Continued Multidisciplinary Project-based Learning – Implementation in Health Informatics

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Summary

Objectives: Problem- and project-based learning are approved methods to train students, graduates and post-graduates in scientific and other professional skills. The students are trained on realistic scenarios in a broader context. For students specializing in health informatics we introduced continued multidisciplinary project-based learning (CM-PBL) at a department of medical informatics. The training approach addresses both students of medicine and students of computer science.

Methods: The students are full members of an ongoing research project and develop a project-related application or module, or explore or evaluate a sub-project. Two teachers guide and review the students' work. The training on scientific work follows a workflow with defined milestones. The team acts as peer group. By participating in the research team's work the students are trained on professional skills.

Results: A research project on a web-based information system on hospitals built the scenario for the realistic context. The research team consisted of up to 14 active members at a time, who were scientists and students of computer science and medicine. The well communicated educational approach and team policy fostered the participation of the students. Formative assessment and evaluation showed a considerable improvement of the students' skills and a high participant satisfaction.

Conclusions: Alternative education approaches such as project-based learning empower students to acquire scientific knowledge and professional skills, especially the ability of life-long learning, multidisciplinary team work and social responsibility.

1. Introduction

Health informatics is a multidisciplinary field. Computer scientists, health care professionals and experts from other disciplines, such as social sciences, work together on research, design and implementation of health informatics systems. Potential patients and stakeholders in politics and economics are also involved. The curricula of universities have to consider that learners have to acquire professional skills such as communication and presentation techniques and project work to support successful multidisciplinary work [1–6].

This motivated the development and implementation of continued multidisciplinary project-based learning (CM-PBL) at the department of medical informatics at RWTH Aachen University[a]. The approach aimed to train students of computer science and of medicine in the field of health informatics and in professional skills. In order to work on a thesis the students joined a research project that served as realistic scenario for the project-based learning approach. Their theses dealt with a project-related application or module, or explored or evaluated a sub-project. The research project worked on the development of a web-based information system on hospitals [7, 8].

In the following we report how CM-PBL has been applied. The addressed period lasted from April 2002 until April 2007. We discuss the opportunities and limits of this approach and what should be examined in future studies.

2. Background

Embedding learning objectives in a realistic scenario yields higher motivation and improves the learning outcome concerning professional skills [4, 6, 9–11]. This led to the concept of problem- and project-based learning. Problem-based learning was developed for law classes at Harvard University during the nineteenth century [12]. The teachers used realistic cases to introduce the students to the topic and to train them on juristic thinking and decision making. In medicine this case-based approach was adapted and found its broad acceptance as problem-based learning from the 1970s on [13–15]. Economics and computer science, to name just two examples, extended problem-based learning to project-based learning [11, 16, 17].

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[a] Please note that the abbreviation "PBL" is in use for problem-based learning and for project-based learning.

Experts have to be able to work in teams and in time-limited projects. At several faculties this led to the idea to assign one or two term courses to research and development projects. The work in realistic scenarios is a convenient platform for cognitive learning [4, 6, 9–11, 16]. During the course of a project the students cooperate in teams. Firstly they identify subtasks and assign the tasks to the sub-teams. They learn project management fundamentals. During the term the sub-teams present their progresses and open questions to the whole group. The teacher and the other students give feedback. This fosters goal-oriented working and the ability to present and discuss issues professionally.

Terminologies and social patterns differ widely between different disciplines. Hence, being inherently multidisciplinary health informatics offers an additional benefit: If project-based learning is performed by a group of students coming from different disciplines, such as computer science and medicine, the participants can learn how to communicate with experts from other disciplines [2, 5, 6, 17–19].

It may be time-consuming to organize a seminar with a project-based learning approach lasting one or two semesters for students of different disciplines [6]. Long-term research projects provide an alternative approach. Students, graduates and PhD students from different disciplines can be integrated in such a project and work on their theses.

At the department of medical informatics at Aachen University students of computer science and medicine are trained in medical informatics. They get the opportunity to work on theses in medical informatics (student's research project), in computer science (diploma theses) and on PhD theses in computer science or medicine. Often they are integrated in larger research projects.

