EXPERIENCES FROM USING OPEN-ENDED AND LIFE-RESEMBLING PROBLEMS IN A MASTER COURSE

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ABSTRACT

Finding the optimum balance between theory and practice is one of the major challenges in higher education. A student-centered approach to learning is argued for by several educational researchers and practitioners, and deep learning could be accomplished by activating the students during the education. This paper reports on experiences learned from a course in Maintenance Data Management, which is thought on the first year of a master's program in Industrial Asset Management, and in specific on how knowledge and skills in computerized maintenance management systems were trained. The course consisted of a series of lectures, laboratory sessions, exercises and seminars. In addition, two study visits and one guest lecture were arranged. In this paper one of the activities is described in more depth. The activity is an exercise in IT system selection, where the students are asked to define functional and non-functional criteria for the evaluation of systems alternatives, to find suitable candidates for evaluation and finally conduct an evaluation and discuss the results. This exercise exemplifies ways to create more open-ended and real-life resembling problems that activates the student in the learning situation, and that simultaneously gives the students possibilities for advanced reasoning and reflection. The detailed learning outcomes of the exercise are described using the CDIO syllabus, and benefits as well as success criteria are highlighted in the conclusion.

KEYWORDS

Student active learning, real-life resembling learning situations, master level course, methods for IT systems requirement determination and selection, Standards: 2, 7, 8

INTRODUCTION

We all know that knowledge and skills connected to the future area of work are important for reaching high employability of students. But that is not all; demands on independence, efficient time management, critical thinking, team work and problem solving skills with limited information, or where several, contradicting requirements exist, are also put on the future engineer/manager (Yorke and Knight, 2007; CDIO, http://www.cdio.org/se/index.html). In addition, understanding for research activities and the ability to apply a scientific approach as well as the ability to discuss and argue for ones solutions and standpoints is required especially for the second cycle education, i.e. on master level. So, is it possible to combine academic stringency with practical understanding? How do we give opportunities for students to experience that the ideal theories described in books differs from the reality and give them possibilities to practice real problem solving for instance in a situation where insufficient information is provided? How can we train the students in critical thinking?

It does not matter how well prepared you, the teacher, are before the lecture, how well you have managed to split the complex phenomenon into digestible chunks, or that you found the very best course literature: learning is an activity made by the student and is dependent on the students' abilities and strategies to learn. Students apply different strategies for learning, spanning from surface learning aiming at memorizing the facts thought, to deep learning, which aims at understanding a topic (Ramsden, 2003). In addition, the students have different levels of previous knowledge and experience, and possess different maturity and age. Teaching could therefore be seen as the profession of creating opportunities for learning in a heterogeneous environment. For coping with the heterogeneity a teaching approach with varying types of learning methods could be applied. Another aspect of learning is the learning situation (Tynjälä et al., 2005). In a teacher-centered approach the teacher shares experiences and knowledge to the students through lectures and speeches, thus the teacher is active while the students are mainly passive. In a student-centered approach the student learns by reading, listening, discussing and doing. The teacher's role in the student-centered approach is the one of a mentor. The teacher creates an active and inspiring learning situation which helps the students to achieve the learning goals set. Several authors and practitioners confirm that a learning environment that activates the students has positive effects on the learning outcome (Macdonald and Scott, 1994; Castles et al., 2009; CDIO, http://www.cdio.org/se/index.html). Macdonald and Scott (1994) claim that learning by doing and an integrated skills training gives connection between conceptualization and reality, develops the ability to think in a holistic way and develops an intuition for engineering. In other words: learning by doing develops both disciplinary competences and general skills and abilities required in higher education.

This paper will describe how different knowledge and competencies could be trained in higher education within the area of maintenance management. The purpose is to illustrate how an active learning situation could be created that will succeed in meeting both the academic goals of education and prepare the students for the future profession. To fulfill this purpose, the paper reports on experiences learned from a course in Maintenance Data Management, which is thought on the first year on a two-year master's program entitled Life Cycle Management of Industrial Assets.

WHAT ARE THE GOALS OF HIGHER EDUCATION?

