Information System Design and Development and Project-based Learning

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Abstract: Teaching the topics from the field of information system design and development presents a specific challenge for the teacher. It is hard to simulate real-life circumstances of complex information system design and development in educational environment. In this paper we present an educational model in which topics from this field are taught using project-based learning. This method is used continuously during the entire study, through a number of interconnected project assignments. Each assignment presents a phase or activity of information system design or development, and approaches students to real-life problems. We propose to implement this model through several courses in undergraduate and graduate study, because assignments require different levels of maturity and knowledge from students. The model follows a basic idea to give a theoretic overview of information system design and development phases in one course and then to teach each phase and its activities in a separate course in detail. In the basic course on information systems special attention should be focused on digital innovations and on students' awareness on application of technology to improve business effectiveness.

1 INTRODUCTION

The field of information system (IS) design and development is rather complex and comprehensive. It is hard to translate a specific IS development problem and its properties from real life into educational environment of a university or a higher education institution. In educational environment, assignments are mostly small, short and realized in different courses independently. Since one semester usually lasts up to 15 weeks, and students attend 2-4 hours of lectures and practical work per week, time constraints and credit constraints do not allow for complex assignments and students focus only on a surface level (Harris, Lang, Oates & Siau, 2006). A set of knowledge and outcomes which students need to adopt during educational process is usually divided in courses.

The model presented in this paper covers two parts of IS development: design (which is usually included to strict IS curriculum) and development itself (which is related to software engineering (SE) methods for development of business software). Often, the term "development" is used for the entire process. In our research we analysed Curriculum guidelines for both Information systems (ACM & AIS, 2010) and Software engineering field (IEEE CS & ACM, 2015). These guidelines define expected student outcomes as well. Undergraduate SE course can be taught by using these models (Shaw & Tomayko, 1991):

- The "software engineering as artefact" model – the subject is taught almost entirely by lecture, while interaction with students is related to questions and difficult points.
- The "topical approach" model – each student is assigned a topic to be presented after reading several papers on it.
- The small group project model – includes a project as part of the course.
- The large project team model – students work on a project in a team of 15-30
- The project only model – the entire course is a project.

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The same principles can be used in teaching IS design and development. In our model we combine "artefact model", "small group project model" and "project only model" and we use project-based learning approach.

"Project-based learning is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006). Project-based learning in engineering positively influences students' motivation (Helle, Tynjälä, Olkinuora & Lonka 2010). Team collaboration, active learning, critical thinking, problem thinking, design thinking and project-based learning are particularly efficient in engineering education (Gil-Gonzales, de Luis Reboredo, González & de la Prieta Pintado 2019), (Diaz Lantada & De Maria, 2019), (Matthee & Turpin, 2019). Project-based learning in engineering is mostly implemented through smaller assignments which cover some part of the development process, for example related to project management (Tynjälä, Pirhonen, Vartiainen & Helle, 2009), database design (Dominguez & Arturo, 2010), system analysis and design (Leitch & Warren, 2007). Although, IS development is taught in depth through a number of courses, the entire development process can be considered as a whole. Similar is sometimes done in the field of SE, for example (Ludewig & Bogicevic, 2012) explain a model that includes a project performed from the first to the last semester.

In this paper we present an educational model covering IS design and development through several courses, but based on one complex project covering the entire process. Project-based approach is used and the entire process is divided in seven smaller project assignments. Methods used for execution of each particular project assignment in this model are suggested, but to solve the same project assignments, other methods can be used as well.

The paper is organized as follows: after explaining research motivation, methodology used for design of educational model is presented. In the next chapter methodology phases and activities are aligned with project assignments. Each project assignment is explained in chapter 5. In the end we present conclusion and future research.

2 MOTIVATION

One of the objectives of the IS and SE study programmes is to prepare students for the real-world challenges encountered in professional system development (Surendran & Young, 2000). In order to create a situation as similar to the real-life IS development problems as possible, we designed an educational model which enables project-based teaching on IS design and development topics. This model is adopted in our study program of informatics. We have developed a group of courses during which we teach our students different topics from this field: strategic planning of IS, business process analysis, data modelling, team work, configuration management, methods and technics used in development of business software and testing.

