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GOOD PRACTICES IN REQUIREMENTS, PROJECT AND RISK MANAGEMENT. A CASE STUDY IN EDUCATIONAL IT PROJECT[1]

Abstract: It seems that nowadays schools do not keep up with the times. Recent studies have highlighted that students' needs are not being met and they are not prepared well enough for future study and/or work. The lack of the possibility to conduct their own experiments (e.g. physics experiments similar to those that should be conducted in physics laboratories at schools) and learning from mistakes result in young people not being able to draw their own conclusions (cause-and-effect thinking) led Gdańsk University of Technology to decide to do something about this problem by designing and constructing a set of virtual educational aids – so-called e-experiments. To avoid the common problems that defeated a lot of IT products, they prepared procedures in accordance with the best practices of software engineering. The present paper describes the process of the e-experiments development, paying special attention to the requirements, project and risk management. The authors try to prove that by not running away from difficult matters, such as careful planning and risk analysis, success can and will be achieved.

Keywords: e-experiments, feasible objective, fruitful cooperation, software engineering in practice, risk, impact on the stakeholders.

1. Introduction

Many surveys have been conducted to find out how many IT projects fail and to determine the factors which result in their failure. The most commonly indicated reasons for IT projects failure are ineffective stakeholder engagement [The Standish Group 1994–2009], a complete lack of executive support, ineffective user involvement

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[The Standish Group 1994–2009; Glaser 2004; Jenster, Hussey 2005; Al Neimat 2011; Coley consulting 2001–2005; Hartman, Ashrafi 2002] and poor project management [The Standish Group 1994–2009; IT Cortex 2011; Kawalek 2007; POST 2003; Sauer, Cuthberston 2003] (insufficient knowledge and competency of project management methodologies – inadequately trained and/or inexperienced project managers; no inclusion of top management involvement and support; inadequate risk management and weak project plans [ISO 10006/2003]). Another important reason is a lack of domain knowledge among project team members and client/end-user commitment usually leading to “challenges” surrounding requirements that can increase the risk of not fulfilling clients’ needs.

Having experience and knowledge deficiencies in the subject area of the project may create gaps (undefined requirements arising from the lack of awareness of the domain of the problem) in software requirement specification or work on unattainable objectives in subsequent project phases. Obviously, 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 the improper organization of the project team’s work. Whereas if we fail to apply particularly accurate forms of risk analysis, we may not indicate certain hazards and undoubtedly get into trouble [Yourdon 2003]. 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 2) 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 the work is as follows. After this short introduction, Section 2 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. Section 4 provides a risk analysis. Section 5 describes the project management method. Section 6 discusses the current status of the project. The work ends with some brief conclusions.

2. The project “e-Experiments in Physics”

In response to a call for innovative projects within the framework of the European Social Fund, the Human Capital Operational Programme, announced by the Polish Ministry of National Education [Polish Ministry… *Documentation*…], Gdańsk University of Technology proposed, in cooperation with the Young Digital Planet SA (Gdańsk, Poland) and L.C.G. Malmberg B.V. (Den Bosch, the Netherlands), a project called “e-Experiments in Physics”, whose main result is a product that addresses some identified problems with didactics of physics in secondary schools [Mostowski 2009; Polish Ministry… *Results*…; Polish Ministry… *Information*…; ASM 2010]. The product is a series of virtual experiments (so-called e-experiments), carried out in the electronic form (as computer programs). The 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) – hence the inability to demonstrate the behavior of such a test system in the accelerating elevator, train or even on another planet. E-experiments give the student the freedom to experiment, allowing for a more and creative research activity, thanks to "touching" the problem of performing the appropriate exercises using a computer, without the fear of destroying any expensive equipment.