In this section we look at some different ways to express and classify the goals of higher education. These goals are all reflected in one way or the other in the activity example described in the next section. Higher education is regulated in international standards as well as by national bodies. In Sweden for instance, the education is regulated in the Higher Educational Regulation (1992). Goals are set for the first and second cycle and in addition there are specific goals for education within a specific profession, for instance for engineers, nurses and basic school teachers. For the second cycle education, the goals for the master degree are the minimum requirements for all students irrespective of the program they are taking. For a Degree of Master (Two Years) nine general goals are set according to Table 1.

Table 1. Learning goals for a degree of masters in Sweden

Category	Goals
Knowledge and understanding	a) Demonstrate knowledge and understanding in their main field of study, including both broad knowledge in the field and substantially deeper knowledge of certain parts of the field, together with deeper insight into current research and development work b) Demonstrate deeper methodological knowledge in their main field of study
Skills and abilities	a) Demonstrate an ability to critically and systematically integrate knowledge and to analyse, assess and deal with complex phenomena, issues and situations, even when limited information is available b) Demonstrate an ability to critically, independently and creatively identify and formulate issues and to plan and, using appropriate methods, carry out advanced tasks within specified time limits, so as to contribute to the development of knowledge and to evaluate this work c) Demonstrate an ability to clearly present and discuss their conclusions and the knowledge and arguments behind them, in dialogue with different groups, orally and in writing, in national and international contexts d) Demonstrate the skill required to participate in research and development work or to work independently in other advanced contexts
Judgement and approach	a) Demonstrate an ability to make assessments in their main field of study, taking into account relevant scientific, social and ethical aspects, and demonstrate an awareness of ethical aspects of research and development work b) Demonstrate insight into the potential and limitations of science, its role in society and people's responsibility for how it is used c) Demonstrate an ability to identify their need of further knowledge and to take responsibility for developing their knowledge

The list clearly shows that traditional teaching and assessment in form of written exams are not enough for achieving these goals. You cannot for instance train the ability to plan and carry out advanced tasks within specified time limits or present and discuss conclusions orally in dialogue with different groups by reading a book and thereafter account for the knowledge during an exam. Other ways of teaching as well as new forms for assessment are necessary.

Table 2. The CDIO syllabus v. 2.0 at the second level of detail

Skill group	Detailed skills
1. Disciplinary knowledge and reasoning	1.1 Knowledge of underlying mathematics and science 1.2 Core fundamental knowledge of engineering 1.3 Advanced engineering fundamental knowledge, methods and tools
2. Personal and professional skills and attributes	2.1 Analytical reasoning and problem solving 2.2 Experimentation, investigation and knowledge discovery 2.3 System thinking 2.4 Attitudes, though and learning 2.5 Ethics, equity and other responsibilities
3. Interpersonal skills: teamwork and communication	3.1 Teamwork 3.2 Communication 3.3 Communications in foreign languages
4. Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context	4.1 External, societal and environmental context 4.2 Enterprise and business context 4.3 Conceiving, systems engineering and management 4.5 Implementing 4.6 Operating

Traditional teaching focus on knowledge outcome but personal and interpersonal skills are required, in addition to the formal subject knowledge, in todays' working life (Yorke and

Knight, 2007). This is one of the driving forces for the CDIO initiative, and similar initiatives aiming at modernizing the engineering education. To meet the demands of the modern engineer, a comprehensive list of skills required was therefore developed in form of the CDIO syllabus (Crawley et al., 2011). This syllabus, see Table 2, covers basic and deepened knowledge requirements, personal and professional skills, interpersonal skills, and skills associated with the product life cycle expressed as conceiving, designing, implementing and operating a product, concept or process. Ramsden (2003) divides learning into two types of processes; a process of reproduction and a process of creating meaning. The first process is often a prerequisite for the second one, and the result is learning that gradually builds upon previous knowledge, or progression. The progression of learning skills has been nicely captured in the taxonomy of Bloom where skills are described on different levels of understanding (http://www.coun.uvic.ca/learning/exams/blooms-taxonomy.htm). The levels of skills according to this taxonomy, from the more basic to the more advanced, are found in table 3. Different verbs that explain the skill are given as examples. Within higher education all types of skills are acquired, but especially the higher level skills are in focus, such as analysis abilities, problem definition and solving and synthesis of different information sources to create new knowledge. The taxonomy could be used for measuring rate of goal fulfillment in form of different grades. For a passed grade classifying skills might for instance be enough, while a distinction requires more advanced skills such as generalization or extensive summary.

