Using constructivist experiential simulations in RE education

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Abstract

Experiential simulations have been used effectively for teaching business, medicine and engineering. Many are supported by computer systems that create artificial virtual spaces so learners can safely practice intricate professional skills. Surprising few attempts have been made to utilise such approaches in teaching IT/IS principles and requirements engineering (RE) in particular. This paper reports on FAB ATM, which is one of those few learning environments which rely on computer simulation and which have been designed specifically to train IS professionals, and in particular, develop their RE skills. In its framework, FAB ATM combines and balances elements of video-based computer simulation with activities, such as classroom instructions. This paper explains the principles of the FAB ATM design, its coverage of RE activities and the anecdotal experiences of students and staff that have used this environment in practice.

1. Introduction

Using computer simulations in teaching management, economics and human resources has become an attractive option in University education, where gaining practical experience is vital in developing professional skills [3]. In such simulations, students commonly play executive roles, make decisions related to business planning and operation, receive feedback on the quality of their decision making process, and re-enter the simulation to improve their performance in the selected business scenarios [3, 12]. Such scenarios may involve operational aspects of running the business, problem solving and diagnostics, crisis management, and organisational or social interaction [12, 15].

The use of simulation in teaching information systems (IS) skills is also gaining significant momentum. We found examples of IS-related educational applications ranging from e-business, supply chain [eg, 5, 32, 33] and knowledge management [eg, 26], to IS development and project management [eg, 30].

Our own experience in deploying role playing, games and simulations in IS [6, 7], begun with educational experiments in implementing Horning and Wortman's [17, 41] 'software hut' principles in running large scale software engineering projects. Such simulations allowed students to experience realistically scoped software development and to practice an entire spectrum of class-room learnt professional tasks. While the approach strengthened students' technical skills across the entire software development life-cycle, the 'software hut' simulations were especially valued for their ability to place students in a typical techno-organisational environment where they had to rely on peer-to-peer collaboration, engagement with clients and developers, and inter-personal communication [36]. Learning in such an artificially generated communication-intensive context was deemed especially useful for student exploration of the earliest stages of system development, i.e. requirements engineering (RE).

Typically, RE incorporates elicitation of requirements from users and clients, analysis of the collected requirements, and then their specification and validation [37]. Since the earliest days of RE education, role-playing and team games, while encountered only sporadically, have indeed been trialled and used as an effective alternative to the traditional mode of teaching in lectures and tutorials

[1]. Using simulation and game playing in RE education, however, poses many challenges for the hosting educational institutions (access to sites, real projects and professional participants) and for the training of RE educators (communication and facilitation skills) [42]. Like many other university IS/IT schools, the staff in the School of Information Systems at Deakin University is looking forward to harvesting the benefits of using simulations in RE education, and at the same time, determining effective ways to address the challenges of using such simulations to support teaching of RE knowledge and skills. Unlike many other IS/IT schools, however, we also rely on computer simulations which create an immersive virtual RE environment where students can practice some of their professional RE skills in the safety of the University setting. While the electronic gaming and computer simulation industry is often seen as purely focused on entertainment, education researchers are increasingly recognising the importance of engaging, immersive and effective learning environments which are also enjoyable [eg, see 18, 21, 34]. The challenge for us as RE educators is to select only the relevant or appropriate aspects of advanced simulation approaches (such as those found in electronic games), and to incorporate them into educational curricula. However, in the absence of examples of such RE simulation environments, we have decided to undertake ongoing research and development to explore novel educational and technological approaches which can be effectively blended into a broader RE learning framework including self-directed study, group and classroom activities, computer simulation and online collaboration.

