Proceedings of the Federated Conference on
Computer Science and Information Systems pp. 1017–1021
ISBN 978-83-60810-48-4

Good practices in requirements, project and risk management in educational IT projects

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***Abstract*—One can find many learning aids and simulations of physical phenomena on the market – provided as a standalone application or as part of an educational package. However, only a few of them allow for the building of interactive experiments: experiments similar to those that should be conducted in physics laboratories at schools. Gdańsk University of Technology decided to fill this market niche by designing and constructing a set of virtual experiments – so called e-experiments. To avoid common problems that a lot of IT products brought to defeat, they prepared procedures in accordance with the best practices of software engineering. The paper below describes the process of the e-experiments development paying special attention to requirement, project and risk management. Authors try to prove that by not escaping from difficult matters such as carefully planning and risk analysis success can and will be achieved.**

I. Introduction

MANY surveys have been conducted to find out how many IT projects end in defeat and to determine the factors which result in their failure. The most commonly indicated reasons for IT project failure are: ineffective stakeholder engagement [1], a complete lack of executive support [1]–[6], ineffective user involvement [1]–[6], and poor project management [1], [7]–[10] (lack of knowledge of project management methodologies and the competence of management – inadequately trained and/or inexperienced project managers; lack of top management involvement and support; inadequate risk management and weak project plans [11]). Another important reason is a lack of domain knowledge among project team members.

A lack of client/end-user commitment usually leads to ‘challenges’ surrounding requirements that may increase the risk of not fulfilling clients’ needs. This means that the software does not satisfy the quality conditions specified in the ISO 9001:2000/2008 definition of software quality [12]. Having experience and knowledge deficiencies in the subject area of the project may lead to gaps (undefined requirements arising from lack of awareness of the domain of the problem) in software requirement specification or work on unattainable objectives in subsequent project phases. Of course the software developer is not expected to know everything. However, it is necessary to fill in the gaps. For this purpose it may be helpful to use other sources of information such as documents, standards and the knowledge of domain experts. On the other hand, poor or inadequate project management contributes to improper organisation of the project team’s work. Then, even if project goals (requirements, tasks etc) are defined properly, the achievement of an objective may be hampered or impossible.

All of these considerations have influenced the project designers who are working on the “e-Experiments in physics” project (see Section II), to make all reasonable endeavours to prepare a product that fully satisfies the future users. Sets of activities were planned to achieve this goal. This paper describes the software engineering process which they view as resulting in success.

The structure of work is as follows. After this short introduction, Section II briefly discusses the IT project, which is the subject of this work, its aims and products. The third chapter discusses issues related to engineering requirements. Chapter IV provides a risk analysis, Chapter V describes the project management method. Section VI discusses the current status of the project. The work ends with some brief conclusions.

II. The Project “E-experiments in Physics”

In response to a call for innovative projects in frames of the European Social Fund, Human Capital Operational Programme, announced by the Polish Ministry of National Education [13], Gdańsk University of Technology proposed, in cooperation with the Young Digital Planet SA (Gdańsk, Poland) and L.C.G. Malmberg B.V. (Den Bosch, Netherlands), project called "e-Experiments in physics," whose main result is a product that addresses some identified problems with didactics of physics in secondary schools [14]–[17]. The product is a series of virtual experiments (so-called e-experiments), carried out in electronic form (as computer programs). Physical phenomena represented by the e-experiments were selected in such a way that every branch of physics is adequately represented. The teachers, even in well-equipped school physics labs, are not able to conduct experiments with some branches of physics (e.g. nuclear physics) – likewise the inability to demonstrate the behaviour of such a test system in the accelerating elevator, train or even on another planet. e-Experiments enable the student freedom to experiment, allowing for a more and creative research activity, thanks to “touch” the problem of performing the appropriate exercises using a computer, without the fear of destroying any expensive equipment.

The project “e-Experiments in physics” is co-financed by the European Union within the European Social Fund.