The development of a web-based information system on hospitals was one of these projects [7, 8]. It requested a multidisciplinary team of computer scientists and health care professionals. Thus the integration of students of both fields made it possible to attain three goals:

1. to perform research on web-based information platforms in health care and the development of a web-based information platform on hospitals in a multidisciplinary team,

2. to mentor students of computer science and medicine during their theses and to educate them in scientific working,
3. to train students in general professional skills.

3. Implementation of CM-PBL

Many reports on the successful implementation of project-based learning, such as [4, 5, 16, 17, 20] and experiences reported for instance by Demiris [19] encouraged us to implement continued multidisciplinary project-based learning (CM-PBL) in the context of a long-term research project. The development of CM-PBL was incremental. Experiences with project work in an international consulting company, literature work, training courses in problem-based learning and last but not least the continued cooperation of the teachers and the students facilitated the development of CM-PBL. Formative evaluation triggered further adaptations and improvements.

3.1 Realistic Scenario: Development of a Web-based Information System on Hospitals

Starting point for the development and implementation of CM-PBL was a research project on a web-based information system on hospitals, called the CERES-Project [7]. The research project strived to offer ubiquitous, up-to-date and valid information about hospitals, their structure, their services and their results. The users shall be able to view different hospitals at a glance using one platform. Identified user groups are for instance citizens (the potential patient) and staff members of hospitals, health insurance companies, institutions of the government and professional medical associations. The central object-oriented database is based on a generalized model of "the German hospital". The user is able to access this database during runtime by different web-front-ends, which are for example "Search", "Tables", "Texts" and "Map". In 2007 a prototype, the "Klinik-Scout", was released on the Internet to discuss this topic with scientists, stakeholders in health care and last but not least with the target group, the potential patient. The user was asked to participate in the web-based evaluation or to send feedback via a free-text form

[8]. In addition to this main research project the research group performed some smaller research projects on mobile computing in health care. The research group's website (http://isg-med.de) gives an overview.

3.2 Integrating the Students in the Research Project

Joining the long-term research project the students work on their theses as full-value team members. The students develop a project-related application or module, or explore or evaluate a sub-project.

A senior scientist acts as project manager and teacher of the students. She conducts the weekly team meetings. A second senior scientist cooperates as co-teacher. Each student attends the weekly team meetings and follows a fixed sequence of individual meetings with the teachers and presentations with group feedback. Intermediately the teachers give short lectures on scientific work, such as literature research, in one of the weekly meetings.

The policy and the roles and tasks of the team members are described in detail in the project documentation that is accessible on the project server (see [21], pp. 6–8).

The students' commitments are:
- willingness to work in the CM-PBL context on his or her thesis,
- willingness to become acquainted with new research areas,
- professionally work on his or her research project and thesis: in time, reliable etc.,
- work in the CM-PBL context:
  - participation in the weekly meetings,
  - communication via e-mail and the research server,
  - adherence to the data security policy,
  - cooperation on the documentation,
  - acting as peer group: support of the other team members in their research projects by giving feedback,
  - preparation of the meetings, of conferences and projects concerning the whole research group.

The project context builds the basis for the training in professional skills, such as presentation techniques, active listening, team work, project work and management [2, 3, 6, 10, 19, 22, 23]. ▶ Table 1 gives an overview on the "Instruments of CM-PBL".

Concern	Instruments
Project Management	Goals
	Policy
	Roles and tasks
	Rules (e.g. etiquette and "Software Development Guidelines" [28])
	Controlling (e.g. "Annual Balance and Outlook")
	Project server: platform for ● Computer-supported collaborative work ● Knowledge management
	Documentation ● Project documentation (internal) ● Theses and presentations (internal) ● Source codes, applications and research data (internal) ● Public website (http://isg-med.de)
Communication	Weekly project team meetings
	E-mails
	Voluntary students' meetings (online and face-to-face)
	Mentoring talks: teachers and student
Reflection and Feedback	Presentation of the ongoing work on the thesis at defined milestones: students act as peers
	Teachers are facilitators, mentors, guides
	Scientific work and professional skills: formative evaluation and intervention
	Teaching approach CM-PBL: formative evaluation and adaptations and improvements

Table 1
Instruments of CM-PBL

The team consists of up to 14 active members at a time from the fields of computer science and health care (medicine, public health, health economics). The well-communicated educational approach and team policy fosters the participation of the students: they build the foundation of transparency and trust [2, 10, 23].