To address these evident gaps in RE education research, this paper reports on our experiences designing and using a simulation environment called Deakin Live Simulator (or LiveSim) - a customisable state-based multimedia environment which supports the development of interview-style experiential simulations. Deakin LiveSim has been used to produce five simulations for use in various disciplines, with the first simulation piloted being the First Australian Bank Automatic Teller Machines (FAB ATM) designed for an IS context. The main objective of FAB ATM is for students to specify system requirements for the new line of FAB's ATMs. Students are initially introduced to the FAB ATM project in class, and then research and brainstorm the general issues of ATM use via online discussion groups and chat rooms. Students then use the FAB ATM simulation (on CD-ROM) to interview simulated bank employees who report on FAB's business and technology, and state numerous requirements for the new ATMs (business, software and hardware). While immersed in the simulation, students identify and analyse redundancies, conflicts and omissions in the collected requirements, and they eventually reconcile, formalise, validate and specify these requirements. Students then participate in a final reflection (or debriefing) session in class and online.

The paper first provides an overview of the FAB ATM simulation design; then it describes the FAB ATM educational framework used in teaching requirements engineering knowledge and skills; subsequently, it reports on the anecdotal experiences of students and teachers who have used the simulation; finally the paper concludes with reflections on the contribution of the study and the future research opportunities.

2. Designing an Experiential Simulation

A vital ingredient of any educational system or an artefact is its learning design. The FAB ATM simulations have been designed around the constructivist epistemological view of learning, which holds that there are many meanings and perspectives (not just those of the instructor) and many ways to structure our understanding of reality [24]. Learning is seen as occurring when individuals interact in (or experience) reality and construct knowledge (rather than acquire it) separately from instruction [11, 24]. Based on this epistemology, instruction does not involve disseminating knowledge, but rather involves supporting learners in their construction of knowledge [10] and development of knowledge construction skills [11]; recognising the value and importance of prior knowledge [25]; and incorporating learning tasks into realistic contexts to facilitate richer mental models and multiple perspectives [24].

Learning in a modern classroom often incorporates educational games and simulations. Games are commonly distinguished from simulations [15] by emphasising players' competitive behaviour as governed by rules, constraints, privileges and penalties, with the primary objective being winning the game. Simulations by contrast involve participants taking on social or professional roles and performing associated tasks which result in privileges and/or consequences; participants making decisions over periods of time in light of problems, issues or events which emerge as a consequence of previous decisions; and simulating dynamic and authentic relationships among simulation objects which change over time. Our intention when designing FAB ATM was for participants to take on the role of a business analyst, display cooperative behaviour by engaging in authentically unconstrained interviewing process of computer simulated characters (bank employees) and make decisions about the elicited system requirements. We believed that FAB ATM can therefore be best described as a simulation rather than a game.

A distinction is often drawn between experiential or symbolic simulations [see, eg, 15]. Experiential simulations are like dynamic case studies where participants are on "the inside" and involve: learners being an essential element of the simulation by performing tasks associated with their role and controlling decision-making; scenarios unfolding in part due to the actions of learners; multiple pathways through the simulated reality in response to learner decisions; and consequences for learner actions in terms of other participants' actions or in the problem context itself. Symbolic simulations, by contrast, are typically computer representations of a function, behaviour, process or equipment where learners manipulate variables in these models and are therefore not a functional part of the simulation itself. Learners are not assigned a role in which they have an invested interest in the outcome, but rather perform professional tasks relating to scientific discovery, explanations, predictions, etc. We wanted students to have a realistic experience of a business environment while using FAB ATM so that different requirements analysis outcomes could emerge depending on student decisions such as which questions to ask, which simulated bank employees to interview, etc. For this reason, we believed FAB ATM was best described as an experiential simulation.

One area in which FAB ATM is unique compared to many experiential simulations in the IS field is that its computer simulation utilises state-based modelling [16]. This approach allows the interviews of the simulated bank employees to move naturally from state to state in response to students' questions, to monitor mental states of the interviewed characters, and to represent the state of students' knowledge in the process. This contrasts with the standard 'programmed' behaviour of many educational simulations and games. The details of the LiveSim's state-based simulation engine and its FAB ATM configuration are beyond the scope of this paper.