Table 3. Bloom's taxonomy

Skill	Describing verbs
Knowledge	list, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name
Comprehension	summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
Application	apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover
Analysis	analyse, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer
Synthesis	combine, integrate, modify, rearrange, substitute, plan, create, design, invent, compose, formulate, prepare, generalize, rewrite
Evaluation	assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize

COURSE EXAMPLE: MAINTENANCE DATA MANAGEMENT

The course Maintenance Data Management is a second cycle course that forms a part of the two years masters' program Life Cycle Management of Industrial Assets. The course is given in the end of the first year and covers 10 weeks full time studies. The course consists of four modules: The first module gives a good understanding of IT systems for maintenance management, with specific focus on the Computerized Maintenance Management System (CMMS), and how IT systems can support the maintenance activities. This knowledge is utilized for matching the maintenance demands with appropriate IT tools. Module two and three focus on the data need within maintenance management. Firstly, the student will lean how to describe the data need through Entity Relationship modelling and the concept of data quality. A further discussion of data need is thereafter held, and the data need is connected to decision making and key performance indicators. The last module covers inventory management and spare parts optimization.

The course is set up as a series of lectures, laboratories, exercises and seminars. The modules are thought in a slightly overlapping mode, where the theoretical foundation of each module is firstly given in form of lectures. Thereafter, deepened knowledge and practical work in form of exercises, assignments and laboratories follow. In the end of each module a discussion seminar takes place. In addition, one guest lecture and two industrial study visits are held in the later part of the course. The study visits provide the students with empirical data for a final essay or report within the topic. The development and design of the course did not face any particular barriers or difficulties. The participating teachers have many years of experience in problem and project based learning and have set up similar courses on first cycle level. The most challenging was to create assignments on a suitable academic level which at the same time were giving the students practical and professional training. This is addressed further in the conclusions when discussing further course development.

THE IT SELECTION EXERCISE

To depict how a student activity could be set up and used as a means for promoting active learning one exercise from the Maintenance Data Management course will be described in more detail in the following. The setup and instructions for the activity, the learning outcome connected to the activity as well as the practical student outcome will be described.

The aim and expected outcome of the activity

The aim of this activity is to reach understanding of the IT procurement process in general, and the procurement of computerized maintenance management systems in specific. To do so, the students follow the process from defining requirements onto selecting a candidate IT solution. The expected outcomes connected to level of grade are accounted for in table 4.

Table 4. Learning outcomes

Learning outcome	**For grade 3**	**For grade 4**	**For grade 5**
Select IT system for maintenance management based on defined requirements	The student **knows** the different steps in the IT procurement process and **can use** a method for selecting the most appropriate IT system for defined business needs. The student **can describe** the business needs in form of functional and non-functional requirements and **is able to weight** the different requirements with respect to importance. The student **can select** one IT solution and **describe the reason** for selecting this solution compared to other solutions.	The student knows the different steps in the IT procurement process and can use a method for selecting the most appropriate IT system for defined business needs. The student **can transform** business needs into functional and non-functional requirements and is able to weight the different requirements with respect to importance, and **motivate** the different weights. The student can select one IT solution and **motivate the selection** based on a discussion of requirements coverage versus cost-effectiveness.	The student knows the different steps in the IT procurement process and can use a method for selecting the most appropriate IT system for defined business needs. The student can transform business needs into functional and non-functional requirements and is able to weight the different requirements with respect to importance, and motivate the different weights. The student can select one IT solution and motivate the selection based on a discussion of requirements coverage versus cost-effectiveness. The student **can reflect** on the IT procurement process and how the quality of the process can affect the quality of the procurement.

The learning outcomes were developed having the nine general goals for a Swedish master's degree in mind. The competencies trained are connected to the four higher skills in the taxonomy of Bloom: application, analysis, synthesis and evaluation, see table 3. The students actively apply a method for IT procurement. They have to analyze the IT requirements of a case company. Thereafter they gather information regarding suitable candidate solutions, thus make a synthesis, and finally evaluate the information for finding the optimal IT support for the given case.

