaboratively over the Internet in a shared online workspace.

Use of collaborative and discourse tools in SE education and working in group projects will provide students with the experiences of communicating, team-working and negotiating with diverse stakeholders with different views and back-

grounds, and also enable the development of transferable skills for working with community tools in the industry (e.g., [14]). During the planning and implementation of wiki activities on the RE course at the OU, we have faced a number of social, technical, and pedagogical challenges. In the paper, we will discuss these challenges and our solutions, drawing on empirical evidence to answer the following questions:

- Did the wiki activities facilitate collaborative learning as intended?
- How might the usage of wiki be integrated with other tools such as a scheduler for organisation, or a group-blog or forum for discussions during collaborative requirements development?
- What are the challenges that students face in collaborative requirements development and specification?

We will draw on empirical evidence to discuss the effectiveness of the wiki in collaborative learning of the RE processes.

The context: VLE programme at the OU and the wiki environment

The Open University (OU) is the largest university in the United Kingdom and the UK's only university dedicated to distance learning. Recently, the OU has embarked on a €7.5m programme to develop its integrated virtual learning environment (VLE) to meet the online learning needs of its 200 000 distance learners. The open source VLE, Moodle (www.moodle.org) has been adopted by the University and is undergoing extensive development to provide the required functionality for the OU. As a result, the adoption of e-learning tools such as blogs, wikis, podcasting, and e-portfolios are transforming the ways that learning is being developed by course teams for the students.

The course team of the postgraduate course, Software Requirements for Business Systems, in the Department of Computing of the OU has been one of the early adopters of the VLE. The course involves teaching systematic elicitation, recording and communication of requirements of software systems. Since, wikis are increasingly being used in organisations for collaboratively developing requirements specification documents ([7] and [15]), in the (November 2006–April 2007) presentation of the course, activities based on wikis were introduced to provide students with the opportunity to engage in small group collaboration in order to emulate RE practice. We hoped that the wiki activities would help facilitate learning and the acquisition of various skills including:

- the creation of explicit knowledge from tacit understanding of course concepts;
- learning through discussion, disagreement and consensus building;
- team working; and
- effective communication of ideas to others through a networked collaborative environment provided by the wiki; articulation, analysis and synthesis of ideas, and knowledge-sharing.

In this paper, we describe the trail of empirical work that led to the evaluation of the collaborative wiki activities on the RE course. The paper is structured around the major phases of the research programme. The next section provides a broad overview of the requirements engineering tools and describes how wikis offer a flexible platform for asynchronous collaborative support to requirements engineers participating on a software development project. The design and implementation of collaboration and wiki activities on the RE course is then discussed. The authors go on to describe the methodology and results of empirical evaluation of collaboration and wiki activities on the course. The paper concludes with a discussion of how our evaluation of students' experiences and perceptions of the collaborative wiki activities has consequences in three areas: (a) designing of wiki activities on SE courses; (b) technology-enabled learning in SE education; and (c) the enabling and disenabling factors for virtual team effectiveness in global SE/RE teams. The steps taken since the evaluation will also be discussed.

REQUIREMENTS MANAGEMENT TOOLS

The collaborative nature of RE requires a platform that can support effective and efficient communication among a large number of diverse stakeholders who may be separated in time and space and may have different cultural backgrounds, different skills with technology-usage or different abilities. These challenges can be addressed through using collaboration tools that are easy and simple to learn and use.

There are many existing commercial RE tools that support collaborative development of requirements, including IBM Rational RequisitePro, Borland CaliberRM, and Telelogic DOORS. While most requirements management tools are desktop applications, Gatherspace and eRequirements are examples of web-based tools (an exhaustive list of tools is available at the website of Ludwig Consulting Services http://www.jiludwig.-com/Requirements_Management_Tools.html (last accessed, 13th February, 2008). Research on collaborative requirements management tools has focused on supporting negotiation among stakeholders, use of new requirements engineering processes, and exploration of new media and platforms [3]. For example, the WinWin [16] was designed to support a requirements engineering process that made negotiation processes explicit in the interface of the tool, with an underlying structure that encouraged resolution of conflicts, creating 'win-win' conditions for involved stakeholders.

In the early stages of the RE phase, techniques such as brainstorming, laddering, apprenticing and stakeholder-workshops help to convert implicit and relevant information for the project into some explicit information but this information is normally imprecise, has multiple views, contains disjointed requirements and may be ambiguous but this elicited information should be documented as it will form the basis for refined and complete requirements later on in the RE phase. However, most commercially available requirements management tools do not support documentation of this uncategorised early communication with stakeholders. Usually the tools require that there already exists a typology of relevant information, *the information model*, including requirements types, requirements attributes and document types. The benefit of having a *Requirements Elicitation wiki* is having an easy-to-use interface that hides the complexity of information structuring. Wikis can support the collection of unstructured heterogeneous information in the requirements elicitation stage of the RE process.

Several studies have confirmed that small and medium-sized enterprises don't use commercial RE tools and prefer to use more general tools such as office suites or Websites [7]. When requirements are stored in office software suites and word processors, they offer low-cost solutions and it is easy to structure requirements in sections. However, collaboration can be chaotic as different stakeholders may make concurrent changes and may send last-minute exchanges by e-mail as attachments. Requirements may get distributed across several documents and this may have the risk of missing out requirements if connectivity to one of the documents is lost in the distribution chaos.

Further, these specialised tools may not be usable for non-technical users, or the user interfaces of these tools may not have been designed for different cultures (e.g. icons, terminology, symbols, colours), or they could be expensive for small and medium-sized enterprises because a license may be required for every stakeholder and for stakeholders in different countries and locations. Instead, wikis are increasingly being used for distributed requirements development and specifically in the early requirements elicitation stage.

Role of wikis in Requirements Engineering

Three types of processes can help stakeholders achieve a shared understanding in RE [4]: knowledge-acquisition and knowledge-sharing processes that enable the exploration of stakeholders' needs; iterative processes that allow the re-shaping of this understanding throughout the entire project; and effective communication and co-ordination processes that support the other two types of processes. To support these processes, and particularly in GSE, wikis offer a flexible platform for asynchronous collaboration to create requirements specifications iteratively, document and share knowledge, and manage communications [7]. Wikis are more powerful than office suites and easier to use and tailor than proprietary RE tools. Wikis have the following features that facilitate collaborative RE [15].

