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Case Study

Remote laboratory development as an action research: A case study

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This work presents a case study about how action research (AR) has been conducted in developing a real-life educational system. An explanation is given of the modified implementation of the classical AR methodology, based on the requirements of a remote laboratory system developed for the vocational training of students in higher education. This study reports a successful implementation of AR stages which established for the development process of a remote laboratory system along with the design of several research questions explored in each step of the system development process. It is believed that the outcomes of the study will help AR implementers to organize their research objectives, more appropriately, by addressing the organizational problems. The results of this study are also expected to guide the AR implementers to better integrate their research in solving domain specific practical problems.

Key words: Action research, remote lab, education.

INTRODUCTION

It is usually hard to build the connection between the real-life problems and research results; thus, creating the possibility of a big gap between research and practice. Today, in order to close this gap between academia and industry, organizations are becoming more focused on making research more relevant to practice (Zmud, 1996), especially in the field of information science. Accordingly, there are an increasing number of publications containing theoretical contributions that address real life problems and action research (AR) is one of the methods that can be used. In AR, researchers mix research and intervention, and involve organizational members as the participants of the research as well as shapers of the research objectives. In that sense, AR is more future oriented, and it implies system development in a collaborative approach by generating theory grounded in action (Gilmore et al., 1986). In other words, AR aims to address the practical concerns of people, as the members of system, in an immediate problematic situation within that system. The main objective is to initiate a change in a desired direction. In the AR approach, ‘action’ refers to all activities undertaken to tackle a real-world problematic situation. The action in AR aims to improve the situation using directly involved research elements to construct precise and generalizable results (Hindle et al., 1995). It is not a discrete event but a process composed of phases or different types of activities which dominate at different times (Mingers, 2001). A classical AR methodology is defined as a cyclical process with five phases: diagnosing, action planning, action taking, evaluating, and specifying learning (Susman and Evered, 1978). The process starts with a researcher diagnosing the current organizational situation systematically and it is very important that they

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have a thorough understanding of both the problem and its environment in order to determine the correct solution Planning specifies sequence of actions to be performed to improve or solve the problems identified in the first phase which identifies the target for change and the method to bring about that change (Baskerville, 1999). Data collection techniques are used before, during and after the action taking phase to collect a rich amount of data for the later analysis. In the evaluation phase, the results are compared to the objectives and expectations; the researchers determine whether the theoretical effects of the action were realized, and whether these effects reduced the problems. If the outcome is successful, the evaluation must critically ask whether the action undertaken was the sole reason for the success or were there other reasons. If the outcome is unsuccessful, improvements, including modifying the hypotheses, for the next iteration of the AR cycle should be created (Baskerville, 1999). Specifying Learning is the last phase which is actually an ongoing process throughout the AR cycle. The knowledge gained in the action taken is reflected on the activities, and results of the project. According to Baskerville (1999), the knowledge obtained during this process may create effects in three ways: restructuring of the organizational standards; unsuccessful results that may provide the basics for diagnosing additional action research; contribution of the information to the scientific society for the future research cases (Baskerville, 1999). The AR cycle may be iterated, if the results of the actions do not provide a satisfactory outcome with the adjusted process phases. Several researchers have studied this approach as is or in a modified way in several domains such as; medicine, operational research, information systems, education or organizational research (Checkland, 1981; Dickens and Watkins, 1999; Baskerville, 1999; Järvinen, 2007).

In this study, the AR methodology is successfully implemented to the European Remote Radio Laboratory project (ERRL)[1]. The main reason for choosing AR methodology for the ERRL project was the complexity of the problem and wide range of end-user expectations. Additionally, the ERRL project was one of the first in the area, therefore, there were several unclear issues that need to be investigated and addressed accordingly. Furthermore, during the implementation of the classical AR methodology, based on the specific features of the ERRL project some stages have been modified. This study discusses how the practical concerns of members of an educational organization and the research perspectives of this process are addressed in this project; the lessons learned from this successful case study and finally, the ERRL-AR approach together with the adaptation and modification of the classical AR methodology. This study aims to contribute to existing AR studies by providing a successful working implementation of AR methodology in projects developed for higher education organizations.