During the weekly meetings one or two students present their work on certain milestones of their thesis and get feedback from their team mates and from their teachers. This fosters social interactions, which are regarded as a crucial part of a good learning environment [9, 10, 19, 24].

3.3 Organization of the Theses

The students work on a thesis in computer science or in medicine:

● A student's research project is a thesis in medical informatics performed during the third year of a diploma study on computer science. It corresponds to a bachelor thesis.
● A diploma thesis is performed during the fourth year of a diploma study on computer science and is comparable to a master thesis.
● Doctoral theses in medicine include: Dr. med. (the candidate studies medicine or is a physician), Dr. med. dent. (the candidate studies dentistry or is a dentist), Dr. rer. medic. (the candidate comes from another discipline, chooses a medical topic and has to fulfill some other requirements, e.g. a course in medical terminology).

Students of computer science develop a project-related application or module. Students working on a doctoral thesis in medicine explore or evaluate a sub-project.

The workflow "Milestones of a Thesis" (▶ Table 2) is intended (a) to support the student in the organization and performance of his or her work on his or her thesis, and (b) to facilitate the guidance and formative review by the teacher, as suggested by Donelly and Fitzmaurice ([6], p. 90). The teacher introduces the student during the first individual meeting to the workflow, which is part of the project documentation. The workflow is accessible on the project server for every team member. It describes the structured conversation of the teacher with the student (Laurillard 1998, see [24]), and the familiarization of the student with the IT environment of CM-PBL.

3.4 The Teachers as Facilitators, Mentors, Guides

In CM-PBL the teachers act as facilitators for the group process, as personal mentors, and as guides in the field of methodology and scientific research. This requires a certain set of skills in addition to specialized knowledge and project management skills, such as guidance of group discussions, intuition and the willingness to get involved with the students [6]. The latter is essential for the formative, individual assessment of the students and for the ability to react flexibly and promptly and make "it easier to remedy the problem of students taking a 'wrong' direction" ([6], p. 91).

The two teachers assess formatively the students' work and skills and offer feedback and support. The teachers meet monthly to evaluate each student's scientific work and professional skills using a set of assessment criteria. Every criterion is described on four levels, A to D. If a criterion is rated as C or D, the teachers start an intervention. Additionally, the teachers decide after a student's presentation during the weekly team meetings, whether an intervention is necessary.

The criteria on scientific work are [25]:
● knowledge and competency,
● methodical and scientific work,
● determination, commitment and autonomy,
● quality of performance,
● quality of presentation.

The criteria on professional skills are [22, 23, 26]:

- dependability,
- open-mindedness,
- purposefulness,
- time management,
- capacity for team work.

Either a student is asked to perform a second presentation of the work one or two weeks later, or the teachers decide to discuss the student's work with him or her in a supplementary conversation. This applies especially for the professional skills, as the teacher and the student have to discuss to a certain extent the student's characteristics. Furthermore, the student can ask the teachers for additional support.

4. Results

The research group worked on some small and medium-sized research and development projects in Health informatics (see http://isg-med.de). Students of computer science mostly developed a project-related application or module (including the systematic elicitation of requirements, the formal definition of programming interfaces and – if applicable – a usability check of user interfaces). Students working on a doctoral thesis in medicine were entrusted with well-defined sub-projects: They carried out evaluation studies of system components and usability studies of the web interface. Alternatively, they supported the modeling process by the elicitation of special aspects of the domain. The productive research environment resulted in the implementation of a prototype of a web-based information system on hospitals, the setup of a web-based evaluation and a software development guideline that was used as a quality assurance tool. The smaller projects covered mobile computing in health care.

The teachers evaluated formatively the students' scientific working and professional skills and the educational approach. The formative assessment of the students' work served to give the students a comprehensible feedback on the progress of their theses and on their acquisition of professional skills, as requested and shown for instance by Heinze and Procter [24] and Demiris [19].