- One-place publishing: there's only one version of the document available and that is regarded as the current version.
- Wikis provide easy linking, which implies that documents within a wiki can be linked by their title using a simple markup; this easy page linking reduces redundancy by making it easier to link content than to copy a page. Thus requirements engineers can start eliciting requirements within the wiki and later link information gathered during prototyping activities or existing source code to it.
- Simple and safe collaboration: which refers to versioning and locking mechanisms that most wikis provide; there is a page-history capture which provides evidence and foundation for requirements traceability on a per-document basis; new users can easily learn wikis and mistakes can easily be corrected by retrieving previous document versions.
- Wikis foster a mindset of a fit-for-use and an evolutionary approach to requirements development; wikis provide the basic features for collaboration and offer the flexibility and simplicity to be adapted and changed to support the evolving RE process: stakeholders; requirements and the artifacts or templates that are used to document the requirements.

The following factors motivated us to introduce collaboration and wikis on the RE course:

- the usage of wikis in SE and RE as reported in recent publications (e.g. [12]), and the experiences with wikis of our industrial contacts in IBM and Sun Microsystems; therefore, we wanted to ensure that our students experience participative RE through working with collaborative tools that are being used in practice;
- the empirical research reported in the role of groupware in engineering education (e.g. [17, 18]); and
- the initiative of providing a networked collaborative environment or knowledge space would help in the development of skills such as teamworking, communication, knowledge-sharing, negotiation and decision-making skills of our students, and making our students aware of the significance of these skills in RE practice and in SE projects.

APPROACH TO COLLABORATION IN THE REQUIREMENTS ENGINEERING COURSE

The course, Software Requirements for Business Systems, is a distance-learning course of five months' duration. The course describes how to

analyse a business problem and develop a requirements specification of a software system that can be used to determine an appropriate solution to the problem. The course describes RE techniques and a disciplined approach to the RE process: eliciting, analysing, communicating and agreeing requirements. The majority of the students on this course are software professionals who register to update their skills in creating, analysing and evaluating requirements. Normally, the students are aiming for a Postgraduate Diploma or MSc. Details of the course (OU course code: M883) are available at http://tinyurl.com/2pke2k (last accessed 20th January 2008).

The key learning outcomes of this course are:

- identifying the stakeholders of a business problem and its solution, and understanding how to interact with stakeholders and managing any stakeholder conflicts;
- resolving conflicts, duplicates and ambiguities in the gathered requirements; and
- dealing with the varying perspectives and views of different requirements engineers in a project-team.

In practice, as we have seen earlier in this paper, the RE processes of interacting with stakeholders, managing stakeholder conflicts, and removing conflicts, duplicates and ambiguities from a set of requirements are generally performed by a small group of requirements engineers who discuss and reformulate the requirements in consultation with the stakeholders [19].

Our aim of introducing collaborative activities in a wiki environment has been to emulate this experience by enabling a group of students to take the roles of requirements engineers in a software development project. For example, the project might involve a sports centre setting up its website. The wiki activities involve a group of students contributing requirements to the group-wiki, discussing the requirements, identifying conflicts and ambiguities within the requirements, and resolving the conflicts through discussions from the perspectives of different stakeholders, to produce an unambiguous requirements specification.

The assessment on the course involves three tutor-marked assignments (TMAs) and an examination at the end of the presentation. The three TMAs on the course involve students in developing a requirements specification for a system that is included as a case study in the TMAs. The wiki activities involve collaborative development of the requirements specification for the case study in the TMAs.

There are around 120 students in every presentation. In the OU's distance-teaching model, students are supported by tutors, with each tutor having a group of 18 students. The tutor is responsible for supporting the students by marking the TMAs, regularly interacting with the students and addressing their queries and concerns throughout the course, and liaising with the course team. To emulate the small group dynamics found in RE practice, we split each tutor group into three subgroups, for the wiki activities, of around six students giving a group size that was big enough to cater for the inevitable drop-out, and small enough to be manageable and effective. One constraint was to avoid significantly increasing the tutors' workload. Therefore, we designed the wiki activities in a way that, we hoped, would be self-managed by the students and requiring minimal or no intervention by the tutor.

We applied the five-stage model (Fig. 1), proposed in [20] and [21], as a guiding framework while we were designing the wiki activities for the

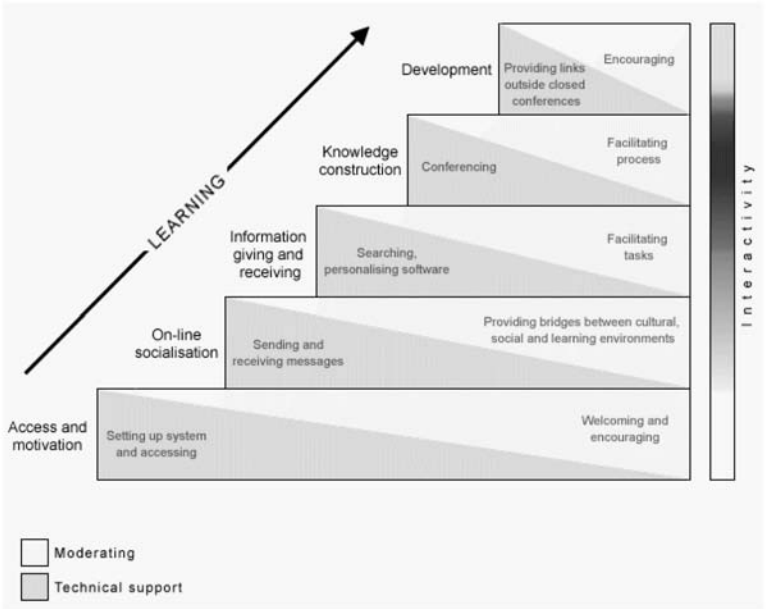

Fig 1. The five-step model (from [23], p. 43).

TMAs. We also took into account the experiences of a distance-taught course on team working in a distributed environment at the OU based on Tuckman's model of team working [22].