It should be noted that the e-experiments will not be typical of all simulations that are widely available on the Internet [Kąkol, Żukrowski 2010]. In contrast, the proposed e-experiments will be as close as possible to reality and will also form part of the scheme design/build/execute/analyze/introduce the results, where it is important to learn from mistakes. The proposed solution involves the possibility of interference in student performance, thus building e-experiments carried out in order to force him or her to an activity and arouse his or her scientific curiosity and identification of the research problems. We will enable students (and of course the teacher) to observe the behavior of the system and its differing parameters, which would be quite impractical within the physical realm. The idea described above has not been previously used in similar solutions.

In the project, Gdańsk University of Technology (further referred to 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. The role of the third partner, L.C.G. Malmberg B.V. (MBG) is to provide editorial and factual support.

3. Requirement management

3.1. Gathering requirements

The group of subject matter experts (domain experts) is involved in work on gathering requirements – staff with a lot of academic experience and students of the Gdańsk University of Technology. 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 (e.g. observation of the changes and its consequences in preparation of the subsequent generation of students) as well as analysis of the current curriculum in force at upper secondary school. The work of the subject matter experts is supported by a methodologist from one of the best secondary schools in Poland.

Additionally, at the request of the of the originator of the project, nationwide surveys among secondary school physics teachers and headmasters were conducted, whose aim was to obtain answers to the following research questions:

- Is the school equipped with multimedia devices (multimedia boards, OHPs, etc.)?
- Is each classroom equipped with a computer connected to the Internet? If not, why not?
- How many computer laboratories are there at school? How are they equipped (what kind of hardware and software, number of workstations, access beyond lesson hours, availability of classrooms, etc.)? Are computer laboratories connected to the Internet?
- How is the quality of subject classrooms assessed (in particular physics classrooms)? What kind of equipment is missing (experimental sets, reagents, proper rooms etc) and why? Is each physics classroom equipped with a computer connected to the Internet?
- Are there any groups of interests at school, if yes, what are they? Who finances the groups of interest?
- Do the students participate in physics contests and what are their results? If not, why not?
- How do headmasters assess physics teachers (assessment focused on didactics, methodology, organization, engagement, etc.)? Are headmasters satisfied with their work?
- What is the attitude of headmasters to innovative actions and experiments at schools testing new methodological and didactic solutions?
- Is the school open to using the newest ICT by teachers in the didactic process? If not, why not?
- Which core curriculum is implemented for physics (basic and extended) in secondary school classes – linear or spiral curriculum?
- What is the manner of using Internet resources connected with teaching and learning physics applied by teachers? How often and where is information searched for and what are the results of it?
- Do teachers have stationary computers or laptops at home?
- Do teachers have access to the Internet at home? If yes, what is the speed of the connection?
- What sections of physics are implemented within the framework of the basic level in secondary schools?
- How often do teachers facilitate their lessons with real experiments? What are the experiments performed?
- What is the comprehension of the problem presented by means of the experiment in relation to typically theoretical issues?

Summing up the results of this research, we may conclude that secondary school students are not much interested in physics. In students' opinion, physics could be more interesting if physics lessons were conducted in a less theoretical way with more experiments made during the lessons and with classes held outdoors, not just in the classroom. Presenting experiments during physics classes does not always need to be “live”. Computer simulations or multimedia presentations may be used for this purpose. However, such possibilities are only used to a small extent. Also among students the use of the Internet in the search for materials related with physics is insignificant despite the fact that almost all of them have computers with access to the Internet at home.

Both of these surveys, completed by analysis performed by subject matter experts and a methodologist, are a solid base to prepare the proper specification of requirements.

3.2. Specification of requirements

The software requirement specification consists of scenarios of each e-experiment, a description of the 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 the 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 on by YDP’s team leaders (at least one of them has acquired the 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 alternative paths, YDP makes an estimation of each path. In this case, GUT decides which 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.

3.3. Verification. Do we build software well?

YDP starts producing an e-experiment based on the final draft of the scenario and numerical engine. During that stage, YDP cyclically provides preliminary versions of the produced software to GUT in accordance with an 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), and comments related to its operation are sent to YDP. These comments are intended to clarify any 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 thus 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. The e-experiment is deemed to be ready when it operates according to the scenario and is accepted by GUT.