This model is an upgrade of the model for training IT professionals actively involved in IS design (Pavlic, Marinovic & Candrlic, 2005) and of the model presented in (Pavlic, Poscic & Marinovic, 2006) which deals with IS design only. One of the main parts in building an IS is to develop software that supports it. In its development it is necessary to use engineering methods. A number of methods are available and the question arises: which should be chosen for teaching and/or learning? In this educational model, the fields of IS development and SE work together in building a final solution: a software that supports the needs of an IS.

The model proposed in this paper is focused on business IS development. Engineering methods taught within this model are implemented to support IS development. Several smaller assignments join to form one complex project assignment executed during several courses of the study programme. We use the term project assignment as an abstract expression of a student assignment. In order to adopt specific knowledge, it is necessary to complete project assignments. The result of each project assignment is in a form of an artefact that is considered a part of the project or project documentation.

3 METHODOLOGY

Although agile methodologies nowadays have an important role in IS and software development, for presentation of development stages through phases and activities, waterfall model is usually used and, typically, a week or two is spent on each phase (Offut, 2013). Sometimes other methodologies, such as V-model are recommended for some IS development phases (Tan, Nakata & Paul, 2018). But, since the real-life IS and software development rarely follows strictly defined and linearly executed development phases, we decided to follow a more flexible methodology in building this model. We have chosen

a methodology called MIRIS - Methodology for Development of IS. The reason for choosing the MIRIS methodology is its simplicity and flexibility. Phases and activities are described as a traditional waterfall model, but this methodology allows to return to previous phases and previous activities as needed.

Table 1: Phases and activities of the MIRIS methodology.

LOGICAL MODELING (DESIGN)
Phase 1: STRATEGIC PLANNING OF IS (SP)
1.1. Analysis: Defining and training a team, decomposition of a process, list of documentation and navigation through the system
1.2. Subsystems: Defining subsystems and relations
1.3. Priorities: Determining priorities
1.4. Resources: Defining complete infrastructure
1.5. Plan: Planning main project and activities
Phase 2: MAIN PROJECT (MP)
2.1. PT: Drawing up project task
2.2. DFD: Interview, analysis, process modeling (DFD)
2.3. MP Processes: Analysis of process, problem and proposal for improvements
2.4. MP Data: Data description
2.5. MP Plan: Planning project realizations
2.6. MP Resources: Defining resource models of the main project
Phase 3: PROJECT REALIZATION (PR)
3.1. ERD: Interview, abstraction, data modeling (ER)
3.2. Translation of data model into DB scheme (RM)
3.3. Architecture: Defining program architecture (APP)
3.4. PR Operations: Design of operation on DB scheme
PHISICAL MODELING (BUILDING i.e. DEVELOPMENT)
Phase 4: SOFTWARE DEVELOPMENT (SD)
4.1. Designing physical data base
4.2. Registering DB scheme in data dictionary
4.3. Producing prototype, generating application tree
4.4. 4GL or 3GL programming
4.5. Writing instructions, explaining program solutions
4.6. Entering test data in DB and testing
Phase 5: IMPLEMENTATION AND APPLICATION (IAA)
5.1. Training user
5.2. Entering initial data in data base
5.3. Testing suitability to users' requirements
5.4. Writing help system for users
5.5. Optimization and parallel work of the new and old system
5.6. Final testing – delivery
5.7. Application of program product
Phase 6: MAINTENANCE (MAI)
Performing previous activities in order to introduce new business processes, replace existing business processes and correct errors

MIRIS does not require long learning and it was used in many successful IS development projects. Compared to other methodologies, MIRIS proposes a smaller number of methods used to create the final product (e. g. SSADM v3 uses 12 methods (Weaver, Lambrou & Walkley, 2002)). MIRIS prescribes phases of development and activities within a particular phase, defines relations between particular activities and the sequence of executing the activities. Phases of the life cycle in the MIRIS methodology are divided in two groups: logical modeling (i.e. design) and physical modeling (i.e. building). Each group has three phases further divided into activities. Table 1 lists phases and activities of the MIRIS methodology (Pavlic, Poscic & Marinovic, 2006).