Introducing wikis to students

In the first month of the course leading to the first TMA, we planned activities that would take students through the *first two steps* of the model in Fig. 1.

Though the OU is a distance-learning university, there are two opportunities during each presentation for staff to meet students face-to-face (but both are optional activities and not all students attend): in an introductory tutorial at the start of the course and in a three-day residential revision school just before the exam. During the first presentation of the course at the residential school, informal enquiries with students indicated that they were either unaware of blogs and wikis or had not encountered them in learning environments. We realised that there was a need to design activities and resources that would help in familiarising them with a wiki environment. So we decided that students would have an introductory paper on wikis to read and analyse as part of their first TMA. After a literature search, we chose Farrell's *Wikis, Blogs and other Community Tools in the Enterprise* [5] since it situates the role of community tools such as blogs and wikis in software enterprises.

We suggested that the students read Farrell's paper as a part of the first TMA but we also placed many other introductory papers and web links related to wikis on the course website to enable our students to familiarise themselves with wikis as collaborative authoring tools and specifically on the role of wikis in SE, RE, education, and project management applications. It was important for us to convey to the students that the wiki activities fit within the pedagogy of the course, otherwise the wiki would have been perceived as yet another online tool that added to the workload on the course. In addition, we developed two guidance documents for students: (a) guidelines for using the wiki; and (b) conducting the collaborative activities in the wiki, rules of collaboration on the course, wiki-etiquette, role of each student in a student-group, and so on.

Students were also asked to participate in their individual groups in an ice-breaker activity. Most of our students generally study on their own and there are no formally constituted meetings (tutorials) as part of the course. Students have the opportunity to 'meet' via a mediated computer conference (forum) for the course but as this is optional, only a small percentage of students use the facility to introduce themselves at the start the course, or for interactions or discussions during the course. Therefore, we realised that it would be essential to have an ice-breaker session before the actual collaboration activity, which would enable the students to get to know one another.

The ice-breaker activity has two objectives: students are able to familiarise themselves with the wiki environment and the activity gives them an opportunity to introduce themselves to their fellow group members. Each student is asked to do two tasks in this ice-breaker session: add a small biography to the wiki; and enter a stakeholder type from a list of stakeholders in the case study. The exercise involves very little collaboration in the sense that little negotiation is required. Care was taken to ensure that there would be no advantage or disadvantage in choosing one stakeholder type rather than another. The choice of stakeholder type is actually a preparation for the second TMA where each student is asked to discuss the requirements for the system in the case study from their chosen stakeholder's perspective. Students are advised to complete this ice-breaker activity a week before the TMA cut-off date. The evidence of their individual contributions can be included in their TMAs by copying and pasting the log from the 'History' section of the wiki (the 'History' function in the wiki records all the changes and contributions made to a page in a wiki).

Collaborative Requirements Engineering

The wiki activities in the second and third TMAs aim to provide practical experience of requirements development to emulate real-practice. The activities have been designed around key course concepts so that students can develop shared understanding and situated meanings via collaboration. As per the stage 3 of 'information exchange' in the model of Fig. 1, the collaboration in these two TMAs involves students individually contributing requirements to the wiki and then discussing them to arrive at an agreed set of consolidated requirements.

The second TMA involves each student in a group adding three requirements to the wiki from the perspective of the stakeholder chosen in the first wiki activity. The aim here is to populate the wiki with a set of requirements from the perspectives of a variety of stakeholders so that the students (in their role as requirements engineers) can practise RE skills. Once all the students have entered their set of requirements, the collaboration involves discussing duplicates, conflicts, and ambiguities with the aim of achieving an agreed set of unambiguous requirements for the system in the case study. Students can also use the forum for discussion while performing this collaboration.

The collaborative activity in the third TMA involves each group checking the accuracy of the requirements developed in the second TMA and specifying a fit-criterion (a quantified measure) for each requirement. The development of suitable fit-criteria can be difficult if a requirements engineer is working on their own and better quality fit-criteria can be obtained by a group of requirements engineers working collaboratively. Hence, the wiki activity asks the students to agree on a set

of fit-criteria for the requirements developed in the second wiki activity.

For educators, the most important issue in wiki environment is that of assessment: establishing the levels of contribution of respective group members in collaborative writing. It is also important the students are clear about what they will be assessed on and what weight each portion of the work carries. In [24], the author states that the students should be informed that they will be graded on their contributions, as long as they document and discuss their experiences. This type of assessment is aided by the wiki's '*versioning capability [which] can show the evolution of thought processes as students interact with the site and its contents*' [25]. Other facilities such as time-stamping, revision history and discussion in the wiki help to provide a permanent record of student ideas and participation for tutors [14, 26]. Especially in collaborative projects, the students need to feel they are gaining something and this helps to '*promote 'pride of authorship' and ownership in the team's activities*' [25].

The marking is based on both the student's own contribution to the activity and on the product of the activity. A significant advantage of the wiki is that it records each and every change to the document, which means that there is evidence of each student's contribution. In the TMAs, students are asked to report on their individual contribution to the collaborative activity, quoting evidence from the wiki which, of course, can be verified by the tutor. There is a sliding scale of marks given to an individual for the process and the product based on the level of their contribution supported by evidence from the wiki and student's own account.

Reflection during and after collaboration

In order to assess the effectiveness of the wiki activities in collaborative authoring of requirements and to elicit students' perceptions of their learning, we asked students to reflect on their experiences before and after performing the collaborative activities in the wiki environment. Further, the students' individual reflections (stage 5 of Fig. 1) have enabled us to evaluate whether collaboration and on-line interactions have facilitated knowledge creation (stage 4 of Fig. 1).

Reflection is the process of stepping back from an experience to ponder, carefully and persistently, its meaning to the self through the development of inferences; learning is the creation of meaning from past or current events that serves as a guide for future behaviour [27]. Reflection is a strategy that may facilitate learning through re-examination and re-interpretation of experience. Experience on its own does not guarantee that learning will occur but it is the process of reflecting personally on your own experience that helps to acquire deeper insights [28].