3.4. 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. Due to the involvement of the project team in the production of the next e-experiment, at this stage it is possible to introduce only minor adjustments to the product; however, all comments gathered in the form of reports 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, all 23 e-experiments are tested in the real world of school – during physics lessons. During these lessons, the product is introduced by teachers as a demonstration of a physical phenomenon in the classroom, using a computer and projector, or interactive board and/or performed by students (alone or in group) in a computer lab. Notwithstanding the above choices, the teacher asks their students to do homework with the e-experiment.

Moreover, the originator of the project is willing to listen to opinions about the product not only from the users and recipients, but also from other advisory and decision-making bodies, such as the National Thematic Network (NTN) for Education and Higher Education (a forum of experience exchange and evaluation of innovative projects that may help in popularizing and incorporating them into the mainstream of education), academic and specialist (e.g. user interaction experts) circles and any other persons or institutions inclined 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. the final version of the product must be validated by the NTN.

3.5. 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 the changes), collected during the testing stage at schools should be taken into consideration in the final version of the product. Unfortunately, for time and budgetary reasons, it may not be possible to include all the desired changes. Therefore, only the significant and feasible changes (not exceeding a period of three months and

10% of the budget) selected by the methodologist will be introduced. This restriction does not apply to the technical bugs reported by users – these bugs will be corrected independently. Some changes, such as reducing the scope of the functionality or the development of less complicated e-experiments open to extend functionality in future, may be enforced by the occurrence of any of the threats listed below (in the risk analysis section). After the selected changes have been acted upon – the final version of the product will then be ready to be incorporated in mainstreaming.

4. Risk management

For the purpose of the project a detailed risk analysis was prepared. The risk analysis was conducted with painstaking care by means of the SoDIS Analysis [Boughton, Płotka 2011]. The first stage of this methodology, Preliminary Analysis, was prepared by asking a set of questions about:

– the project context in terms of overall project risk, such as financial controls, key stakeholders, defined and documented functions/deliverables, outline of project structure and software development process (methodology, change management, development environment);
– the project plan in terms of developer team risk (preparation and capability of the team);
– the identified tasks risk (i.e. clarity of tasks and their outcomes, capability of the team);
– the identified stakeholders risk (i.e. understanding/acceptance of project, requirements);
– the impact of each project tasks on the stakeholders.

This enables to determine “if a project is ready to begin without a risk of failure by reviewing the content of the proposed project” [Boughton, Boughton 2009].

Although analysis results show some problems in the preparatory stage of the project, such as the lack of clearly defined deliverables, documented specification and/or binding agreement among the stakeholders, since it was a development of a preliminary version of the project and preparation of a strategy of project implementation, these concerns should be treated rather as a lesson for the future – information where particular attention shall be paid to in the next stage (what has been done) than the real hazard of the project failure. This stage has also revealed the need for the preparation of some procedures of conducting project activities and a more rigorous developer team member selection process in respect of the required technical knowledge, as well as experience in the task’s subject matter. Again, it must be remembered that the project is of an innovative and testing (research) character; therefore, it is expected to encounter and then resolve such problems and gain new experiences. Disclosure of the aforementioned and drawing conclusions in such an early preparatory project phase has helped to improve the project development process of the implementation stage thus avoiding problems that can end up in failure.

The other risk factors described in project documentation, such as technical, cost (budget) and time (schedule) [Innovation project…], are provided in the Tables 1–3. Technical risk factors are collected in Table 1 (risks RT1–RT3), budget and schedule risk factors are included in Table 2 (risks PR1 and RS1, respectively).

Table 1. Technical risk

	RT1	RT2	RT3
Concern:	Problem with developing 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 an e-experiment with a smaller scope of 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 optimized version of the e-experiments; placing e-experiments on the cloud computing

Source: own elaboration.

Table 2. 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 less complicated versions of the e-experiments	Solution:	Developing of less time-consuming versions of the e-experiments

Source: own elaboration.