An informal report is handed in by the student after the exercise session, and the exercise is also discussed at a seminar the week after. As a preparation for the seminar, the students are given a written assignment. The final assessment is based on the exercise work (performance during the exercise occasion), the exercise report, the discussion held during the seminar and the written solution to the assignment referred to above. In other words, the learning outcome is assessed using a variety of practical, written and oral assessment methods. The attendance on the exercise and seminar is graded as either passed or failed. Active participation in the group work and the ability to discuss the specific topics addressed are required for passing the activity. For ensuring that all students are actively taking part in the exercise one instructor is observing the process during the full activity. The instructor also assess the groups' ability to describe the different steps taken during the exercise session; first for assessing the ability to transform business needs into requirements and motivate different weights applied on the requirements, thereafter for assessing the ability to motivate the final selection. If the students did some mistakes or need to adjust their work, this are thoroughly discussed, and the groups correct their mistakes before continuing with the exercise. The main part of the learning outcome is thus assessed on group basis and the students would not be able to proceed with their exercise if they do not show up the abilities required. The ability to reflect on the quality of procurement process is assessed individually based on the answers to the individual assignment and the discussion held regarding this during the seminar.

Activity setup and instructions

The activity is conducted three and a half weeks into the course at a scheduled three-hour session held in one of the computer rooms. The students have prior to the activity learned about different IT systems for maintenance management in theory and in practice (laboratories in a real CMMS environment), and about IT systems and their application from a technical, organizational and economic perspective, with specific focus on the maintenance business. The students are divided into smaller groups consisting of three to six students before the actual exercise session. The groups are given the instruction that they will act as the newly hired maintenance manager at a plant and as such they should run an IT procurement project because the current maintenance management systems were obsolete, see appendix A. Thereafter they are asked to read one of two case company descriptions provided. Half of the student groups will work on the first case and the other half on the second case.

The two cases represent two types of plants, a printing works and a paper mill respectively, with different levels IT maturity and different IT needs and consequently different requirements of IT support. In the printing work case no formal computerized support is used at the moment for the maintenance management, and the group should therefore find a candidate IT system with basic functionality. In the paper mill several IT systems are already in use but there is a need for additional IT support for condition monitoring data analysis and decision support. The printing works represents an IT immature organization while the paper mill represents a mature IT organization. Even if the needs and requirements differ the procurement process to follow is the same for both cases.

A note on the instruction description: This situation, i.e. that a newly hired manager was to run an IT procurement project is quite unrealistic in a larger organization, but in a smaller company it could happen. The author of this paper knows about at least one real occasion. From the students' point of view this is quite the situation though: in the assignment they will assess and evaluate an IT solution based on scarce information and no real understanding of the company they "work" on, and therefore they will resemble newly hired managers more than experienced ones. The groups are also given brief descriptions of the plant operations, maintenance and maintenance goals.

The groups are given the same instructions consisting of the task description, the exercise aim, the expected learning outcomes, the material list and a work plan. The work plan consisted of following six steps to be conducted during the three hour session (see Appendix A for a detailed description):

1. Planning
2. Brainstorming
3. Requirements selection and prioritizing
4. Selection of candidate systems for evaluation
5. Evaluation of systems
6. Choice of system

In the first step the group has to plan the three hour session, and this plan is communicated to the instructor. Thereafter brainstorming takes place for finding the requirements, both functional and non-functional (for instance user friendliness, performance or security) based on the description of the case company. In step three the requirements are grouped, prioritized and filled in to a Multi Criteria Decision Making (MCDM) matrix that is used for assessing the alternatives. Next activity is to find suitable candidate solutions. This is made by searching on the Internet for suitable vendors. As a help some useful web sites are mentioned in the instructions, but the students are not restricted to use only these.

The two groups meet twice during the exercise for a joint discussion led by the instructor. The first meeting is held after step three approximately half way through the session. During this, the selected requirement criteria and weightings are presented and discussed. The formulation, level and importance of each criterion are discussed, and thereafter the groups could make changes in their requirements list before starting to work on step four. Another meeting is held after step six, when the results of the MCDM are discussed, and the selected IT solution is presented and motivated for. These results form an excellent basis for discussions regarding requirements of maintenance management IT and how they differ depending on for instance the size, organization, maturity, IT architecture and maintenance strategies applied by the company.