It should be noted that the e-experiments will not be typical of all simulations that are widely available on the Internet [18]. In contrast, the proposed e-experiments will be as close as possible to reality, will also form part of the scheme design / build / execute / analyse / introduce the results, where it is important to learn from mistakes. The proposed solution involves the possibility of interference in student performance, thus build e-experiments carried out in order to force her/ him to an activity and arouse their scientific curiosity and identification of the research problems. We will enable students (and of course the teacher) to observe the behaviour of the system and its differing parameters, which would be quite impractical within the physical realm. References to the interdisciplinary nature of science will be indicated on the e-experiments, for example, the results will be analysed using statistical methods (mathematics) and developed using a spreadsheet (computing). Additionally, some e-experiments will be bordering on physical chemistry. Currently, these kind of references are rather sporadic. The idea described above has not been previously used in similar solutions. Moreover an exercise book demonstrating its potential use within its genre will be supplied to each e-experiment.

In the project, Gdańsk University of Technology (further referred as GUT) is responsible for the scenarios of the e-experiments, numerical engine and the exercise books. Young Digital Planet SA (YDP) is responsible for technological tasks: coding, providing graphics and user interface to the application. Role of the third partner, L.C.G. Malmberg B.V. (MBG) is to provide substantial support.

III. Requirement Management

A. Gathering of Requirements

The group of subject matter experts (domain experts) is engaged in work on gathering requirements – academic staff and students of the Gdańsk University of Technology. At the head of the group is a coordinator who builds a team of qualified personnel and supervises the team's work. All of them work on the preparation of the scenarios of e-experiments, based on their best knowledge and experience gained during their academic work as well as analysis of the current curriculum in force at upper secondary school. Additionally, at the request of the of the originator of the project, nationwide surveys of the teachers and students of physics in secondary schools were conducted, among other things, to determine the order in which experiments should be built. The work of the subject matter experts is supported by a methodologist from one of the best secondary schools in Poland.

B. Specification of Requirements

The software requirement specification consists of scenarios of each e-experiment, description of tools necessary to build the experimental set, and prototypes of the e-experiments in the form of C++ codes (numerical engine). A preliminary version of the specification is prepared by domain experts of GUT. In the next step the methodologist reviews the preliminary version of the script and proposes any amendments or modifications. Subsequently, the documents drawn up are sent to YDP, to verify the feasibility of the proposed solutions. The scenarios are commented by YDP's team leaders (at least one of them acquired domain knowledge of a project subject – in physics) and sent back to GUT. These two steps are repeated until any ambiguities are eradicated, and the final scenario is accepted by both partners. In the next step, YDP estimates the time effort (man-hours) needed to implement the final scenario, and provides the result to GUT. When a scenario contains alternate paths, YDP makes an estimation of each path. In this case, GUT decides what path will be implemented. Then, the developer's project team at YDP starts implementing the final version of the scenario (using the Adobe Air / Alchemy technology).

All of these activities are repeated for each of the 23 e-experiments planned to be carried out.

C. Verification – Do We Build Software Well?

YDP starts producing e-experiment, based on the final draft of the scenario and numerical engine. During that

Table I.
Technical risk

	RT1	RT2	RT3
Concern:	Problem with developing of the e-experiments	Insufficient technical and informational preparation of teachers that take participation at the stage of testing the product in schools	Insufficient efficiency of the computers used at the stage of testing
Likelihood:	Unlikely	Unlikely	Likely
Severity:	Critical	Significant	Significant
Solution:	Choice of an experienced partner; employment of suitably qualified personnel; developing of the e-experiment with smaller scope of the functionality or less complicated open to add new functionality in future; enhancement of qualifications of the team members	All the necessary training for the users of the product is planned; preparation of the instruction for the users to each of the e-experiments	Choice of the school provided with the necessary equipment; preparation of the optimised version of the e-experiments; placing e-experiments on the cloud computing

stage, YDP cyclically provide preliminary versions of the produced software to GUT in accordance with agile approach, to avoid ambiguity in the interpretation of the content of the script. Each version is being tested at GUT (by substantive experts and methodologists), comments related to its operation are sent to YDP. These comments are intended to clarify ambiguities in the interpretation of the scenario. There are allowed minor adjustments to the scenario, but not affecting the general idea presented in the final version of the scenario. Testing of each version of the e-experiment should be completed no later than one week after its transfer to GUT.