During a five-year period (2002–2007) 32 students and four trainees joined the research

Table 2 Workflow "Milestones of a Thesis". (*) Formative evaluation of the CM-PBL approach: expectations, satisfaction, suggestions for improvements

Period	Milestone	Means	Involved
Orientation	Request for a thesis topic	First contact (e-mail or call)	Student to teacher
	Becoming acquainted with each other and the project	First individual meeting	Student and teacher
	Announcement of participation	E-mail	Student to teacher
Planning	• Study design • Draft of the thesis plan	Second individual meeting (*)	Student and teacher
	Becoming a team member	First participation in a team meeting	Student and team
	Access to the project server	E-mail	Project assistant to student
Performing	Proposal	Working paper	Student to teacher
	• Research question • Study design • Thesis plan	First presentation	Student to team
	Support in open questions and problems	Further individual meetings (*)	Student and teacher
	Conduct of the thesis, e.g. • Requirements analysis • Design • Implementation • Evaluation	Further presentations	Student to team
	Basis for further research and development (R + D)	Provision of the developed application, the research data and the final thesis report on the project server	Student to team
	Acceptance of the work	Final presentation	Team to student
	Acceptance of the thesis	Final thesis report	Teachers to student
	Closure: Discussion of future R + D ideas and profesional plans	Final individual meeting (*)	Student and teacher

team. Twenty-five (78%) students finished their thesis successfully: 16 student's research projects in medical informatics, four diploma theses in computer science and three (plus two nearly finished) PhD theses in medicine plus four trainee's projects. The drop-outs comprised five PhD students (after three months) and one master student in biomedical engineering (after four months). They abandoned their work due to time management problems. One student, who worked on a diploma thesis in computer science, had to suspend the thesis due to an illness. Five students presented and published their work on conferences and in journals as main authors

(see http://isg-med.de for the list of publications).

The professional skills depend on the experience of a student so far and can improve during project-based learning [4, 6, 9, 10, 19]. All students showed improvement of their professional skills, for instance, increasing self-confidence and professionalism in their team work and in the presentation of their theses, both written and orally. The students were open-minded for the interventions and suggestions of the teachers, which were based upon the formative assessment. The students appreciated the feedback by the team members during and after their presentations.

The teachers evaluated the educational approach formatively to obtain continuous improvement, as it is requested for the implementation of an alternative teaching approach for instance by [2, 3, 18, 19]. Group interviews during the weekly meetings were performed regularly in the context of the annual balance and outlook and intermediately on demand. With each student three individual interviews took place during the personal meetings with the teacher (see Table 2). The first interview dealt with the expectations of the student. The second interview reflected on the progress of the student's thesis and satisfaction with CM-PBL so far. The final interview asked especially for possible improvements of CM-PBL.

The evaluation showed a high participant satisfaction and facilitated the continuous improvement of CM-PBL. For instance during one group interview the students asked for a guideline how to perform a thesis. This led to the explicit formulation of the workflow "Milestones of a Thesis" (see Table 2). The students reported that the work on the thesis became a lot easier after the introduction of the workflow. In the following, an assortment of student comments during the evaluation is presented.

The students appreciated the supervision and guidance, e.g.: "The teachers attend my thesis in a structured way and reliably. The feedback is useful." The integration in one's studies was easy, e.g.: "As the project work is well defined, the meetings take place weekly and the project work is well documented, for instance by the meeting protocols, it is easy for me to integrate my participation in the research project in my studies, even if I have to miss one or more meetings." The research project served as realistic scenario for the acquisition of professional skills, e.g.: "I learn how to communicate with other experts and laymen." (All comments have been translated from German to English by the author.)

5. Discussion

The need to train students both in their field and in professional skills led to the successful introduction of project-based learning in computer science and in medical informatics [4, 5, 17–19, 30]. The approach facilitates the learning and training in realistic scenarios and fosters the cognitive learning process. This empowers the student for lifelong learning [3–6, 9–11, 16, 24].

The project environment strengthens team identity and team work. This improves students' performance and research results, according to DeMarco and Lister "The Whole is Greater Than the Sum of the Parts" ([23], p. 123)]. Our results in research and development and the evaluated students' satisfaction reflect this.