Activity follow-up: Outcome discussion and methods reflection

The final systems selection made in the exercise is not only affected by the above mentioned factors; it is highly affected by the method itself and the choices of the student group. The exercise makes thus an excellent basis for discussing how the quality of the process affects the quality of the outcome, in this case the actual decision of which system alternative to choose. Consequently, this exercise gives a real-life resembling experience of how hard it is to make an optimal decision, from defining the decision criteria to making an appropriate selection from a set of options available. It especially illustrates how sensitive the decision making process is with respect to information retrieval and own judgments. The choice, weighting and formulation of criteria will for instance directly affect the outcome. These steps are all based mainly on own judgments and previous experience. The selection of different alternatives is made based on information available, and during the joint discussions held at the exercise the students especially pointed out the problem in finding information that fit the set criteria and which were comparable. Using real information sources, in this case the IT system vendors own web pages, demonstrators and brochures, gives the students a good understanding of what they might expect to find in form of information resources in a real working situation. Also, the actual decision could be made based on several factors of the MCDM, not only the total sum of each alternative. One could for instance take into account to mandatory requirements coverage, i.e. to see which alternative covered the criteria weighted "100" in the best way, even if the total sum of the alternative might be lower than other alternatives, or to take the cost into account and select the most cost-effective alternative. This kind of decision considerations were also discussed during the exercise with the basis in the MCDM results.

The students were asked to hand in a written solution to following question: ***"Reflect on the IT procurement exercise and the outcomes from this. How can the quality of the process (i.e. how you conduct the different steps, like determining criteria, weighting criteria, selecting alternatives and final choice of system) affect the quality of the procurement in total?"*** In other words, they were requested to reflect on the methods used, how reliable the data and the methods were, and how the results have been affected by the method applied. The written reflections spanned from quite simple analyses of the procurement process to reflections showing good understanding of the process. One example of the latter is: *"In the next step we have selected the main criteria of the systems that originated from brain storming and allocated the weight to the based on their importance for the required system. This was very much important step, the wrong selection of criteria will move us away from the target and their wrong weight age will increase or decrease the importance of the criteria. // If we have allocated the wrong weight to integration [one of the criterion, author's comment] from 100 to 50 it surely has changed the quality of the system purchased as weight is multiplied (in the MCDM analysis, author's comment)."*

Notable is that the full procurement process was covered in only three hours. The results as such would not serve as a good basis for a real IT procurement decision. The main aim was not to reach a solid decision either, but to depict the process itself and the different problems that might occur during it. The students did understand very well that this kind of activity takes weeks or months in real, and that additional resources in form of consultants and other personnel from the company are involved in the process. The real time to complete the full process was asked for by the instructor during the session, and it was also addressed in the student reflections: *"After weighting these criteria, we searched for possible software alternatives. In real cases, this process takes more than 1 month but we searched among the internet and found 3 alternatives. // This selection is depending on a short study and some* *assumptions so it is not certain solution for the company. Making a wrong decision in this process can cause fatal losses especially economical loss. Purchasing wrong software may lose time, effort, and money as well as it slows the work in the company. Companies usually contact with consulting companies for such decisions."*

Skills trained during the exercise

Several different skills are trained during the exercise. In Table 5 the most important ones are listed with respect to the four groups of skills of the CDIO syllabus version 2. The exercise trains skills from all four groups, but especially from groups two and three, because the personal, professional and interpersonal skills are a necessity for succeeding with the assignment. Without good team operation and dialogue the group will not be able to cooperate. Similarly, without problem solving and analytical skills the group will get stuck in arguing without being able to make necessary trade-offs and decisions.