Overall, FAB ATM's design is clearly set in the constructivist epistemology and relies on experiential learning theory and a state-based behaviour: it models the real world (eg, the workplace setting) in an authentic manner; it involves learners adopting a role within this setting (as they would in the workplace); it encourages learners to perform tasks and test ideas in a new (simulated) situation resulting in new experiences; and it involves educators facilitating learner reflections on these experiences [see, for example, 4, 12, 38]. The FAB ATM simulation therefore supports the typical stages described by experiential learning theorists such as Dewey [9] and Kolb [22].

In the next section we explain how FAB ATM supports the authentic learning of RE knowledge and skills.

3. FAB ATM Project and Computer Simulation

The FAB ATM project exposes students to both business and technology issues and problems in the context of a fictitious bank - the First Australian Bank (FAB), which has a long tradition and established clientele. The FAB's main objective is to lift its image by providing banking services which could be attractive to the new (young) customers, while at the same time, ensuring that these services would be accessible to existing (aging) customers. Modernisation of the bank's ATMs (Automatic Teller Machines) is deemed as the means of delivering these objectives. The FAB ATM project provides a simulation framework which involves individual work (research), collaborative effort in distributed teams (brainstorming, analysis and specification), some tasks conducted in the classroom setting (backgrounder, validation and debriefing), and activities undertaken in a virtual environment (computer simulated interviewing).

FAB ATM simulations constrain the students' experience by focusing on the important tasks and thus generating what we call a 'circumscribed reality'. We define such simulations as those which attach only key aspects of authenticity to its objects and environment [35]. They may sacrifice some degree of reality and yet they never cross the threshold of acceptability to the learner. To heighten the perception of immersion in this circumscribed reality, FAB ATM is highly interactive and real time, and relies on high fidelity images, sound and videos. To facilitate learning tasks, the employed media forms and interactions are designed to be very simple for the student user; nevertheless, the simulations often presents some serious challenges by creating complexity in the mind of the learner. To ensure the FAB ATM experience is believable, the simulation provides a continuum of learning activities occurring in the real (e.g. in the classroom) and the virtual worlds (e.g. the computer simulation, online chat rooms, etc) - an approach commonly known as 'blended learning'.

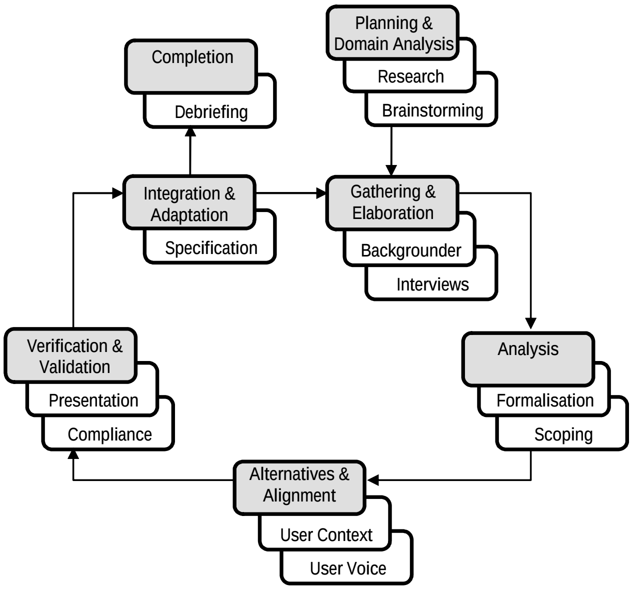

Figure 1: Requirements engineering process model, its activities (shaded) and student tasks (white)

In terms of the learning outcomes, the FAB ATM simulation allows students to experience typical RE tasks, which are commonly (and specifically in FAB ATM) undertaken in the context of business and IT alignment, improvement to a legacy system, changing business processes, existence of a rich stakeholder community, technological innovation and the need for past and future technology reuse. In the process, students follow an RE life-cycle, which fuses the elements proposed by Cybulski and Reed [8], Loucopoulos and Karakostas [29, ch 2] with those reviewed by Kotonya and Sommerville [23, sec 2.1]. The resulting RE process (see Figure 1) features a range of RE activities, which permit students to conceptualise the problem and its solution in a series of steps from fuzzy to formal, as follows.

