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Using Multimedia to Enhance Problem-Based Learning in Elementary School

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Problem-Based Learning (PBL) is a contemporary teaching approach that has become an increasingly applied way of academic education since its beginnings in the 1960s. Its popularity grew when it was introduced into medical education and spread to various fields in the last decades. This small group learning approach using major principles of situated learning and situated cognition, however, has been applied almost exclusively to adult education. In this article we examine the introduction of multimedia to enhance computer-based PBL in elementary school. We compared a PBL-class with a traditional lecture-based class of fourth-graders from a German elementary school. An analysis of cognitive, metacognitive, and motivational outcomes revealed some benefits of self-directed learning in the PBL-class compared to the control class.

Problem-Based Learning (PBL) is a teaching and learning approach that has its origins in medical education at McMaster University, Hamilton, Canada. PBL uses case-based learning in small groups and is designed as a curriculum rather than just as a single lesson approach. As the name suggests, a PBL process starts with a problem presented to the learners. Problems are ill-designed cases that are open-ended. The typical function of the problem is to trigger or initiate a problem-solving process within a group. Students discuss the problem, identifying subproblems, subgoals, their prior knowledge, the problem's background, strategies to solve it, and so forth. Such problems may be presented in paper-based format, by audio-visual media, or by peer-actors, such as in medical education where peers can simulate patients (or standardized patients are used, e.g., Barrows, 1985). To solve a problem, complex knowledge and skills from different domains are required. Students, for example, not only have to learn the facts about a specific disease, but also need to know about according processes, specific facts from basic sciences, social consequences of the illness, and need to use social skills. In addition, the need to have knowledge about differential diagnosis and appropriate treatment as well as treatment plans. Due to the realistic setting in which learning ideally occurs, knowledge acquired in PBL sessions is not inert, declarative knowledge. It is rather applicable, procedural knowledge, including problem-solving competence and meta-cognitive skills.

While discussing new problems, students define learning objectives by means of identifying what they actually know about the case and what they presumably need to know to develop solutions. Tutors typically mentor this process of problem discussion in small groups identifying prerequisite knowledge and learning objectives. They facilitate problem discussions and help groups to stay on topic.

After a small group discussion and a learning phase of individual knowledge acquisition the PBL-process continues in the following manner: students use libraries, data bases, books, journal articles, ask professors, and experts to complete the learning issues defined in the small group discussions. After this individual learning phase, another tutored small group discussion takes place to provide solutions to the problem, to discuss further encountered problems, and alternative perspectives. If a problem is completely solved (i.e., learning objectives defined by a case author or faculty are reached) another problem starts a new PBL-cycle.

The process described in Figure 1 is the typical PBL-process. It may vary in use of resources, tutoring processes, group size, design, and presentation of problems, and so forth. We regard all of these different forms of instruction as part of a PBL-family (although some authors demand a "pure" PBL; e.g., Maudsley, 1999).