During the first phase, Strategic Planning of IS, the main question that has to be answered is WHY – the problem is defined; during the Main Project phase the main question is WHAT – the problem is analysed; during the phase of Project Realization the question is HOW – the solution is worked on. After the logical group of phases, activities of software production, quality assessment (check), and the first implementation with testing and maintenance are performed. The logical modeling group of phases of the MIRIS methodology uses three basic methods: process modeling method, data modeling method and application architecture modeling method. These methods are adapted and expanded following the requirements and goals that are set. Project assignments of the educational model are linked to activities and phases of the MIRIS methodology as described in the next chapter.

4 PROJECT-BASED LEARNING ACTIVITIES

After choosing a methodology, we recognized the most relevant activities of it, those which should not be skipped in development process, and focused on them. These activities are sufficient for a student to create a final product by following them and therefore are included in project-based learning model. When building an IS, a developer should analyse documents used in the business system, analyse business processes, build data model, define architecture of the future business application, design algorithms and build program code, test application and prepare it for future use. These activities helped define project assignments each student should go through on his/her way to diploma of an IS developer.

Table 2: Project assignments and IS development phases and activities.

No	Project assignment	Development phase and/or activity
1	To collect, organize and analyse IS documents	MIRIS methodology in general 2.4 Data: Data description
2	To analyse business processes and build context model and DFD	2.2 Interview, analysis, process modelling 2.3 Analysis of process, problem and proposal for improvements 2.4 Data: Data description
3	To analyse the data from each document and build ERD	3.1 Interview, abstraction, data modelling 3.2 Translation of data model into DB scheme
4	To build Application architecture model	3.3 Defining architecture of program product
5	To define algorithms and their pseudocode	3.4 Operations: Design of operation on DB scheme 4.4 4GL or 3GL programming
6	To build an application, prepare test cases and implement	4 Software development 5.2 Entering initial data in data base 5.3 Testing suitability to users' requirements
7	To create strategic plan for IS development	1 Strategic planning of IS

Relations between specific project assignments and their corresponding development phases and activities are shown in table 2. However, some activities prescribed by the MIRIS methodology are not covered with the proposed educational model. Activity 2.1 is not linked with a specific project assignment, because in order to prepare a project task, students would need practical experience, and in this stage of their study they do not have it. To avoid the gap, previously developed project tasks are shown to the students. Activity 2.5 Plan would be executable only in a broader system with a number of projects. However, students are bounded only to one project. Activity 2.6 Resources is concerned with ICT needed for system implementation. Phases 5 and 6 are connected directly to application of software in user environment. They are very demanding and time-consuming for the user and require a number of meetings with him/her. In business it is hard to perform activities without proper business motivation, and it would be impossible to find enough business partners willing to perform such a demanding and long-lasting phase for educational purposes only. Only some activities necessary for software implementation from this phase are covered in the proposed educational model. However, the model is complete and concludes the IS development cycle. Each project assignment is assigned to the corresponding course and their sequence is based on didactical and methodical principles: to teach from easier to more difficult, from known to unknown, from simple to more complex.

On the basis of this model we have designed a vertical educational line which starts in the 1st year of undergraduate study, ends with the 2nd semester of graduate study and consists of these courses: Information Systems, Process Modelling, Data Modelling, IS of an Organization, Introduction to SE, Software Engineering and IS Strategic Planning. Apart from project assignments, assessment of students' knowledge is performed by several other methods: paper-based tests or online tests (Candrlic, Asenbrener Katic & Holenko Dlab, 2014), self-online tests (Holenko Dlab, Asenbrener Katic & Candrlic, 2015), oral exam etc., depending on the course. These methods are not a subject of this paper.

5 PROJECT ASSIGNMENTS

In this chapter project assignments are presented. They are designed to fit the complete educational model of project-based learning in the field of IS design and development and to offer enough knowledge and experience to future IS developers.