1. *Planning of the requirements process* (in terms of organisational context and strategic management goals) [40] is done in conjunction with methodical *collection and organisation of domain-specific information* (in terms of domain knowledge and technology reuse) [20]. In the FAB ATM project, students undertake research of banking products (with emphasis on ATM technologies), they attend a backgrounder meeting with a bank employee (which is a class exercise), and finally conduct team-based brainstorming sessions resulting in a SWOT report which analyses the problem [39], its possible solutions and the problem-solving strategies likely to benefit the client.
2. Elaboration of needs and objectives (for business) and gathering of system requirements (for technology). At this stage, students conduct a series of virtual (computer-simulated) meetings with two FAB employees (either separately or together), each representing a distinct body of knowledge (banking processes and ATM technology respectively). Students initially plan the interview and then, via the simulation interface (see Figure 2), they ask questions, listen to the answers and discussions, interject when needed, observe body language, take notes, collect tabled documents and artefacts, and, under pressure of time, work collaboratively with incomplete data. An annotated transcript of all interviews is delivered at the end of this project phase.
3. Requirements analysis, which includes identification of needs and requirements, their representation and formalisation (in various UML models [27], e.g. use cases, sequences and collaborations and class diagrams), as well as, scoping and prioritisation of all the collected requirements [27]. In the process students need to determine how to capture (forms, diagrams, handwritten notes), condense and analyse the collected data (text, written reports, pictures and photos).
4. Evaluation of alternative views and interpretations [13, 28], as well as the alignment of business needs with system requirements which also allow inclusion of design constraints in the specification.

To this end, two basic methods are used by students in their projects, i.e. user context and user voice analysis - both drawn from Accenture's Foundation Method [2] and also utilised in the QFD and Six Sigma methodologies [31]. In the process, student teams identify and characterise stakeholder groups, conduct viewpoint analysis, reconcile conflicts, fill in omissions, and link problem statements with user needs and against system functional, data and event requirements.

5. Verification and validation of requirements needs to be conducted to ensure the requirements are high quality and they are ready for the final delivery. In FAB ATM, student teams ensure the specification's compliance with the standards and they present the selected (controversial and problematic) aspects of their specifications to the clients (either face-to-face in the classroom or remotely using online communication tools such as online discussions), with a view to obtaining feedback from the senior bank employee (i.e. the learning facilitator), to remove identified ambiguity and conflicts, to ensure requirements consistency and to identify missing information [14].
6. As the new solutions provide an improvement to the existing legacy systems, it is therefore necessary that legacy requirements are identified and adapted. The new systems will primarily consist of COTS and reusable components, so that their requirements also need to be integrated with new system requirements to complete the entire specification document.
7. Finally, all information sources and their views (students' own, their team members, and those representing the bank's novice and senior employees, management and technical staff) are all captured in the final version of the requirements specification document and submitted to the client. Throughout the process students are required to reflect on their learning outcomes and they receive regular feedback on their progress and on the quality of their submissions. However, at the end of the project a formal debriefing is also conducted to evaluate the entire project and students' experience with its various tasks.