[1] Guest access is available at http://errl.atilim.edu.tr with both user name and password being “visitor”

MATERIALS AND METHODS

The ERRL system

The ERRL system aims to resolve real life problem of higher educational organizations. The ERRL system is physically established at the Atilim University, Turkey, providing continuous support through the Internet. It is very important to provide theoretical background and practical opportunities to the technical personnel such as engineers and technicians working in the field of radio communications that is very implementations for telecommunications, security systems, or defense systems industries. Because of its importance, today in most of the vocational training schools, there are many radio communications related courses. However, since the equipment required in high-frequency telecom/radio laboratories is high technology and very expensive, these educational organizations lack adequate laboratory and experimental equipment to support and demonstrate the practical application of the theory. As a result, most vocational schools cannot afford this equipment and the establishment of appropriate laboratories.

The ERRL initiative aims to develop a remote laboratory platform with distance access to high technology equipment via the Internet. It will provide theoretical and specifically, practical radio communications training, targeting personnel working in information and communication technology (ICT) who have a basic theoretical background (such as engineers, technicians), graduates of electrical, electronics, telecommunications or computer departments of vocational schools, and graduates of engineering level training organizations, as well as senior students enrolled in those educational institutions. The duration of the project is 2 years with a budget of approximately half a million euro funded by European Commission (EU). Several educational institutions across Europe have contributed to the project. As a transnational laboratory, the ERRL intends that its users will perform web-based experiments and follow course materials at any location or time. In comparison with other remote laboratories, ERRL intends to serve a more specialized group with a more diverse profile. In addition, the scope and capabilities of ERRL is much wider, with more sophisticated and diverse objectives. ERRL aims to furnish the qualifications demanded by the ICT industry. It aims to provide access to modern teaching materials and complicated experiments with very expensive equipment that cannot be currently accessed by many students, engineers and technicians. Since remote access to equipment used at high frequencies arouses, by its nature, different problems, this project demands different solutions than those previously provided by remote lab systems. Hence, the ERRL project has planned to develop innovative approaches to address these concerns.

By providing up-to-date curricula and teaching materials, ERRL offers new opportunities to training organizations to update their courses. ERRL also provides a cost-effective alternative for industrial sector wishing to avoid excessive investment in radio communications equipment and training staff to provide the initial and ongoing training for their personnel.

With the goal of developing and fostering of “e-competencies”, special modules have been developed for promotion of these competencies for vocational students and other relevant target groups as well as teaching staff. Additionally, the project supports self-learning processes by the appropriate didactical design of multimedia-based learning environment.

As previously described, the ERRL project is organized as AR which aims to develop new approaches and alternatives for the existing educational systems of the domain by addressing the current problems of the educational system.

ERRL-AR methodology

This methodology is based on the stages of the classical AR methodology in the pilot implementation and integration processes these stages were adapted. A full publications list related to this project can be obtained via the Atilim University web site[2].

Stage 1: Diagnosing

In this stage, the researchers working in the project and the ERRL target user groups came together to better understand the requirements and problems, then address the main features and expectations of the target user groups. These groups are mainly divided into: the learners, and the instructors or the educational system providers. The target learner group of the ERRL can be considered as the undergraduate students of the Electrical/ Electronic Engineering Departments, engineers and the technicians in this field. Therefore, the first part of the research of the project was established to reveal the target user groups' learning behaviors as well as their expectations from the ERRL system. Accordingly, data was obtained from a group of potential users of the system through questionnaires and interviews. The results of these studies were analyzed to better understand the target user groups' expectations and perspectives. In summary, the results show that different user groups have different expectations from the system. Furthermore, different learner groups behave differently in e-learning environments. The results derived from the data obtained from the students, engineers' and technicians' (Cagiltay et al., 2007) and the educators' (Cagiltay et al., 2009) perspectives and expectations were published in scientific journals to share this knowledge with the researchers working in similar areas.