At the end of this repeated process, the penultimate version of the e-experiment is tested once again, to eliminate any remaining bugs. The observed defects, errors in functionalities and technical defects found are reported to members of the YDP project team. These amendments may be submitted within one month of the penultimate version. YDP interprets and evaluates the reported bugs, then implements fixes in the next version of the e-experiment. e-Experiment is deemed to be ready-made, when it operates according to the scenario and is accepted by the GUT.

D. Validation – Do We Build Good Software?

Thereafter, the teachers (the users of the product) of the selected upper secondary schools are asked to test and make comments on the given e-experiment. At this stage it is possible to introduce only minor adjustments to the product (because the project team has been already engaged in production of the next e-experiment), however all comments are recorded for later use. When all these indispensable and well-suited corrections are introduced, the e-experiment is delivered to schools for students (the recipients of the product). Thus, the e-experiments are tested in the real world of school – during physics lessons. During these lessons, all teachers introduce the product in a uniform manner:

a) with the help of e-experiment, the teacher demonstrates a physical phenomenon in the classroom, using a computer and projector, or interactive board,

or

b) classes are held in a computer lab, all students perform the e-experiment alone or in groups, depending on the organisational capabilities of school.

Notwithstanding the above choices, the teacher asks their students to do homework with the e-experiment.

All the comments from this stage of testing are gathered in the form of reports. All of these activities are repeated for each of the 23 e-experiments planned to be accomplished.

Moreover, the originator of the project is willing to listen to opinion about the product not only from the users and recipients, but also from other advisory and decision-making bodies, such as National Thematic Network for Education and Higher Education (forum of experience exchange and evaluation of innovative projects that may help in popularising and incorporating to mainstreaming of education), academic and specialist (e.g. user interaction experts) circle and any other person or institution who inclines to share their opinion about the project. Their opinion can be crucial when it comes to a decision on the future of the product, e.g. final version of the product must be validated by the National Thematic Network.

E. Change Management

As the product is proposed to be incorporated in mainstream educational policy, the teachers' and students' comments and remarks (which can be translated into changes), collected during testing stage at schools should be taken into consideration in the final version of the product. Unfortunately it may not be possible to include all desired changes – mainly for time and budgetary reasons.

Therefore, only the selected changes will be introduced, so that their implementation does not exceed a period of 3 months and 10% of the budget (in the average sense for all e-experiments). This restriction does not apply to the technical bugs reported by users, these bugs will be corrected independently. The selection of changes will be performed by the methodologist, who will take into account their significances and feasibility study, prepared by YDP. After the selected changes will be acted upon – then the final version of the product will be ready to be incorporated in mainstreaming.

IV. Risk Management

For the purpose of the project a detailed risk analysis was prepared. In accordance to certain widely accepted rules it was decided to measure success [19], [20] of this undertaking by the scope/requirements (technical risk), cost (budget risk) and time (schedule risk) [21]. As every effort

Table III.
Budget and schedule risk

PR1 Concern:	Cost of the e-experiment may exceed the passed budget	RS1 Concern:	Time of the e-experiments developing may overrun schedule
Likelihood:	Unlikely	Likelihood:	Possible
Severity:	Critical	Severity:	Critical
Solution:	Consultations substantive supervision with technical side of the project; developing of less complicated versions of the e-experiments	Solution:	Developing of less time consuming versions of the e-experiments

was taken in order to prepare a product that will be well-accepted by the Ministry of Education, people who make decisions, educational circles, teachers and students' social-ethical issues [22] (social risk) were taken under consideration. Technical risk factors have been collected in Table I (risks RT1–RT3), budget and schedule risk factors are incorporated in Table II (risks PR1 and RS1, respectively), and social risk factors are collected in Table III (risks RE1–RE4).