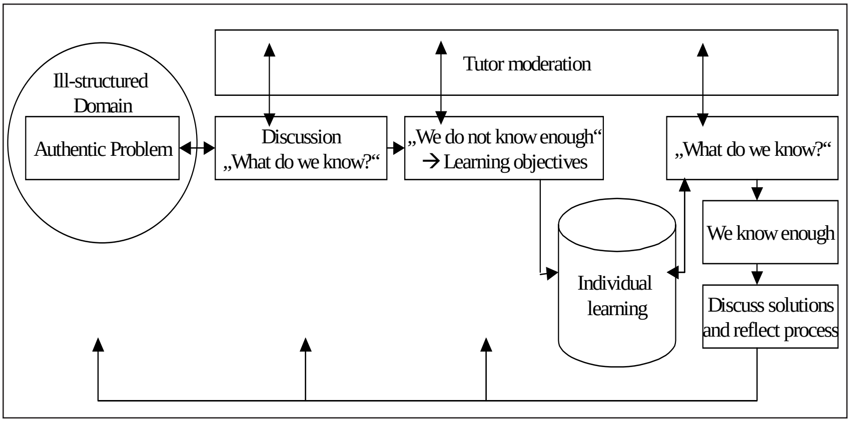

Figure 1. The PBL-Process

RESEARCH IN PBL: ROLE OF COMPUTER TECHNOLOGIES IN PRIMARY EDUCATION

There is much research on comparing PBL with traditional Lecture-Based Learning (LBL), on the role of tutors, problems, group size etc. A current overview of studies is provided in meta-analyses (Albanese & Mitchell, 1993; Dochy, Segers, van den Bossche, & Gijbels, 2003; Vernon & Blake, 1993) showing advantages in problem-solving and some slight disadvantages regarding factual, basic knowledge in PBL compared to LBL. The review of Norman and Schmidt (1992) showed that—compared to traditional lecture forms—PBL may lead to better retention of knowledge after some weeks up to months and years. This was found even when the factual knowledge in the PBL-group directly after the curriculum was weaker than in the LBL-group. The authors suggested various explanations for the initial poorer learning in the PBL-groups: one possible explanation is that students actually learned less than their colleagues in the traditional setting but that they processed the information in a more effective way (Dods, 1997). Another possible and empirically proven explanation is that problem-based learners were higher motivated to get a deep insight into the topic even after the class was over (Schmidt & Moust, 2000). Furthermore compared to traditional lectures, PBL led to better curriculum evaluations by students and staff (Albanese & Mitchell, 1993; Vernon & Blake, 1993).

PBL also has negative impact on learners such as an increased stress level as reported by Kaufman, Mensink, and Day (1998). They could show that students of a first-semester PBL-curriculum experienced a higher level of uncertainty compared to peers in a lecture-based course. They had little expectations about course objectives and reported insufficient feedback for their performance. Consequently, these students experienced significantly more stress caused by the learning environment.

Another problem in PBL is naïve learners' unfamiliarity with this form of teaching and learning. Especially when introducing PBL, it is necessary to familiarize students with issues of collaborative learning, self-regulated learning and problem-solving.

Authors such as van Merriënboer (1998) advocated the use of computer technology to overcome such problems especially among PBL-beginners: next to many possibilities of presenting interactive problems and learning resources it is rather the opportunity of integrating learner support into the learning environment that makes computers attractive for PBL. There are many ways of providing scaffolds for problem-solving, to adapt problems to the skill-level of learners or to offer context sensitive help when necessary (Hoffman & Ritchie, 1997). Although there is a high potential of computer technologies for supporting PBL, there still is a lack of empirical research. Most of recent research related to computer assisted PBL is descriptive or provides case studies only. In addition, studies using Internet technology or conferencing software to support distributed PBL (Cameron, Barrows, & Crooks, 1999) or virtual academies providing PBL-courses (Cheesman & Heilesen, 1999) are rare. Furthermore, most of the few empirical studies include only adult participants in college education (Devitt & Palmer, 1999; Farnsworth, 1997; Terlouw, van der Veen, & van Diepen, 1998) or vocational training (Marshall, Brett, Stewart, & Ostbye, 1999).

Especially when entering PBL-curricula in higher education, students often report difficulties related to self-directed learning. As most students have had a career of several years in teacher-directed lecture-based learning they are overstrained with the degrees of freedom offered by this kind of learning (Schmidt, Boshuizen, & deVries, 1992).

But why is PBL (or other self-directed learning approaches) not used more frequently in the earlier stages of education to avoid the origin of passiveness in learning? Are children in elementary school not capable of dealing with a self-directed learning environment? Again, there are authors describing problem-based learning environments for children starting from kindergarten (Neal Boyce, VanTassel-Baska, Taylor Sher, & Johnson, 1997) to elementary and high school (Fogarty, 1997), but generally research related to these age groups is scarce. Gallagher and Stepien (1996) are one of the few authors that conducted a controlled study comparing high school students in a traditional versus a PBL-class (in history education) finding no significant difference in learning outcomes between both groups. Dods (1997) compared the efficacy offered by PBL, traditional lecture, and a combination of PBL and traditional lectures in understanding and retention in biochemistry among gifted senior and junior students. Outcomes revealed that the lecture tended to widen the content coverage, while understanding and retention were promoted by utilizing PBL. De Corte, Verschaffel, Lasure, Van Vaerenbergh, Bogaerts and Ratinckx (1998) examined the effects of PBL versus LBL in the mathematics classroom. Outcomes revealed that participants (fifth graders) learning in a PBL-scenario performed better than peers in traditional lecturing, in recall-tests as well as mathematical problem-solving.

Taken together, these results indicate that PBL is not limited to courses or learning environments for adults and self-directed learners. The use of computer technologies to support PBL appears to be beneficial. But after all, there is still need for research about the combination of both: the use of computer-supported PBL among learners of minor grades.