Table 5. Skills trained according to the CDIO syllabus

Skills group	**Skill**	**Activity where skill is trained**
Disciplinary Knowledge and Reasoning	Advanced engineering fundamental knowledge, methods and tools	Overall exercise level
Personal and Professional Skills and Attributes	Analysis With Uncertainty	Choice of system
	Solution and Recommendation	Choice of system
	Survey of Print and Electronic Literature	Candidates selection for evaluation, Evaluation of systems
	Thinking Holistically	Requirements selection and prioritizing
	Emergence and Interactions in Systems	Brainstorming
	Prioritization and Focus	Requirements selection and prioritizing
	Trade-offs, Judgment and Balance in Resolution	Requirements selection and prioritizing
	Initiative and the Willingness to Make Decisions in the Face of Uncertainty	Overall exercise level
	Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility	Overall exercise level
	Creative Thinking	Brainstorming, Candidates selection for evaluation
	Critical Thinking	Requirements selection and prioritizing, Evaluation of systems
	Time and Resource Management	Planning
	Ethics, Integrity and Social Responsibility	Overall exercise level
	Professional Behavior	Planning
Inter-personal Skills	Team Operation	Overall exercise level
	Oral Presentation	Choice of system
	Inquiry, Listening and Dialog	Planning
	Negotiation, Compromise and Conflict Resolution	Requirements selection and prioritizing
	Advocacy	Brainstorming
C-D-I-O Systems	Understanding Needs and Setting Goals	Overall exercise level

CONCLUSIONS

In the above given activity example the focus was set on the process rather than on the result, and therefore this kind of activity forms a good basis for further discussions. In the case above the exercise was followed by a written reflection as well as by a discussion seminar. This allows the teacher to capture mistakes and poor decisions and use them as a real experience for further learning. As teacher, you have to be able to capture what happens during the learning situation in order discuss it later. Thus, the teacher is not a passive part in the exercise. The exercise occasion is also an excellent opportunity to discuss the subject with the group or the individual student, allowing for one-to-one communication with the students. One example is the question regarding how long an IT procurement project would take in real that was raised informally during the session. The benefits with this type of learning activities are many: students who takes an active part in the learning, activated students throughout the full course (and not just the week before the written exam), possibility to set up a good progression of learning goals within the course and the full education program, and independent students planning and taking responsibility for their learning.

To succeed with this, it requires thorough planning and preparation. The teacher must plan the exercise thoroughly, for instance in form of well written instructions and transparent learning outcomes telling what you expect for different grades and how to achieve these outcomes. Written instructions and the time plan should be shared and clearly described for the students well in advance. The students should have clear instructions so less time is spent in understanding what to do rather than doing. This means investing a little more time in the planning phase of the course, but in return you will have a course that runs smoothly and where the demands of the participants, both the teachers' and the students', are well defined. Students should have basic knowledge in the specific area, in this case computerized maintenance management systems and IT procurement. Therefore, the activity was given towards the end of the course. Moreover, each individual student must enter the exercise with willingness to act and share their thoughts, and a wish to participate actively throughout the exercise. They should possess the ability to speak freely, and not only when asked for. Moreover, the student group should be confident with each other and allowing, thus let all participants contribute based on their qualifications. The teacher must be participating, however in a non-controlling, sensitive and allowing manner. This means that the teacher should allow the students to make their own decisions even if they might not be the optimal, but have the ability to guide the group throughout the exercise and in the end discuss the outcome from the perspective of pros and cons in the strategy applied.

In addition, willingness to take the risk that there are no definite right or wrong answers to the problems you deal with during the course is needed. As a teacher you have to adapt a student-centered approach to succeed, because once the activity started you are not in full control of the process. Instead, the students are the active part, and as teacher you need to be careful not to steer the process too much. Thus, an environment where it is allowed to make mistakes and test own ideas must be created, or else the activity will not achieve its goals.

Course evaluation and further development

How was the course perceived by the students and the teachers? The student point of view was captured in the oral course evaluation. Especially the laboratories and the exercises, which were practical and real-life resembling activities, were appreciated by the students.

Also the guest lecture and study visits received positive response. In contrast, the assignments, i.e. mainly theoretical studies, were something that could be improved according to the students. The assignments were not encouraging or realistic, they said. Instead there could be real case studies to work on. The course coordinator agrees with the student comments, and makes following comment in the course evaluation: “The assignments could be more realistic and the idea of case studies is well suited. The case could be utilized for assignments, exercises as well as for the laboratories.”, and in continuation: “Best would be to have a real industrial case to work on during the course.” The latter is hard to achieve though because it demands good collaboration with dedicated industries that have real problems to solve which are relevant for the course content. Another obstacle is the time. The course runs over ten weeks and as such gives few possibilities to follow the full process of for instance IT procurement. Yet another aspect to take into account is that the written assignments together with the final project are means to take active part of the current research within the topic. Sufficient time must thus be given for searching, assessing and reading scholarly material and not only for the practical work with e.g. data gathering and analyzing.