V. Project Management

As the project is co-financed by the European Union within the framework of the European Social Fund, the supervising institutions expect the preparation of a few formal documents. These papers together with records created by the team on its own initiative force the provision of paying proper attention to detail good planning and appropriate risk analysis. If any problems with the execution of the project are found, relevant procedures are implemented. For example: when a delay in the completion of a task arises, the primary schedule may be updated or the work of the team may be reorganised without the risk of postponing the final deadline. These actions have been already implemented when – as a result of working on other activities – YDP could not commit enough staff (programmers) to the project, so the pace of performance tasks was slackened. The lost time was made up by increasing time efficiency of the experiments. The human resources management also undergoes changes. When an employee cannot manage to do his or her assigned job for a long period of time, the reorganisation of the team is considered. A further example is that when a change in the initial assumptions proved necessary because of problems with coding equations describing the motion that preserves realism. This task was delegated to the subject matter experts who had appropriate knowledge and experience in using programming languages.

VI. Current Stage of the Project

This project is currently at the stage of product testing in schools. Testing will continue until mid-2013, then the final version of the product will be created and validated. The preliminary version of the final product (10 e-experiment of planned 23) has already been demonstrated at conferences, seminars and programme meetings of the Human Capital Programme, and National Supporting Institution. It has been extremely well-received everywhere. This which we believe can only bode well for the future.

To date, the project has encountered no serious problems that could jeopardise its realisation. In the design phase adequate time and budgetary margins were provided, usual difficulties in crossing the schedule and budget did not

Table III.
Social risk

	RE1	**RE2**	**RE3**	**RE4**
Concern:	Wrongly informed about the product and its capabilities unprepared teachers who may have limited interest to use e-experiments if product is included in mainstream educational policy	Lack of interest/enthusiasm from students	Incompatibility of e-experiments to the curriculum due to reforms in education	Inadequate training/knowledge of teachers resulting in poor use and ending result
Likelihood:	Unlikely	Unlikely	Possible	Unlikely
Severity:	Critical	Critical	Significant	Critical
Solution:	Popularisation of the project in the educational circles during the conferences as well as by publication articles, information on project's web page and in social networking services such as Facebook; ensuring a high visual and functional attractiveness of the product; soft and hardware multi-platforming, and independence - available for multiple, differing operating systems and types of computer equipment (desktops, laptops, tablets, etc.) and multimedia boards	Ensuring a high visual and functional attractiveness of the product; soft and hardware multi-platforming, and independence - available for multiple, differing operating systems and types of computer equipment (desktops, laptops, tablets, etc.) and multimedia boards; creation of the project profile on the social networking services such as Facebook	Admission in the recruitment process for classes with basic through to extended physics teaching programmes so to ensure the comprehensive testing stages; set preparation of the e-experiments that can be used in different levels of education (e.g. in lower secondary schools or on the first years of studies)	Preparation of the instruction for the users to each of the e-experiments

reveal the extent which would require a strong reaction, as described in Table II. Only minor changes were introduced in the order of producing e-experiments to adjust the production cycle to suit the current school curriculum. Additionally it has been noticed, that 15% of teachers and students in selected schools where the product is under going testing, have found some problems associated with the appropriate use of the product due to a lack of computer knowledge (Table II, the risk of RE4). To remedy this, we plan to conduct nationwide training of teachers (in cooperation with the relevant educational institutions), so that the percentage of people that will not be able to fully benefit the e-experiments will be even less.

VII. Conclusion

Developing educational tools for young people is not a trivial task. This kind of software has to satisfy two contradictory interests – educational valour and attractive software. To achieve success – develop good software that young people will be willing to use – there was decided to take into consideration both needs. It was of paramount importance to involve and execute the support of stakeholders' into the project. The presence of a few different sources of requirements may cause some of them to overlap. To resolve this problem it is necessary to confront and/or prioritise sources. This also applied in the case of gaps in requirement specification. Even when several sources of information are present, this does not provide a guarantee for filling in all the gaps. For this purpose it may be necessary to use a more sophisticated tool. But this is the subject of another survey and will be described in detail in further work. For the purposes of this project, in the first place is the compliance with compromise between an educational need and attractiveness of the product.

In the process of the development of any IT product it is of the greatest importance to follow the best practice to achieve success. We proposed a set of such practices for a educational IT project. So far, the project shows the correctness of the chosen solutions.

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