Quality assurance is essential for the successful implementation of a teaching approach [1, 3, 10, 27]. In CM-PBL several features were used: the "second set of eyes" principle by performing CM-PBL with a teacher and a co-teacher; the formative evaluation of the students' scientific work and professional skills; and the formative evaluation of the students' satisfaction and suggestions for further improvement. The access of every team member to the current state of each student's work and the regularly presentation during the weekly team meetings encouraged each member to deliver high quality.

Project-based seminars are generally organized as one or two-semester courses. The students come from one discipline and have a similar background [5, 16–18]. CM-PBL adds two aspects: 1) The students from different disciplines learn how to communicate with each other [2, 5, 6, 17–19]. 2) The students perform theses on different levels (student's research project, diploma thesis, doctoral thesis) and the team slowly changes its formation. Members join and leave the team. Thus the students learn how to deal with turnovers and how to introduce new team mates. These skills are mandatory in their later professional career [2–6, 9, 10, 23].

As stated above: medical informatics is inherently interdisciplinary. The CM-PBL approach provides an excellent means to introduce learners to the process of multidisciplinary collaboration. Moreover, even in fields not multidisciplinary by nature multidisciplinary learning issues are known to "evolve from individual problems" ([6], p. 96), i.e. they are induced by the project-based learning approach. A team of students coming from different disciplines provides the unique chance of adequately addressing such issues.

CM-PBL shows characteristics of blended learning by combining facilities of eLearning and face-to-face learning [11, 17, 24]. The regular face-to-face meetings of the project group and additional personal meetings on demand are complemented by an IT infrastructure supporting an efficient online-cooperation and a remote access to shared resources.

We decided to use a low-tech but nonetheless powerful alternative to sophisticated groupware solutions: the Concurrent Versioning System (CVS) in combination with TortoiseCVS-Clients and secured by the university's Virtual Private Network (VPN). This platform provided an adequate means to cooperatively maintain the project documentation, to implement project guidelines, to share a project bibliography, to develop and to version program code and to write project-related publications.

Static resources (e.g. theses or presentations) were uploaded to the project web server. The platform proved to be easy to adopt by new project members and was equally well accepted and used by both students of computer science and medical students.

This protected internal area is complemented by the team's public website. The website shows the team members, describes the projects of the team and lists publications. Thus it is of use for the communication with the scientific community and any interested citizen. Furthermore it is a useful tool for project controlling. It offers at a glance the status of the projects, the team, the theses and the publications.

Our experiences with CM-PBL showed a win-win-situation for the students, as described above, and the teachers. The teachers trained alternative teaching. The project setting and the structured cooperation of the two teachers in the formative assessment and support of the students facilitated to improve one's expertise in being a facilitator, mentor and guide for the students. Furthermore the teachers could successfully proceed with the research projects, which built the scenarios for the project-based learning, and to which the students contributed significantly (e.g. [28, 29]).

6. Conclusion

We have described the development and implementation of CM-PBL in the setting of a health informatics research group at RWTH Aachen University. CM-PBL aims to train students of computer science and medical students working on a thesis on scientific work, to mentor them during their theses and to train them on professional skills.

There is wide consensus in the literature, that alternative education approaches such as cooperative learning, problem- and project-based learning empower students to acquire scientific knowledge and professional skills, especially the ability of life-long learning, multidisciplinary team work and social responsibility [3–6, 9–11, 17, 18]. Similar approaches, either mono-disciplinary (e.g. [20]) or multidisciplinary (e.g. [19]), corroborate the appropriateness of CM-PBL. Thus, an adaptation of CM-PBL to the requirements of other faculties and other research projects seems feasible.

Evaluation should comprise traditional and alternative approaches, such as term-related project-based settings and CM-PBL implementations [30]. The comparison of CM-PBL with other methods will have to investigate resources (hard- and software, network, finance [2]), teachers' qualifications [1–3, 6] and participants' outcome (students' scientific work, professional skills, long-term professional success; see for instance [5, 27]). Furthermore, the integration in long-distance learning [20] and in virtual universities [11] may offer a further application area.

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