To help students get started, we provide a reflection template containing some 'trigger' questions or 'probes' to help them think about the various elements of the course as they work through them. The reflection is performed along three dimensions: on experience of using the wiki as a tool; personal views of the course and collaboration in particular; and the use of collaboration in RE. Students are asked to examine these three dimensions in each collaborative activity and to record their experiences. This can be done with any suitable tool (word-processor or even a paper-notebook) but we encourage students to use Moodle's (the VLE's) Personal Journal tool. Further, the practice of reflection on this course, which is uncommon on professional computing courses [29], will contribute towards their development as reflective practitioners.

RESEARCH QUESTIONS

As members of the course team and in our role as educators, we have been keen to receive feedback from students on their experiences on the collaborative activities—whether the collaboration contributed to or enhanced their learning of the course concepts. Next, as researchers of e-learning environments, we are interested in investigating the pedagogical effectiveness of wiki as a tool for collaboration in distance education and the effectiveness of collaborative activities in the wiki environment towards the students' learning experiences on the course. Consequently, we have focused on the following research questions:

> Q1: Did the wiki activities facilitate collaborative learning as intended?
> Q2: How might the usage of wiki be integrated with other tools such as a scheduler for organisation, or a group-blog or forum for discussions during collaborative requirements development?
> Q3: What are the challenges that students face in collaborative requirements development and specification? These challenges include: resolving conflicts in the perspectives of different team-members; building trust and shared values; norms for communication; and the roles of the team-members contributing to a wiki (authors, editors, readers, facilitators).

To address these research questions, we devised a set of more concrete questions to elicit feedback from students. In the third TMA, which was scheduled in the last month of this five-month course and after the students had completed the wiki activities, we asked the students to report on the reflections that they had been recording in the reflection template throughout the course. These reflective questions in the TMA are related to one or more of the research questions listed above:

1. Where was your understanding of the RE process enhanced by your involvement in collaborative exercises? (to provide input for Q1)?

2. Is a wiki a good medium for collaborative work on a distance education course? (for Q1, Q2 and Q3)?
3. Is a wiki a good medium for collaborative requirements development? (for Q1 and Q2)?
4. Does collaborative authoring contribute to a better requirements engineering process? (for Q1)?

Data sources and data analysis

Since the TMA question (listed 1–4 in the previous section) had 15% marks allocated to it, the majority of students answered it (we had responses from 117 students). Of these responses, we have analysed a random sample of 70 (60%). In this sample there were 13 (18.6%) females and 57 (81.4%) males compared with 20 (17%) females and 97 males in the full data set. All students on the course are adults studying part-time and most of them are professionals in the software industry.

Along with the reflective accounts in the third TMA, we collated and analysed discussions by students on the forum (70 in all), direct e-mails from students discussing their wiki experiences (15), and e-mails from tutors (14—an average of two e-mails per tutor) discussing their perceptions of the wiki activities and their experiences with students in their tutor-groups.

Using the research questions to guide us through the collated data, we performed an inductive analysis of the various accounts of students' and tutors' experiences and their perceptions to identify the emerging themes, sub-themes and the inter-relationships between them. This involved:

1. Collecting the forum discussions and e-mails from students and tutors pertaining to the wiki tool and collaborative activities into a Microsoft Word© document.
2. Extracting the reflective accounts from the answers for each of the questions in the TMAs into a Word document.
3. Reading the different sociological accounts in detail to gain an understanding of the positive accounts and the obstacles that had been described in the data.
4. Identifying the emerging themes for both the positive accounts and obstacles, guided by the research questions. From these emerging themes, the top-level common themes were identified. The lower-level themes were found from multiple readings of the data.
5. Analysing the accounts in e-mails and the discussion forum in a similar way.
6. Assigning the sociological accounts from the various sources to the themes and sub-themes of which they most explicitly conveyed the core essence.
7. Validating the cataloguing scheme through dual-coding by independent researchers (coders) in order to ensure that the sorting criteria were operationalised effectively and that the sorting process was consistent. The process was iterative and the two researchers met to examine any discrepancies. These were resolved through discussion, and the sort criteria (the themes) were merged and documented. Following this another subset of data was sorted independently using the agreed criteria. Again any discrepancies were resolved, and the sort criteria were updated accordingly. This process was repeated one more time (three sorts overall) until discrepancies were minimised. Each time, the categories of themes and sub-themes became more concrete and more fully articulated. Finally, the entire data set was sorted using the stabilised sort criteria, and the two independent sorts were compared for consistency.

EVALUATION

The purpose of investigating the first research question (Q1) 'Did the wiki activities facilitate collaborative learning as intended?' was to evaluate these key aspects:

(a) the pedagogical effectiveness of collaborative activities in a distance-learning environment;
(b) whether and how the understanding of the RE process was enhanced; and
(c) the effectiveness of wiki as a tool for collaborative authoring.

We will now present the results of each of these aspects of Q1 and of the other two research questions (Q2 and Q3).

Pedagogical effectiveness of collaborative activities in a distance-learning environment

The following sub-themes for *collaborative learning* emerged:

- *Understanding of the course concepts:* We received many positive responses of which the following are representative of the benefits that the students have stated in terms of knowledge-sharing and learning.

  > I did gain something from it. By working [through] the activity it did improve my understanding of gathering and refining requirements.

  > . . . a more comprehensive list of requirements may be achieved as some will be included in the list that may not have been thought of by an individual. I realised a couple of requirements that I had not thought of myself when analysing the appointments system [the case study].

- *Peer review and feedback:* The students have mentioned about benefiting from comments received from fellow students during the collaboration.

  > The old adage 'two heads are better than one' is truly apparent during the collaborative exercise. This can be seen visibly when one author posts an item on the

wiki and subsequently other authors make comments as to its correctness.

. . . how the meaning of a requirement might be clear to the originator but ambiguous to others, and how collaboration helped to remove this ambiguity.

- *Clarification of own contributions and understanding:* The inputs and views from fellow students facilitated the students to clarify their understanding of the course content related to the collaborative activity.

  Even though I understood exactly what I was trying to specify, it wasn't until I received feedback, and, indeed, gave feedback that I realised that some of what I had written was open to misinterpretation. This enabled me to remove ambiguity from my requirements.