Stage 2: Action Planning

Based on the results of the requirements determined in Stage 1, an experiment list to be provided through the ERRL system was prepared. Then, the selected experiments were categorized into three different qualification levels according to the European Qualification Framework (EQF) (EU report, 2008). The scope of each level was identified according to the EQF and 14 experiments were identified under three levels; beginners, intermediate and advanced. Descriptions of the experiments, including objectives, methodology and measurement setup and procedure, were prepared. Additionally, a list of the topics in the courses that were related to the experiments was prepared using the need analysis report along with the outcome of Stage 1. Various architectural approaches and tools were evaluated for the technology to be used in the development of the system. Among these different approaches, a software development platform and software tools were identified.

The research established during this period was also published in different scientific platforms (Kolberg et al., 2007; Ozbek et al., 2010).

Stage 3: Pilot Action Taking

Due to the complexity of the architecture and the need for several different components to be integrated in the ERRL project, the pilot action stage is added to the classical AR methodology. The aim in this pilot action is to provide an assessment concerning the technology to be used, and then to finalize the ERRL architecture, accordingly. For this purpose, a pilot experiment set was selected from previously determined list of experiments for the ERRL system. Then, a pilot development phase was accomplished, based on the chosen architecture for the experiment and its hardware setup. During this process, required software platforms were assessed and prepared for use in the project. A work-bench server (WBS) software to provide web services to the user in controlling the equipment communication was developed for the pilot experiment set in the main device was a vector network analyzer (VNA). Then, a network communication structure was successfully implemented for the pilot experiment setup.

Another component of a remote laboratory platform is the management of the service multi-user access. Learning management system (LMS) software was found to be quite a good candidate for this management. Accordingly, LMS software was chosen for the project. Then, missing functionalities of the chosen LMS to satisfy ERRL requirements were set and the architecture for the ERRL was designed, accordingly, to use with an open source LMS. Finally, the multi-user environment modules were developed and integrated into the system. The ERRL web interface was developed for the pilot study. The experiment was built around a VNA and the teaching material content for this equipment was designed using an Electronic Performance Support System (EPSS) which would accompany the user when she/he is running the experiment (Alparslan et al., 2008). In order to conduct a remote experiment via the Internet, the software and hardware were integrated. At this stage, a complete remote experiment module for the pilot experiment was prepared ready for access through the Internet. The remote access to the pilot module was achieved after the creation of workbench server coding, instrument control codes including the EPSS and installation of the LMS and pilot course material with identified objectives. This was a two-fold task, first the learner should be able to understand the theoretical notions and also find procedure guidelines to conduct the experiment. Accordingly, an environment was designed that taught the learner how to use the buttons on the equipment board and gave instructions on how to use the equipment. In this system, the parameters that the learner should know (instructions about the use of these parameters was prepared) were defined and important parameters required by the learner to achieve the experiment were introduced. Afterwards, the pilot experiment interface was prepared. The theoretical content (instructions) concerning the experiment, interactive instructional material to support this content such as animations and short video were prepared at this stage.

Stage 4: Pilot Action Evaluating

This stage is also an additional component to the classical AR methodology. In this stage, according to the results of the pilot action, the aim was to finalize the ERRL architecture using the appropriate technology, by better addressing end-user expectations and considering the sustainability of the system. After the development of the pilot study was completed, in the pilot action and evaluating stage, the quality of the definition of the experiment was assessed feedback was collected. The pilot module was tested by the sample target user groups and improved according to their feedback. Several improvements were implemented in this stage.