As every effort was taken in order to prepare a product that will be well received by the Ministry of Education, the people who make decisions, educational circles, teachers and students' social-ethical issues [Gotterbarn 2002] (social risk) were taken into consideration. The main findings of the social-ethical analysis (inspired from the SoDIS Analysis) are collected in Table 3 (risks RE1–RE4). This issue will be also more widely described in our further work.

Table 3. 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 with 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:	Popularization 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 programs so as to ensure the comprehensive testing stages; set preparation of the e-experiments that can be used at different levels of education (e.g. in lower secondary schools or in the first years of studies)	Preparation of the instruction for the users to each of the e-experiments

Source: own elaboration.

5. 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. For this purpose some useful Agile techniques can be used, such as:

- retrospection: looking back at the process and its outcomes to analyze received results/products and team members' work
- adaptive approach to requirement, risk and project management: a flexible (if possible) and quick reaction to any change that can lead to missing project goals has been involved to improve the development process or reorganization of the project team and their work [Beck et al. 2001].

Any finding is a piece of valuable information to be implemented in the relevant procedures. 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 reorganized without the risk of postponing the final deadline. These actions were 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 the time efficiency of the experiments. A further example is 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.

6. 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 has already been demonstrated at conferences, seminars and program meetings of the Human Capital Programme, and the National Supporting Institution. It has been extremely well-received everywhere, which we believe can only bode well for the future.

To date, the project has encountered no serious problems that could jeopardize its realization. In the design phase, adequate time and budgetary margins were provided, and the usual difficulties in overrunning the schedule and budget did not reveal the extent which would require a strong reaction, as described in Table 2. 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 the teachers and students in selected schools where the product is undergoing testing have found some problems associated with the appropriate use of the product due to a lack of computer knowledge (Table 2, 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 from the e-experiments will be even smaller.

7. Conclusion

Developing educational tools for young people is not a trivial task. This kind of software has to satisfy two contradictory interests – educational value and attractive software. To achieve success – developing good software that young people will be willing to use – project team decided to take into consideration both needs. It was of paramount importance to involve and execute the support of the stakeholders' in 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, it 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, which will be described in detail in further work. For the purposes of this project, what is most important is compliance with the compromise between an educational need and the attractiveness of the product.

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

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DOBRE PRAKTYKI W ZARZĄDZANIU WYMAGANIAMI, PROJEKTEM I RYZYKIEM. ANALIZA PRZYPADKU EDUKACYJNEGO PROJEKTU INFORMATYCZNEGO

Streszczenie: Wydaje się, że dzisiejsza szkoła nie podąża z duchem czasu. Ostatnie badania pokazują, że potrzeby uczniów nie są realizowane i nie są oni dobrze przygotowywani do przyszłych studiów i/lub pracy. Brak możliwości przeprowadzenia własnych doświadczeń (np. doświadczeń fizycznych, które powinny być przeprowadzane w szkolnych laboratoriach fizycznych) i uczenia się na błędach skutkuje tym, że młodzi ludzie nie są zdolni do wyciągania własnych wniosków (myślenia przyczynowo-skutkowego). Politechnika Gdańska postanowiła zająć się tym problemem poprzez zaprojektowanie i wykonananie zestawu wirtualnych pomocy naukowych – e-doświadczeń. Aby uniknąć wielu typowych problemów, które wiele informatycznych produktów prowadzi do niepowodzenia, przygotowano procedury w oparciu o najlepsze praktyki inżynierii oprogramowania. Niniejszy artykuł opisuje proces tworzenia e-doświadczeń ze zwróceniem szczególnej uwagi na zarządzanie wymaganiami, projektem i ryzykiem. Autorzy próbują udowodnić, że rozwiązywanie trudnych kwestii, takich jak szczegółowe planowanie i analiza ryzyka, może być gwarancją sukcesu.

Słowa kluczowe: e-doświadczenia, inżynieria oprogramowania w praktyce, osiągalne cele, owocna współpraca, wpływ na udziałowców.