COMBINING PBL, COMPUTERS, AND ELEMENTARY SCHOOL

The following study was conducted to evaluate the use of multimedia-enhanced PBL in comparison to traditional lecture-based learning in an elementary school. As the German school system is mainly based on traditional lecture- based learning the introduction of a self-directed learning course or curriculum is critical, especially in elementary school. In addition, institutionalized multimedia-based learning is rare, especially in minor grades. In a first step, we examined the introduction of computer-based PBL in a fourth grade of a German elementary school with pupils of the ages 10 to 11. To evaluate the outcomes of multimedia-based PBL-use we compared this experimental class with a traditional lecture-based class.

METHOD

We developed a single PBL-unit dealing with the badger. In our PBL-program a highly interactive learning environment was developed with MS *PowerPoint*. Based on a story telling approach, fourth-graders were introduced to the trigger problem of this lesson: They walk through the forests and, attracted by some strange noises, find a baby-badger. Major objectives that derive from this problem are to find out what kind of animal this is (many children in big German towns have never seen a badger and even do not know that they exist) and learn how to behave upon encountering wild animals. Above all, knowledge about young animals, rabies as well as other diseases found in natural wildlife in German forests is important. Figure 2 is a screen taken from our program showing a badger.

Figure 2. Screen from our PBL-program showing a badger

The program was presented on multimedia PCs with sound capabilities. Five pupils formed a group and worked simultaneously together on the program. To reduce extraneous cognitive load we made sure that the children were experienced in working on computers. Before the problem scenario was presented, the children were introduced in general communication rules for collaborative working and instructed on how to manage upcoming problems. Additionally, one of three adult tutors monitored each group and helped the children to solve technical questions or navigation problems. Tutors did not interfere on a content level, but stimulated cognitive processes by asking questions about what the children had learned what they thought about the problem or what kind of solutions they had developed. After problem presentation the children developed their learning objectives in small group discussions under the supervision of the tutors. In the knowledge acquisition phase pupils navigated collectively through the program to attain the information needed to complete their objectives. At certain points in the program leading questions were posed so that the children could check whether they were on track and had acquired sufficient knowledge (in the sense of a scaffolding mechanism). When the group decided to develop a final solution for the problem scenario, they were able to exit the program. In small group discussions, they explained their considerations to their tutors. Each session lasted about 1½ hours from beginning to end, including a pre and posttest.

In the control group the teacher used a traditional lecture-based approach to accomplish the same learning objectives as in the PBL-program. A major part of the lecture consisted of a movie about badgers and forest animals, the other part consisted of verbal explanations as well as questions and answers. This lecture also lasted 1½ hours including time for pre- and post-test.

The pre and posttest were administered to the children of both classes directly before and after the treatment. Five weeks later a follow-up test was conducted to assess long-term effects. Between post- and follow-up test pupils were not further exposed to the topic at school.

Dependent Variables

In all three phases we assessed pupils' knowledge concerning the topic of the lesson, their problem-solving ability regarding rare animals, their motivation in class, intrinsic learning motivation, as well as their subjective certainty regarding their answers in the knowledge test.

The knowledge test consisted of seven open items and three multiple choice questions.

Students' motivation was assessed by using five-point rating-scales facilitated by corresponding thumbs-up and thumbs-down icons (Figure 3).

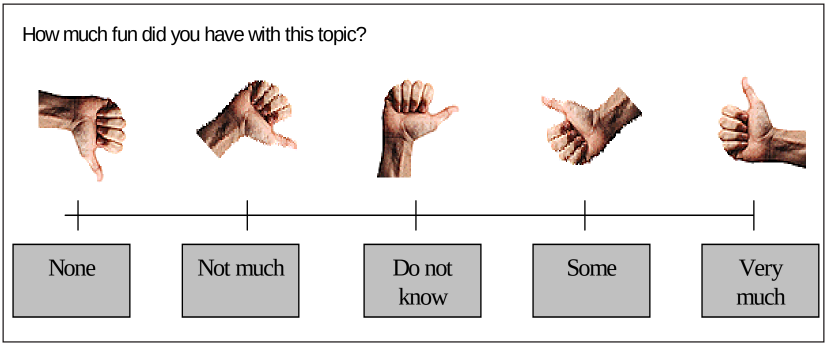

Figure 3. Rating scale

We assessed problem-solving behavior by providing eight different descriptions of situations similar to the scenario presented in the PBL-program. For each scenario we provided a set of multiple-choice answers representing possible behavioral strategies. In addition to the questions in the knowledge test and problem-solving assessment we asked our subjects about their certainty in answering each question. Therefore, we also used a five-point rating-scale similar to the scale used for motivational assessment.