The FAB ATM computer simulation is an integral part of the project, as described briefly in step 2 above. Students use the FAB ATM interviewing system to conduct a series of one-on-one or group interviews, which take place in a typical business environment (see Figure 2), featuring its own corporate colours, logos and stationery, commonly encountered office settings with familiar sounds and noise. Students take on the role of a business analyst and decide: what questions to ask (which elicit system requirements) of simulated stakeholders; who to interview; in what order; and in what combination (e.g. individually or together). Students' decisions determine the consequences for the simulation outcomes in terms of what requirements are elicited and, in some cases, even how stakeholders answer the questions (eg, when interviewed one-on-one or in a group session). This way, the state-based interview model used in the simulation allows for different teams to follow multiple pathways and arrive at distinct outcomes. Learners can therefore gain some degree of control over the elicitation process and can influence the elements which are important to the curriculum and the learning, without being overwhelmed with unmanageable complexity or responsibility.

The simulation also presents users with realistic complexities of a business meeting; which includes interviewees volunteering useful or useless information, tabling important documents, occasionally misunderstanding questions and making mistakes, contradicting or agreeing with each other when in group situation, or deciding to terminate an interview when they feel they are not listened to, or when the time is up. FAB ATM also creates irritating, though very real, distractions (such as phone calls and interruptions). In addition, the FAB ATM simulation is designed to overwhelm students with 'factual' information, and challenge them with unfolding events and time constraints.

Outside the computer simulation, students have opportunities for social interaction to discuss their learning, experiences and the knowledge they are constructing, including online, during class and in teams. For instance, after using the FAB ATM simulation, student teams reconcile their notes and observations, and conduct post-interview analysis and reporting. Before lodging the final specification document, the teams validate their findings in a formal presentation (face-to-face or by video-conference, synchronous or asynchronous) and receive feedback from a bank employee (this time a real person – the facilitator). Post-simulation debriefing sessions are run so that students can confront their imagination, preconceptions and ideas with the facilitator and fellow students.

In FAB ATM students are not merely "playing" their interviewing roles in the simulation, but they are fully immersed in the simulated environment emotionally [19] and experientially [35] by visibly turning into interviewers and becoming IS business analysts who are practising their professional skills. By taking on the immersive role in such an interview-style

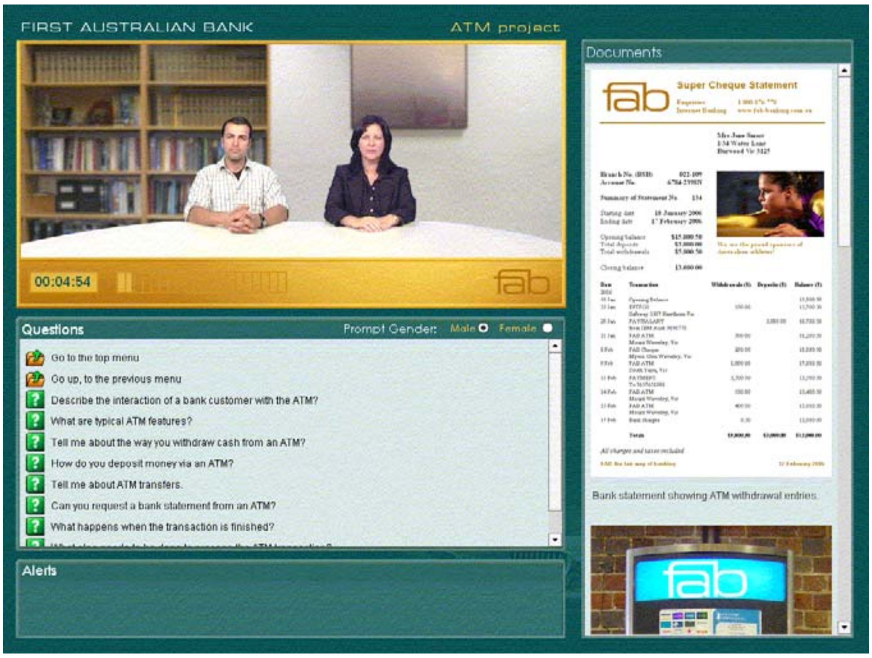

Figure 2: Sample FAB ATM screen

experiential simulation, FAB ATM allows students to engage in professional practice without leaving the safety of the educational environment.