- *Re-interpretation and self-reflection of one's contributions:* Students felt that peer-review and assessment helped them to re-assess their understanding of the course concepts and to reflect on their individual contributions and learning.

  The collaborative activity allowed me to see how the others addressed this question and evolve my own contribution and understanding based on these.

  The discussions from this activity helped me to reflect on my own views and potentially modify them (and the requirements).

- *Integration of multiple viewpoints*: The students appreciated the role of multiple viewpoints in clarifying understanding.

  . . . improved results. The collaborative approach incorporates more views; [if] properly managed, this usually leads to better results.

- *Aggregation of group knowledge:* The students acknowledged the collaborative construction of knowledge within the group. The first quote also outlines the role of wiki in RE.

  Wikis because of their simplicity with little process or workflow overhead allow content to be created and changed quickly, with the changes immediately visible to everyone involved. Anyone involved can submit new ideas, change existing content if incorrect and take issue with points raised. Because everyone's contribution is identified it empowers everyone involved. The group knowledge quickly becomes aggregated in one place instead of being dispersed throughout multiple communication channels. This improves requirements engineering since the quality and tempo of team interaction via the wiki has been enhanced.

- Collaboration facilitated learning and knowledge-sharing in a distance-education environment:

  Brings distance learning students together from different parts of the country to work on a topic when they would normally have to work in isolation.

However, students had mixed perceptions about collaborative activities: they were positive that collaborative activities were a way to bring students involved in distance-education together but some perceived collaboration as being onerous and not in sync with OU's philosophy of flexible (open) learning and learning in one's own time.

Obstacles to collaboration

- *Loss of flexibility in study patterns:* In a part-time distance-learning environment of the OU, students have the expectations of studying in their own time and any collaborative activity is considered to be a burden.

  I tend to study once every few weeks and do several chapters at once—basically, I organise my studying around my life. Now . . . I'm being asked to organise my life around my studying.

  Students are already pushed for time to complete courses; this is an extra time intensive task to perform. Enthusiasm to participate will drop when other work pressures are high and students may do as little as possible. When pushed for time participants may not want to argue a point in order to finish the exercise quickly.

The following quote highlights several interesting aspects and is representative of several comments that we have received on the loss of flexibility in part-time distance education due to collaborative activities that are assessed and have to be completed by some specified deadlines.

> The ethos of the Open University is that you can work in your own time, to your own time scales, in your own way (as long as the TMA deadlines are met). Forcing people into collaborative work produces a strait jacket that works against that flexibility.

This quote highlights some of the challenges that global software development teams would face if the stakeholders and other project team members are based in locations where internet connection and even having access to electricity could slow the collaboration and affect the project schedules.

- *Waiting for others to contribute:* Collaborative activities on the course require everybody to contribute well before the deadline to give sufficient time for giving feedback to one another and achieving an agreement towards the final product the group has to produce. Waiting for others to contribute was one of the main obstacles in the positive experience of the students.

  Non participation and late participation may have a negative effect on others within the group. Groups may split into early participating and late participating sub groups.

  Where a wiki does not work well with OU studies is the sporadic nature of group members' contributions. Some will contribute a lot at one time and then not return for a number of days. Effective collaboration requires regular contributions.

On the other hand, some students felt that the asynchronous environment of wiki was an advantage in allowing group-members to contribute at a time that suits them:

> In terms of collaborating on an OU course, the benefits seem to outweigh the disadvantages; it is

> difficult for all people collaborating to be able to arrange a pre-determined time to collaborate, so using the wiki as collaboration medium is quite effective.

Then there were issues of *peer-reviewing and critiquing* (as is common in group-work).

> Some students just weren't professional and felt they had the right to criticise other students work without being constructive.

Collaborative activities facilitated learning of the course concepts (RE) and the RE process.

Understanding of RE concepts and the RE process

The activities in the TMAs were designed to give students the practice of working through the following course concepts:

- specifying functional and quality (or non-functional, e.g. usability, security) requirements from the perspective of different stakeholders in the case study (TMA01);
- collaboratively arriving at a set of requirements that do not have conflicts, ambiguities, and duplicates (TMA02);
- collaboratively specifying the fit criteria (quantitative measures) for the requirements and to ensure that the requirements are specified in a way that they can pass through the quality gateway and, hence, can be included in the requirements specification (TMA03).

In addition to these explicit assessment-driven activities, our intention was that students gain the experience of working in a team, learn to negotiate and to take decisions to arrive at the end-product required for the TMAs. The collaboration facilitated the explicit learning of the course concepts that we had intended but the students also reported *incidental learning,* as discussed below. Our previous experiences in this course and related courses (e.g. the Human–Computer Interaction) in the SE curriculum in our department are that it can sometimes be difficult to convey through course-texts the significance of stakeholder-participation and participative RE, and that RE is an iterative evolutionary process and requirements change and evolve with time. However, through the collaboration on this RE course, the students discovered these key characteristics of the RE process through their own experiences. This is a consequence of *experiential learning* which implies a, 'direct encounter with the phenomena being studied rather than merely thinking about the encounter, or only considering the possibility of doing something about it'. ([30]: 9 quoted in [31]).

- *Participative RE helps in refining and validating requirements*:

  > Identifying duplication, ambiguity and conflict in requirements: This is often the hardest activity, and one which benefits from a variety of views rather than those of one person.
  >
  > . . . It is this 'openness' that will lead to a better quality process in the long run: For example, the simple fact that my requirements were going to be viewed by other members helped me to think clearly about specifying my requirements. This, in turn, led to me writing less ambiguous requirements.

- *Significance of stakeholder-participation:*

  > The collaborative activity helped to elicit missing requirements for the product. This was particularly evident as each group member was of a different stakeholder type, and therefore focused on a different set of issues and requirements. The collaboration between different stakeholders highlighted the benefits which can be achieved by ensuring all stakeholders are included in the Requirements Engineering process.

- *The RE process evolves and is iterative in nature:*

  > Before this course, I had in mind that requirements would be written and then 'set in stone'. The collaborative activities have helped me to understand why this approach would not work successfully in the real world. The iterative approach in the activities led to higher quality requirements which could pass through the quality gateway.

Next, we report the evaluation of the third aspect of Q1: how effective is wiki for collaborative authoring?