5.1 Project Assignment 1

The first step in understanding IS design and development is to face it as a whole. By learning about different development methodologies students get the general view on IS development. The chosen methodology (MIRIS) is taught in detail, since it will be the basis for further project assignments. In parallel with theoretical knowledge, a practical assignment is also set. Students are instructed to choose an IS system they will analyse in detail and to gather documents that are used in the chosen system, whether as internal documents, or as input/output from/to external systems. Examples of some systems students choose for analysis are: front office of a bank, pharmacy, shipyard, chain of stores, university, library, accounting office, etc. The practical assignment results in a seminar paper in which students give an overview of the chosen business system. They recognize the purpose of each

document and analyse each data on the document by its meaning and structure. For example, one of the data on the invoice is invoice number. Invoice number will be shown in the seminar paper in the scope of document analysis, as one row of one data analysis table (Table 3). The same technique is used for each data on the document. This is the first step of the analysis and a starting point for the next assignment.

Table 3: Data analysis.

Data	Example	Data type & length	Description
Invoice number	2019-232	String (10)	Issue year and ordinal number of the invoice in that year
…			

After receiving general knowledge on IS development, assignments related to each particular development phase follow. Although Strategic Planning of IS, according to MIRIS is done in the first phase of development, the assignment of preparing IS strategic plan is rather complex and students have to adopt broad knowledge, develop their creativity and mature as analysts in order to perform it properly. This phase and its corresponding assignment will be explained the last.

5.2 Project Assignment 2

Students chose their system already in the previous assignment and gathered the documents. The next step is to perform interviews and meetings with the representatives from inside the system. It is a complicated task that is not always easy to perform. The students are taught Structured Systems Analysis. By following this method, the results of student's paper will include: Data flow diagrams (DFD), context diagram, function tree of the processes and detail description of each process.

After completing this assignment, seminar paper that shows several levels of process model is made and the students have a more detailed view of the business system. Abstract models of the entire system and its subsystems are produced. An example of one part of student's 2nd project assignment is shown in Figure 1.

5.3 Project Assignment 3

The third assignment is related to data modelling. Students are already familiar with the procedure of document analysis. In this phase they learn methods and technics for data modelling. The final goal is to design database and prepare for application development. Students are taught entity-relationship (ER) method, relational models and normalisation and they use it to prepare complex data model of the documents gathered in previous assignments.

Data model consists of ERDs and relational database model (RDBM) built for the documents gathered in first two project assignments. RDBM is the basis for further development. By solving this assignment, students learn to use designer's way of thinking and problem solving and to critically review different ERDs. An example of one part of student's 3rd project assignment is shown in Figure 2.

5.4 Project Assignment 4

The next assignment is to design software architecture model. The APP method (Application