4. Experiences Using an Interview-style RE Simulation

Students undertaking a course in RE with FAB ATM are of a mixed background. Some of our students are enrolled in a Masters or in Honours degree, with either IS or Commerce specialisation. The modality of the undertaken course is also varied. While in the past RE students were attending classes on-campus, today we also have a large proportion of off-campus and online students (some from remote campuses, some inter-state and others resident overseas). While there is only a small number of graduate students taking an RE course (the numbers vary between 50 and 70), students' expectations of the course, its teachers and teaching standards are very high. Some of the students are working professionals and already have gained experience in IS development, client communication and consulting activities. Some students have been involved in the RE process itself. In all this variability and richness of student profiles, we are also required to comply with the university policy for comparability of assessment, which states that all student cohorts need to undertake the same projects and be assessed in exactly the same way.

Considering the benefits of experiential simulations on one hand and the students' mixed profiles on the other, over a period of six years we experimented with various types of RE role playing and experiential simulations. For example:

- In 2002, we organised external clients to be interviewed by students. We found that we had very little control over educational outcomes.
- In 2003, non-associated members of staff played the role of clients. Those members of staff had very little training, interest and commitment to RE education;
- In 2004, we used RE tutors to play the role of clients. This approach resulted in success, however, in the subsequent years budgetary problems prevented us from re-implementing this model.
- In 2005, the RE lecturer played the role of a remote client to all teams, he used email answering all student interview questions, which resulted in unacceptable workload as he wrote 20,000 words.
- In 2006, we used FAB ATM, in which the computer simulation performed all labour-intensive project functions. The use of FAB ATM simulations presented no major problems so far.

Over the years, we have eventually arrived at the RE project solution, which presently features a mix of real-life activities, intensive online communication and a CD-ROM based experiential simulation (i.e. FAB ATM). In essence, the way in which experiential simulations such as FAB ATM can be “blended” with other learning approaches can be quite varied, with the simulation providing the impetus for research, discussions, team work, etc.

The FAB ATM project, which followed the RE process outlined in the previous section, was first used at Deakin in the graduate RE course during first semester 2006. Since it was the first trial of the approach, we did not undertake a formal evaluation, compare student learning outcomes, etc. Instead, we present here some anecdotal, preliminary observations and experiences which will form the basis of future research to investigate the learning outcomes of students and evaluate the learning approach described in this paper.

In terms of student experiences, at the end of FAB ATM project outlined in the previous section students were asked to reflect on their learning experiences, their difficulties and the strategies which they employed to overcome these difficulties. Students were not asked any specific questions about the simulation environment; nonetheless, many insights and reflection were recorded on the FAB ATM simulation. Examples of the indicative, anecdotal responses from students included the following:

- “Overall, this assignment has been a change from any other assignment, in terms of interacting with clients in a computer simulated environment.”
- “The interview CD is really a very good idea, which offered us a virtual interview environment via multiple media technology.”
- “The interview stimulation program did offer us a chance to be a part of interview, to touch it, to feel it and to experience it.”
- “The actual interview simulation session was very informative and convenient allowing some flexibility in the actual interview technique.”

At the same time, some students voiced concerns with some aspects of the simulation:

- “The interview transcripts were actually hard to produce, given the speed at which the interviewees talked at, and the limited knowledge we had on the subject.”
- “Some questions were too generic and did not add value to the interview.”
- “Interviewing was a bit hard as the CD didn’t answer most of the questions that we came up with during brainstorming.”
- “The most difficult part was consolidating the interview transcripts.”
- “I also found the interview tool limiting, in that it did not really allow us to display any of our skills in interviewing.”

As evident from the above comments, many of the difficulties students found were not in the use of the simulator but rather related to problems associated with the real-life tasks of collecting and analysing interview data. This is the very essence of the experiential simulation of circumscribed reality.