Effectiveness of wiki in collaborative authoring

This account also provides inputs for the second research question (Q2): 'How might the usage of wiki be integrated with other tools such as a scheduler for organisation, or a group-blog or forum for discussions during collaborative requirements development?' The following sub-themes emerged in our analysis.

- *Availability 24x7:* Students mentioned the advantages of wiki being web-based and accessible 24x7 which helps in supporting remote collaborations.

  > The advantages are that it is easy to use (no training required), simple to access (you only need a basic PC), and available 24 hours a day 7 days a week, which makes it ideal for students who have to work at odd hours.
  >
  > The wiki is a good medium for collaborative work on an OU course as it provides a central point of access since the location of its members is spread far and wide across the country and even the world. The tool is accessible 24-7, however it is assumed that each member has access to the Internet.

- *Group-work:* Some students found that the wiki facilitated collaborative work.

  > The main advantage of a wiki within collaborative work is the ability for multiple individuals to work on the same content. This enables people to collaborate independently of each other.
  >
  > It is difficult to see how our group could have produced and reviewed a set of requirements in the space of 2–3 weeks without the Wiki. I found the group discussion pages useful to make suggestions to

other members of the group and to make arrangements for editing the TMA Wiki.

- *Saving costs of travel:* Students mentioned how wiki-based collaboration can help reduce travelling costs for face-to-face team meetings.

  Online wiki-based collaboration will be less expensive than hosting meetings at a site to which each travel member needs to travel (and possible stay in hotels).

- *History and evidence of contributions:* The wiki has a history function that keeps a record of the changes that are made to the wiki by the different authors in the collaborative activity. This function has been particularly useful for assessment. Students were asked to post the entries on the History page as an evidence of their contributions towards the process and product. The history function is particularly significant in requirements development where each requirements engineer has a sense of ownership and responsibility for the requirements that he/she contributes to the RE process.

  The most important function, for my opinion, is the possibility to trace all entries, changes and deleted entries. With the aid of that function it is very comfortable to get a good overview on progress of work and also a history which gives one the possibility to create reports, for example.

  With the ability to quickly assess the modification history, it is also possible to easily track changes.

  It [wiki] allows a history and audit trail of documentation to be automatically maintained and referenced in the future therefore enabling traceability of requirements through to development.

While investigating research questions Q1 and Q2, our analysis uncovered several *technological obstacles* with the wiki in OU's VLE.

Technological obstacles

One of the obstacles was related to the *user interface design of the wiki environment.* The editing window in the wiki is small and does not provide enough context and content for the document being edited. Students had to scroll the content up and down while they were entering text in the wiki via this editing window.

> However, I feel that the wiki tool we used is quite limiting. The editing window was very small and it was difficult to get your formatting right.

The *poor navigation w*ithin the wiki was another obstacle:

> It is a time consuming tool to use, as navigation is poor, for example one must always return to the root before viewing another branch, i.e. if the user is in the general discussion, they must exit to the level above before entering the relevant TMA page.

The students had to keep going back to the wiki to check if any new contributions by other group members had been made.

> It would have been good to have some mechanism for requesting alerts on certain pages to save you constantly having to check.
>
> One of the problems I found was that there was no method of automatically being notified of wiki changes. I found myself having to log in intermittently in order to see whether my fellow collaborators had added anything to the pages. It would have been useful to have perhaps an RSS feed, or e-mail notification option available that notified other users of changes.

During the collaborative work towards the second TMA, we (the course team) came across a major technical obstacle: this was the *absence of a locking mechanism* to prevent concurrent updates. That is, if two people tried to edit the same wiki page at once, conflicts would occur. On our request, the software developers modified Moodle's wiki for the third TMA so that a particular wiki page on which a student (in a particular student-group) is currently working would be locked for usage by other students in that student-group, and only tutors could override the lock. But the absence of the locking mechanism in the second TMA affected (negatively) students' experiences with wiki.

> Depending on the Internet connection and traffic volume at the time this is can be a frustrating user experience, especially where a user is locked out until another user has finished updating the wiki.

This sociological account is representative of the various *user interface design issues* with the wiki environment:

> I feel more effort should be invested in looking into how the user experience of the wiki can be improved. Things like alerts on pages, formatting text and creating structures should be more intuitive to allow the student to focus on content.

Next, we analysed the data for Q2: How might the usage of wiki be integrated with other tools such as a scheduler for organisation, or a group-blog or forum for discussions during collaborative requirements development?

Role of wiki in collaborative requirements development

The collaborative activities involved receiving feedback from one another and discussing issues to arrive at an agreed set of requirements. We had suggested to the students that they should use the wiki not only for collaborative authoring but also as a discussion medium. Over half the students in our sample referred to the *inappropriateness of the wiki for discussion*. If the students used the 'discussion' page that we had set up for each TMA, there was no way to relate the changes in the wiki-content to the discussion or the dialogue-thread that resulted in those changes to be made. If they used the main TMA page for discussion, they found it difficult to separate out the discussion and follow it up midst the requirements descriptions:

> The nature of collaboration is discussion and debate. . . . The Wiki is a poor tool for keeping a sense of order to these multiple discussions. The Wiki does not create a 'thread' that can be followed. The Wiki does not clearly identify the contributor. The Wiki does not clearly time stamp contributions. The Wiki does not separate discussions about points so a great deal of searching is required before a thread of a discussion can be followed.

The lack of structure in the wiki and also when the wiki-content grew, students found it difficult to keep track of the discussions and the actual requirements, and suggested that we provide them with a document-structure in a wiki.

> Much has been made of the free-form nature of the wiki but even in our small collaboration I found the totally free-form nature of the wiki made it difficult to read through addition after addition and find threads for each requirement.

Lack of synchronous communications within the wiki environment: Over half the students in our sample mentioned the need to engage in some form of synchronous communication for discussion and debate ranging from face-to-face sessions to telephone conferencing. Many suggested the use of a forum so that there could be identifiable threads of communication. Indeed, some groups did engage in some form of synchronous communication.