For example, the experiment user interface and software architecture was modified. Additionally, because of the integration problems, the meta-data details to be defined for each learning object in the system had not been defined as planned. Several other changes were implemented in the design of the ERRL system

[2] http://www.atilim.edu.tr/~nergiz/ERRL_pubs.htm

according to the feedback taken in this stage. Also, a test system to assess the learners about the pilot course was prepared and used in this stage.

Stage 5: Parallel Action Taking

After the successful implementation of the pilot study and improvements to the design of the ERRL system based on the results from the pilot study evaluation, the remaining experiment modules were developed. In this process, the procedure in the pilot study phase was followed and the previous experiences were taken into consideration. This approach provided a suitable environment and time for the development of the whole system.

Stage 6: Parallel Action Evaluating

After completing the development of all experiments in the ERRL system, the whole system was evaluated according to the performance metrics that included the target user groups' satisfaction in terms of the use of the system. In this stage, the appropriateness of the design for the learning process was assessed from different aspects such as the quality of the asynchronous learning and self-learning. For this purpose, first, all the modules were tested by sample target user groups and feedback was collected. According to the feedback, all experiment modules were improved. The main consideration in this assessment was the measurement of how the developed system affects the current educational methods. More specifically, how the ERRL platform could improve the classical education system was the main research question that needed to be answered in this stage. Since the ERRL platform is already used in some courses, the main feedback from the participants, either the students enrolled in these courses or the instructors offering these courses, have been collected through qualitative and quantitative approaches. Additionally, in some courses, experimental research studies have been established to examine student performance on the courses that used the ERRL system. This data was compared with the student performance on the course that did not use the ERRL system. Hence, the benefits of the ERRL system for the current educational system were analyzed in several different dimensions. The results show that the ERRL system dramatically improved the classical educational system. The analysis results and experiences during this stage have also been published (Aydin and Cagiltay, 2011).

Stage 7: Specifying Learning

Based on the evaluation results of Stage 6, the classical curriculum of the courses were modified by the integration of this new laboratory environment to the course curriculum. Currently, the ERRL system has been successfully integrated into more than seven courses at the Atilim University. The experience regarding the extension of the ERRL platform and an assessment of the didactical outcomes has been regularly published (Kara et al., 2011; Cagiltay et al., 2011a; Kara et al., 2010) and there are still ongoing research projects concerning the extension of the ERRL platform. Moreover, the experience gained from different didactical approaches and their assessments, especially, on remote or virtual laboratory services have also been discussed in different publications (Cagiltay et al., 2011a; Kara et al., 2010). By specifying learning through the ERRL project, some generic principles have been proposed to guide similar initiatives (Cagiltay et al., 2011b). In general, from the information acquired in the course of the development of the ERRL platform, Atilim University has started re-structuring the curriculum of these courses. These courses are being re-structured by exploiting ICT tools and techniques in the form of virtual and remote laboratories, and technology enhanced teaching approaches. A recent publication explains how a course curriculum that is offered by a higher educational organization can be restructured by utilizing the ERRL environment (Aydin and Cagiltay, 2011).

RESULTS AND DISCUSSION

This study provides a description of a research project that solves a real-world educational problem by developing a remote laboratory platform (ERRL) which was carried out based on AR methodology. This successful case study can be used as an example of good practice of how AR methodology can be implemented in developing technology enhanced educational tools and systems. Moreover, it can be used to prove how AR methodology can work well in solving real-life educational problem. The ERRL platform development process also demonstrates how the research objectives of a project could be determined according to the real-life educational problems, and how these objectives could be fulfilled to provide better solutions for an educational organization. Furthermore, the publications describing the results and experiences of the implemented stages of the ERRL-AR methodology have been referenced here and these are evidence of how the connection between relevant researches with the practice has been successfully established.