As main development for the next course occasion it was decided to reformulate the assignments into more realistic cases while not compromising the scientific level of the assignments. Thus, the assignments were to be reformulated into realistic tasks that a professional might face, and as a part of the execution reading, reviewing and utilizing current research would be necessary. The other course activities and the schedule design will not be subject to larger changes. Another area of development would be to describe grading criteria for all skills trained, and not only for the knowledge outcome. The personal, professional and interpersonal skills are today expressed in a separate sheet for the education program as a whole and are implicitly included in the leaning outcomes, but by formulating them explicitly as separate course goals, the training of these skills would be highlighted.

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BIOGRAPHICAL INFORMATION

Mirka Kans, Ph. D. holds a position as associate Professor in Terotechnology and has been program director for several educational programs since 2004 and forward. She is active in developing the education practices and curriculum according to student centered and active learning concepts (e.g. in form of CDIO), and in close collaboration with industry. The research is focused on data and IT requirements for maintenance management and how to support maintenance by means of IT.

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Appendix A. Exercise description

Exercise objective:
Exercise 1 aims at
- understanding of the MMIT procurement process

Task:
You are a newly hired maintenance manager at one of the case companies (either the printing works or the paper mill). The IT support is obsolete, and you are asked to run the IT procurement project.

For the printing works, the project is focused on finding a suitable IT system that will replace the mainly manual system in work today. Focus is on automating the planning work and get better support for maintenance execution.

In the paper mill, they already have a lot of IT systems implemented, but the integration between them is not optimal, and therefore they look for a better solution to the current patchwork of systems that are loosely integrated today. One common and integrated solution would be a good alternative. Focus is on getting full support for decision making and follow up, and to maintain the high degree of automation in work order handling and inventory/equipment management.

Material:
Case company presentations (Kans, 2008), CMMS, ERP and EAM system descriptions from the web (see examples in paragraph 4), post its, MCDM-matrix.

Learning outcome connected to the exercise:

Select IT system for maintenance management based on defined requirements	The student **knows** the different steps in the IT procurement process and **can use** a method for selecting the most appropriate IT system for defined business needs. The student **can describe** the business needs in form of functional and non-functional requirements and **is able to weight** the different requirements with respect to importance. The student **can select** one IT solution and **describe the reason** for selecting this solution compared to other solutions.	The student knows the different steps in the IT procurement process and can use a method for selecting the most appropriate IT system for defined business needs. The student **can transform** business needs into functional and non-functional requirements and is able to weight the different requirements with respect to importance, and **motivate** the different weights. The student can select one IT solution and **motivate the selection** based on a discussion of requirements coverage versus cost-effectiveness.	The student knows the different steps in the IT procurement process and can use a method for selecting the most appropriate IT system for defined business needs. The student can transform business needs into functional and non-functional requirements and is able to weight the different requirements with respect to importance, and motivate the different weights. The student can select one IT solution and motivate the selection based on a discussion of requirements coverage versus cost-effectiveness. The student **can reflect** on the IT procurement process and how the quality of the process can affect the quality of the procurement.

Work plan

1. Plan

Plan the work and set a brief time table.

2. Brainstorming

Brainstorming to find functional and non-functional requirements. Use post its to document these. Discuss the requirements, group, sort and evaluate the requirements.

3. Select and prioritise requirements

Select the most relevant requirements. (Around 10-15 would be suitable.) Rank the requirements according to importance. Use the scale 0-100, where 0 means unimportant and 100 mandatory. Fill the MCDM matrix with criteria (requirements) and weights (ranks).

4. Select systems for evaluation

Search for suitable systems for the evaluation. Use for instance one of following links:
http://www.maintenanceresources.com/cmms/index.htm
http://www.plant-maintenance.com/CMMS_vendors_A-L.shtml
http://www.cmms-directory.com/cmms-software-guide.htm

Select 3 up to 5 systems for closer evaluation.

5. Evaluation of systems

Read about the system alternatives. Try to assess the grade of which they can fulfil your requirements. Give each alternative a ranking using the scale 0-5, where 0 is no support at all and 5 full support. Fill the MCDM matrix with your assessments.

6. Choose system

Calculate each system's ability to meet the stated requirements. Based on the information in the MCDM matrix, choose the system that fits your needs in the best way.