> I do not believe that a Wiki can be used in isolation when collaborative working, rather it should be adopted alongside other more traditional methods e.g. telephone conferencing and face-to-face meetings. . . . face to face meetings should take place at various points in the requirements process in order to ensure that the process is managed correctly and difficult issues reviewed.

Thus, the students were generally in agreement with our own view and the views expressed by the tutors that while a wiki has strengths in recording decisions and for supporting collaborative authoring, it needs to be supported with a medium for synchronous discussion to facilitate timely decision making (face-to-face meetings are not possible in this distance-learning course).

> In TMA 02 we had a split of the communication methods that the group members wished to use, half used messaging and half used the group discussion wiki. Members using the messaging would occasionally post comments on the wiki whilst doing the bulk of their work on messenger. . . . So I've learnt that you should pick the right method of collaborative communication in the right situation.

Another major obstacle was the *relative lack of socialisation between group members*. The students do not meet face-to-face in this course and, therefore, it is only through online socialisation activities that the students will get to know one another. Whilst we did incorporate an 'ice-breaker' into the first TMA, this has proved to be inadequate and several students have commented on the difficulty of working with a group of relative strangers.

> Where project teams already know and understand each other, electronic communication is fine. Where strangers do not, all non-verbal communication is lost, leading to misunderstanding and potential conflict.

Finally, some students felt that for a smooth process towards production of a consolidated artefact (a set of requirements), individual student members should have *pre-defined roles.*

> To optimise collaborative authoring (and therefore the quality of the output) roles and responsibilities for authors are required to ensure issues such as identifying dependencies and conflicts between requirements can be fully resolved.

In spite of the obstacles, students felt that the wiki did meet their needs for collaborative requirements development:

> In the requirements process I see a structured Wiki being a very powerful tool in deriving requirements from many people on a large project that may be located around a country or the world. It centrally brings all the requirements together for all to see and update constantly. It allows more experienced Engineers to have an input in remote projects that in the past would have required reports to go back and forth, whilst losing time and competitive edge.

For the third research question (Q3), 'What are the challenges which students face in collaborative writing and requirements development?', we uncovered a number of obstacles in the sociological accounts.

Challenges in asynchronous collaborative requirements development

The obstacles that the students experienced ranged from not having synchronous communication mechanisms that they felt were vital for negotiation and for arriving at a consolidated set of requirements in requirements development, to not having 'rules' for collaboration, and not having formal 'roles' in the group about managing the collaborative process.

> Face to face working reduces the time involved and the chances of written suggestions or amendments being misunderstood as in the case of the wiki, with no need to wait for confirmation etc. Additional tools such as net meetings or video conferencing can help. . . .
>
> A much better medium . . . would be a face to face meeting, as members of the group can discuss in real time and come to an agreement much more quickly.
>
> As there is no specific owner for the collaborative work, there was a dependency on one person voluntarily pulling all the strings together, for example in TMA02 to incorporate all the suggestions into the final presentation. This is an extra burden for one person.
>
> Also, the collaborative tools used (i.e. the Wiki) and the 'rules' which collaborators have to abide by, in my opinion, have a significant impact on the effectiveness of the collaborative process.

Further, they felt that a wiki might become unusable and unmanageable for a large project.

> . . . in medium or big ones [projects] one will probably lose the audit ability. There are missing some fundamental functions like a real professional version control, for example . . .

These observations by students are in sync with those reported in [32] where wikis have been suggested for early requirements elicitation and thereafter a requirements management tool should be used.

Although students were working on a case study and we had designed the activities to simulate, real-life RE practices, the students did realise that the TMA-deadlines forced them to arrive at some early decisions, which may not always be possible in real-life where negotiations could be difficult at times and also time-consuming.

> The collaboration exercise has reinforced the difficulty of reaching a consensus between colleagues and users. As students taking on the roles we do not have the same problems or pressures that genuine role players would have, so we can give and take points without any 'political' damage.

In the next section, we will discuss how this evaluation has consequences in three areas: (a) designing wiki activities on SE courses; (b) technology-enabled learning in SE education; and (c) enabling and disenabling factors to virtual team effectiveness in global SE/RE teams.

DISCUSSION

Designing of wiki activities on SE/RE courses: Revisiting the first research question (Q1), we can conclude from our analysis, that wiki activities on the course facilitated collaborative learning of RE. Some students have expressed reservations about the collaborative work in a distance-learning part-time course and this is understandable. In an institution such as the OU where flexibility in studying patterns is one of the main advantages that it offers, collaborative work can seem inflexible. However, if we (the course team) continue to emphasise the pedagogical effectiveness of the collaboration in students' learning, development of their communication and team-working skills, and transferable skills for industrial practice, the students will be better able to appreciate the benefits of collaboration. To emphasise the role of collaboration in requirements development, we have been integrating readings (papers from conferences/journals) on GSE and distributed RE in the course materials.

Since the RE course is at a post-graduate level and the majority of our students are software professionals, we adopted a non-prescriptive approach to team-working and deliberately avoided discussing with the students issues relating to group management, such as co-ordinating group responses or organising dates and times for group discussion, or assigning the team-members individual roles of facilitators, moderators, time-keepers and editors, and so on. However, based on our analysis of the second and third research questions (Qs 2 and 3), we are now developing guidance for the next cohort of students to suggest the possible roles in group-work, group-management issues, and the rules or social norms of collaborating in a networked environment (for example, making contributions in time and as per the schedule)—but we still expect students to be self-organising.

Further, to address the problem that the students faced in scheduling time for collaborative activities, we have now suggested to the next cohort of students that they should consider using a simple meeting scheduler, e.g. (http://www.meetomatic.com/calendar.php, last accessed 20th January, 2008), to plan a schedule for collaboration and synchronous communication. We have also encouraged students to use instant messaging for discussion of the feedback that they receive from one another while collaboratively developing the requirements specification in the wiki environment.

Unlike some other wikis, the Moodle wiki does not have an embedded discussion forum and our analysis has revealed that it is essential that students have a usable discussion medium and that they are able to link the discussions with the contributions/changes that they make on the wiki. In response to the feedback from our students, the OU's wiki has now been enhanced to include a commenting facility where students can comment on individual requirements on the main wiki page itself. Students also found that the lack of structure in the wiki was not in sync with the structured RE templates and processes that the course focuses on (Volere process and templates in [19]). We have now developed a structured template (in a Word© File and which can be copied and pasted into the wiki) as an option that students can use within the wiki as an alternative to unstructured wiki. The need for a document-structure and usage of templates has also been discussed in the account of using wikis in RE development in industrial practice (e.g. [7, 15]).