The ERRL project research stages followed the AR proposed in the literature (Susman and Evered, 1978; Hindle et al., 1995; Gilmore et al., 1986; Mingers, 2001; Checkland, 1981; Dickens and Watkins, 1999; Baskerville, 1999; Järvinen, 2007), however, it should be noted that some practices may require additional stages in AR cycle as in the ERRL-AR practice shown in Figure 1. The main contributions of the ERRL-AR to the classical AR methodology are; the Pilot Action Taking and the Pilot Action Evaluation stages (Figure 1). Action research addresses a real-life problem and involves different parties such as, in this case, researchers, domain experts, ICT experts and those, who may use the provided solutions in their daily lives as well as other organizational members in the process. To be specific, the ERRL platform development lifecycle as an AR involves teachers, students and engineers, as primary target groups, and researchers as the main parties while technicians, service providers and members of maintenance teams in hardware and software tools in the hosting organization are some of other parties involved in the AR cycle. The roles, the expectations and the backgrounds of these people in the project vary as expected. For example, target user groups' perspective and researcher's perspective for presenting a concept may differ substantially in such projects. Therefore, it may be necessary to slightly change the AR methodology

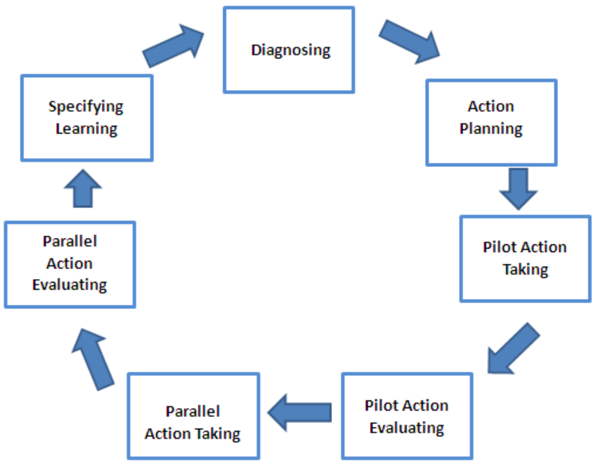

Figure 1. ERRL-AR methodology.

according to the requirements of the project. In the ERRL-AR methodology, a pilot implementation phases (Pilot Action Taking and Pilot Action Evaluation stages) provided an opportunity to negotiate between these diverse views, solutions and alternatives. The technical alternatives or views are tested in these stages and the most appropriate one is chosen. From the management point of view, these additional stages help the participants clarify the project management and technical issues and reach a common consensus. The success of the ERRL-AR process was that it enabled the collection of contributions of different participants of the project which led to changes being made on both the architectural design of the system and the technologies to be used in the ERRL platform design. The project team believes that these changes improved performance of the whole system gaining time for the project management and provided an efficient way of using project resources. Once the architecture is decided upon and the proposed approach is tested in the pilot study, the other similar parts of the project are all developed in parallel according to the results of the pilot study.

Finally, following the AR methodology in the ERRL project has provided several advantages and benefits. First, the research results established in Stage 1 (Diagnosing) have shown that the behaviors and expectations of the different target user groups of the project may be diverse. Hence, the instructional design of the system is established by considering these different expectations and views. Without this research result, it would, therefore, be difficult for some user groups to be satisfied with and therefore, benefit from the ERRL system. Similarly, the research conducted in Stage 2 (Action Planning) guided the project team to the most appropriate and flexible architecture for the project. This was a critical factor both for the sustainability and the maintenance of the final platform. The modified AR methodology followed by the project team in the implementation of the remote laboratory for radio communications, provided a different way of complementing theoretical courses in a higher educational environment, and dramatically changed the educational system in this domain. As a result, the authors believe that, this AR methodology eliminated most of the risks such as deciding an inappropriate technology, facing problems during integration of different parts of the project and not addressing educational outcomes in the course of the project, and it was the major reason why the project was successful. The ERRL system has been under continuous improvement by collecting user needs, specifically, on the user interfaces along with the content and educational features of the system in the cyclical manner of action research methodology.

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