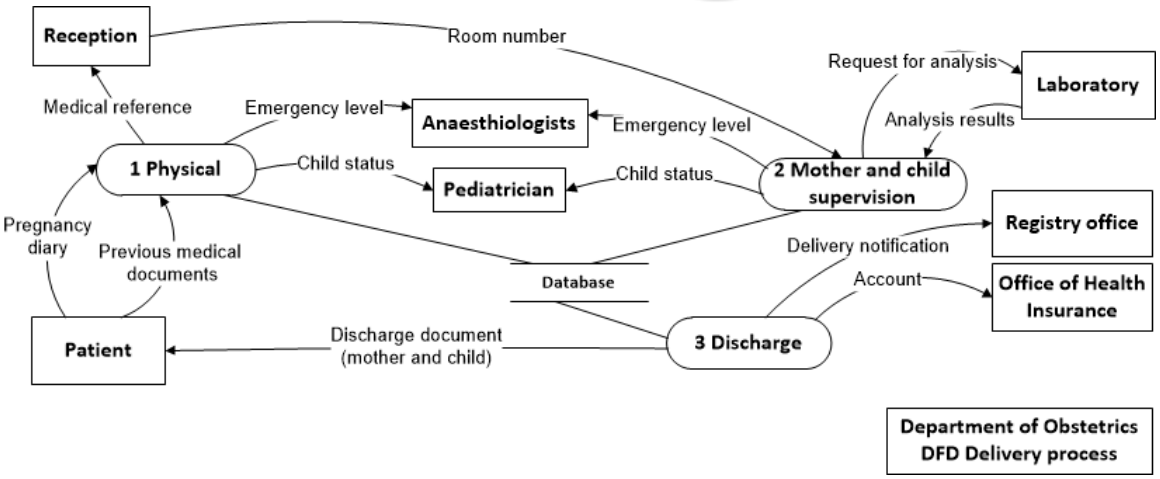

Figure 1: An example of student's DFD (an excerpt).

Architecture Method) is used. It is an original method defined by the MIRIS methodology that relies on DFD and ER methods. By using models designed in the previous project assignments and knowledge about different development tools (gathered in different courses independently of this educational model), students are able to estimate the best solution for their business application. The result of this assignment is a seminar paper with an architectural model that presents future software structure.

5.5 Project Assignment 5

After finishing IS design activities, the next step is to perform activities of physical development i.e. to build a software that supports IS. Different algorithms concerned with specific problems in IS development are analysed. Students learn how to use the capabilities of the chosen CASE tool. The importance of user interface design and user experience is underlined. Students design mock-ups and wireframes. We must emphasize that knowledge and skills in the area of programming are taught in several other courses independently of this project model. These skills are the base for successful execution of project software development.

5.6 Project Assignment 6

In the next step of development, students continue to work on their models created in previous assignments. On the basis of DFD, ERD, APP diagram students estimate remaining development efforts and costs, plan remaining activities, meta-model and develop software in teams. Each team consists of 4-5 members. Since each student finished previous project assignments, a team has an opportunity to choose one business system they will continue to develop among 4 or 5 project ideas elaborated up to that moment to a certain point. They make their choice on the system together with the teacher, on the basis of project analysis. As in any other team, students have complementary knowledge and different previous experiences. Special attention is paid to collaboration in team, team organization, project planning, configuration management, etc. Students take responsibility for different modules. In the end, business application is made. The final assignment of this phase is to present it to others, to discuss and to retrospect the development process. Teams of students can compare their independent work and benefit of each other's knowledge.

5.7 Project Assignment 7

In the end, the final assignment is related to the first MIRIS phase. In order to define the priorities of the business system and subsystems, students work with users from the business system. They try to identify gaps in the process and to estimate the level of support business applications offer to business processes. They estimate the priorities for new business software development and assess their development and implementation efforts, as well as advise about changes and improvements of IS. If students observe a need for software upgrades, they define the scope and business processes covered with it. They prepare the schedule for future activities. Although this topic belongs to the first phase, it is complex and requires a lot of deep knowledge, insight and experience.

5.8 Assessment and Evaluation

After finishing 6th project assignment, software developed in teams is evaluated by representatives from software industry. Teams present their work to

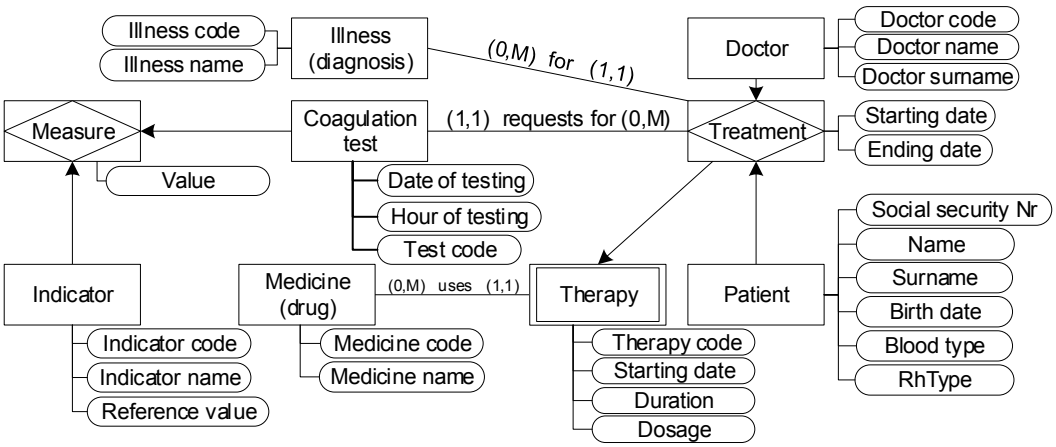

Figure 2: An example of student's ER diagram (an excerpt).