From the teacher’s viewpoint, FAB ATM provided many opportunities to rely on innovative and highly effective student learning styles (see Figure 3). In addition to the traditional ways of learning by ‘being told’ in lectures, ‘by discovery’ in tutes and ‘by doing’ in projects, FAB ATM also provides avenues for students to learn by experiencing work and by taking on professional roles. All these learning styles are actively pursued in lectures (FAB ATM demonstrations), tutorials (FAB ATM discussions) and projects (FAB ATM virtual environment). This is achieved by students immersing in an authentic and believable environment, and by conducting realistic tasks; the tasks, which allow students to learn ‘by observing’ people’s behaviour in a complex corporate setting, ‘by playing’ the professional roles, ‘by communicating” and ‘by collaborating’ with their team members and with the simulated characters (in both virtual and real context). Finally, students also take on the responsibility of teaching each other in face-to-face meetings and online discussion. Richness of the available learning styles offers RE teachers alternative paths to students’ minds, to seamless creation of new knowledge and skills, and most importantly, to the effective development of professional experience.

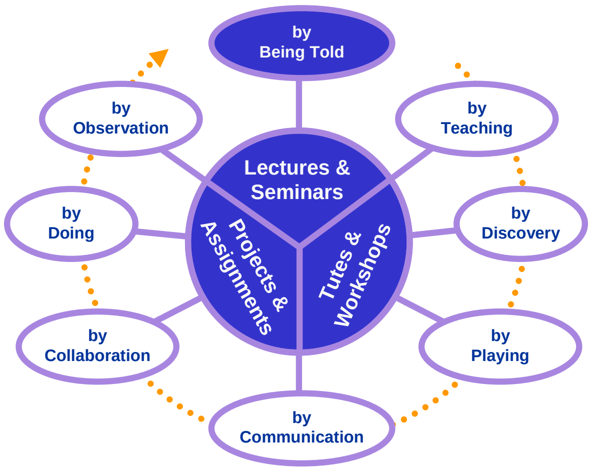

Figure 3: Learning styles available in FAB ATM simulation

5. Conclusions and Future Research

This paper has made an important contribution to RE by presenting the design of a novel approach to RE education, which involves a combination of traditional approaches (eg, classroom discussions), online approaches (eg, chat rooms, online discussion groups) and a computer simulation in which students conduct interviews with simulated characters. We have also described how such a blend of learning approaches can be used to teach students all aspects of a real RE process involving planning, requirements gathering and analysis, evaluation of alternative views, verification/validation of requirements, developing solutions and presenting a requirements specification. The FAB ATM computer simulation allows RE projects to be undertaken by remote off-campus students working in fully distributed teams. Our anecdotal findings from the FAB ATM project confirmed previous research in this area that role playing can contribute to the effective teaching of RE knowledge and skills. Fully immersive blended learning, as employed in FAB ATM, further enabled students to experience the realistic RE tasks in a simulation environment. Generally, students enjoyed the FAB ATM experience and believed that it had a positive impact on the development of their professional skills. The main difficulties faced by the students were mainly related to the RE tasks rather than the simulation environment itself.

While the experiences presented in this paper are largely anecdotal, there are a few practical implications which we believe are noteworthy. Firstly, the paper demonstrates that it is possible to develop a simulated RE workplace using a range of simulation and gaming techniques which allows students to engage in an authentic, but safe, learning environment to practice core RE skills. Our future research will involve making the simulation environment more configurable (for teachers and simulation designers), more user customisable (for students in terms of accessibility and internationalisation), so that other RE exercises and settings can be easily developed, without significant cost/time overheads. More emphasis will be placed on the automation of assessment tasks and computer-assisted debriefing of students, so that better services and assistance can be provided to off-campus students working in a largely asynchronous study environment. We also plan to conduct more detailed qualitative research into students' reactions to and learning outcomes from their participation in FAB ATM to gain further insights into this area.

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