As with every technology, usability is the key attribute for a positive user experience and poor usability of an educational technology can overshadow the pedagogy and disrupt the learner experience. Almost all the usability obstacles with the wiki tool discussed in this paper, including the editing window being too small, the inappropriate locking mechanism, and the discussion/rationale being separate from the requirements specification, have since been addressed by the OU's VLE team and the software developers in the latest version of the OU's wiki tool. Since the OU's VLE's development is ongoing, we will continue to feed back students' requirements to the VLE team and conduct usability evaluations of the wiki as and when new features are implemented and before it is introduced to the students.

Technology-enabled learning and SE education: Several lessons have emerged from the evaluation of our wiki initiative in the RE course. First, we have learned that there are key success criteria for the introduction, design, and implementation of technology-enabled learning. Examples of these criteria include integrating the usage of technology within the pedagogy of the course; a direct link between the learning outcomes and the activities the technology will support on the course; engaging all the stakeholders and specifically considering the requirements of tutors and students before and after the implementation in terms of staff-development and guidance/support documents, and ensuring that the technology is usable and accessible through extensive user-based evaluations before the technology is deployed. In SE programme and at post-graduate level in a distance-education environment, it has been challenging to introduce collaborative activities where students have always worked through the course materials on their own. However, our evaluations have shown that technology-enabled collaboration has facilitated learning and students have become aware of and sensitised to the various issues and challenges of team-working in virtual teams in real-world SE projects. The reflective activities have made the students re-interpret their experiences on the course and relate them to practice. The reflections have enabled them to raise issues and propose solutions for effective virtual team collaboration: for example, synchronous communication should accompany asynchronous collaboration; need for a facilitator, moderator and/or editor to manage the collaborations; and 'rules' or norms are required for effective participation and collaboration.

In [33], the authors discuss that global SE teams should go outside boundaries, that is, instead of just learning within their groups (*internal learning*), which fosters shared understanding, the individual group-members should interact with other teams and external individuals (within the organisation or outside) so as to acquire new knowledge and this *external learning* could be a source of innovation. We are exploring whether we can introduce an additional activity where individual group members are asked to interact with other wiki-groups on the course (for e.g. to validate requirements or to discuss the case study) to simulate the desired practice in global SE teams of internal learning (within the group), and the more diverse external learning.

Re-visiting the *five-step model* in Fig. 1: we have applied the first three steps/stages to design the collaborative activities (as discussed in the section 'Approach to Collaboration in the Requirements Engineering Course'). The evaluations have shown that the processes of information sharing, knowledge construction (stage 4) and learning have occurred. The reflective activities on the course are aimed at the development of cognitive skills (stage 5) where students will learn to reflect on their learning, relate the learning to their practice, and evaluate their work-practices in view of their learning on the course. In the current presentation of the course and since the evaluations reported in this paper, we have integrated reflective activities/questions in all the three TMAs of the course.

Enabling and disenabling factors to virtual team effectiveness in global SE/RE teams: The most important deficiency in the present scheme has been the relative lack of socialisation between group members. The students do not meet face-to-face in this course and, therefore, it is only through online socialisation activities that the students will get to know one another. Since the course has a short presentation period (around 5 months), there is little time to allow students to engage in essential socialisation activities. Whilst we did incorporate an 'ice-breaker' into the first wiki activity, this has proved to be inadequate and several students have commented on the difficulty of working with a group of relative strangers.

In [33], the authors state that co-ordination of work in distributed teams is accomplished through spontaneous informal communication and an important precursor to informal communication is *awareness* of other team members: what they are doing, and when they would be available for collaborative work. We are, therefore, designing an alternative ice-breaker activity in TMA01 where students introduce themselves and also collaboratively plan a schedule for completing the collaboration in TMA02. We are hopeful that this early planning and discussion of each other's time-constraints and other commitments may make them 'aware' of one another.

As is common in group-working settings and also reported in research on computer-supported collaborative environments (e.g. [34]), our students were sometimes hesitant to change the contributions of others or comment on one another's contributions, and some of them felt that the peer assessment was not constructive. Such concerns are common in virtual collaborations (e.g. [35, 36]), where trust, shared understanding and depth of relationships are discussed as being the antecedents for effective collaboration. Though the 'new' ice-breaker activities that we have suggested may help in developing 'awareness' of one another, the course's duration may not be sufficient for the development of trust and shared understanding.

Face-to-face communication can promote relationship building [35], and as we have seen in the analysis reported in this paper that in collaborative requirements development, face-to-face encounters can help expedite negotiations and decision-making. Face-to-face meetings are not feasible in this distance-education course, so we are considering about generating the sense of presence of fellow-learners in the virtual space through real-time interactions within a 3-D multi-user virtual environment (MUVE). 3-D MUVEs provide virtual

worlds which have avatars (digital surrogates) that move around within the digital world and interact with others and with the objects in real-time in a virtual environment. Second Life (www.secondlife.com) is an example of 3-D MUVE and is being increasingly employed by academia (e.g. [37]) and industry for a variety of initiatives: collaborative designing, holding live events in the virtual world with audio and video streaming; organising meetings and interviews; displaying arts, posters and banners for sales and marketing; and so on. Virtual worlds such as SL offer realism, immersion and interaction, and a sense of presence for the 'Avatars' which may facilitate relationship-building which is an antecedent for effective operation of a virtual team. We are planning to set up work-spaces and activities in the '*Open Life' Island* of the OU in Second Life for real-time interactions such as: ice-breaking tasks; holding meetings in SL and making notes/keeping records of transcripts of conversations in SL (for reporting in TMAs); and attending live events in SL.

We are continuing to monitor the student experience of collaborative requirements development through the reflection aspects of the assignments, student- and tutor-interviews, as well as formal university end-of-course surveys to see how effective our changes have been in practice and we intend to present our further evaluations in future publications.

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