them and discuss about their ideas and solution. According to feedback gained from the students, this element motivates them the most to invest a lot effort and to achieve the highest marks and best comments on their work. Assignments 1-5 and 7 are assessed by teachers just after finishing each. Students' grades received for each assignment are a part of their summative assessment in different courses.

6 CONCLUSIONS AND FUTURE WORK

In this paper we propose a model for project-based learning in the field of IS design and development. Methodology for IS design and development was enriched with new ideas and project assignments which helped to better understand and connect educational and industry environments. Project assignments designed within this educational model are a part of project-based learning model implemented through several courses during several semesters. The described model is in use through a set of undergraduate study of informatics (design topics) and graduate courses of business informatics study (development topics) at Department of Informatics, University of Rijeka, Croatia. The authors have been improving this educational model constantly for the last ten years. Students learn step by step and improve through active participation in project development. The final artefacts are included in IS project documentation and software itself.

We did not describe all assignments students face during their study, and we did not mention the rest of assignments from the described courses. Only project assignments that are a part of the project approach are described. There are other courses that pay attention to different methodologies or tools for software development. Several other courses are partially connected to this model, but are not part of it: courses concerned with programming (Programming, Object-Oriented Programming, Data Structures), Project Management, Databases, etc.

The benefits of this approach are in building a complex solution from the start, and this solution is built with a complete students' understanding. Project-based learning principles help to improve students' motivation and get better view on the design and development process as a whole. We cannot neglect the fact that students get the feeling of accomplishment when they finish a big project. According to students' feedback, learning through assignments is more interesting, they are motivated to learn and to implement their knowledge into the final product. By following project assignments, students get an idea of project development in business and software industry. Final assessment of the project in which participate representatives from software industry offers additional experience. These claims are based on the results of a survey which students of the last two years fill in after finishing the last project assignment. They asses with very high grades (grade range was 1-5) their motivation to work on the described project assignments (4,20), project approach used for learning (4,44) and expected benefit from this experience for their future work (4,25).

We are aware of the shortfalls of this model. Planning assignments is time consuming for the teacher and requires collaboration of a number of teachers who teach different courses. It is also demanding for students, but the benefit of complex development experience is undoubtable. In the end students see the results of their long-time effort. However, not enough time and effort is paid to software testing and we plan to improve this and create a new project assignment and a separate course that would deal with this complex phase. It is important to note that the team is formed only in the last phase of development. Previous activities each student performs on his/her own. The idea to form teams for all project assignments has been evaluated, but considering drop-out and personal differences in students' study advancement, it would be unrealistic to expect to have the same teams throughout the entire study. Also, assessment of group assignments concerning software development is rather challenging. We suggest using some methodology.

This educational model is based on the MIRIS methodology for IS design and development. Its use in educational environment enables flexibility in choosing assignments and focus on two main elements important for IS: processes and data. Agile methodologies bring more dynamics in development process, but considering students' still limited knowledge, its application in education would not always suffice. In addition, considering development activities and its flow recommended by agile methodologies, it would be hard to define integral assignments through several courses as described. Waterfall model, although very clear, would bring a significant rigidity in execution of key assignments.

The final goal of this educational model is to present a compact set of knowledge in the field of IS design and development to the students. Our model offers an opportunity to upgrade knowledge and further develop through the educational and

professional process. Through this educational model students cover IS design and development topics in depth and build the basis for better professional flexibility which makes them more competitive in the market. In our future work we will continue to improve our educational model and try to implement more activities concerned with the testing process and interaction with the user.

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