Motivation was measured in terms of how much fun the children reported when in class and when studying with computers. The scale ranged from 0 to 4 and again statements were supported by the thumps-up and thumps-down icons. Intrinsic motivation was assessed by asking the children how much more time they had spent with the topic (“The Badger”) after the lesson.

Participants

Forty-nine subjects participated in this study. In the experimental group there were 13 male and 11 female students with a mean age of 10.2 years (*SD* = 0.51). The control group consisted of 14 male and 12 female students with a mean age of 10.1 years (*SD* = 0.49).

RESULTS

We computed a motivational overall value from the four motivational items. An ANOVA comparing pre- and follow-up test five weeks after treatment revealed a significant interaction (F (1, 44) = 5.78; p = 0.02; Eta^2 = 0.12): PBL led to an increase in motivation. LBL had no significant effect on that variable. A significant difference between the classes vanished from pre- to posttest.

Intrinsic motivation was measured by the amount of time the children spent dealing with the badger during the five-week period (in which the topic was not relevant to class). Participants in the PBL class spent significantly more of their holiday time with the badger than participants of the LBL class (F (1, 44) = 4.01, p=0.04; Eta^2 = 0.094).

An analysis of children's performance in knowledge tests revealed differences between the two classes at the day of the treatment that could not be reduced by the lecture. Still both treatments had equal effects in fostering knowledge acquisition, but PBL lead to a significant better result in the follow-up test (F (2, 43) = 14.9, p<0.001; Eta^2 = 0.41; Figure 4).

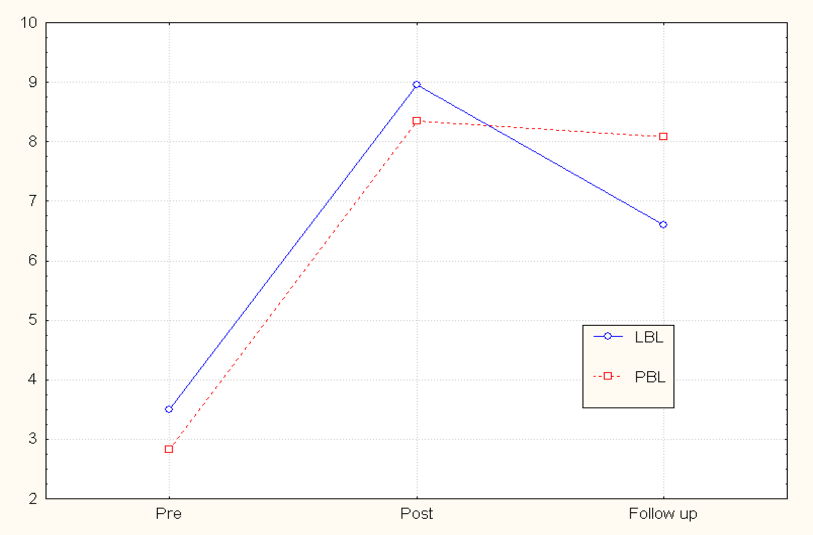

Figure 4. Factual knowledge

Analysis of children's problem-solving performance yielded no significant results, neither between both groups nor among all assessment times (F (2, 43) = 0.03, p=0.97; Eta^2 = 0.002). Results indicate a slight advantage of the LBL-condition (Table 1). Regrettably, the level of the questions used for this analysis appeared to be too low for the subjects. Both groups reached a very high score at the top of the scale (which is 40 points here) indicating a ceiling effect.

Table 1
Means and Standard Deviations

Variable	Mean LBL (*SD*)			Mean PBL(*SD*)		
Time of measurement	**Pre**	**Post**	**Follow-up**	**Pre**	**Post**	**Follow-up**
Motivation	3.52 (0.35)	N/A	3.47 (0.47)	3.16 (0.54)	N/A (0.5)	3.53
Time spent on topic outside class	N/A	N/A	0.15 (0.49)	N/A	N/A	0.55 (0.76)
Knowledge Acquisition	3.5 (2.02)	8.96 (1.19)	6.6 (1.23)	2.83 (1.51)	8.35 (1.47)	8.08 (1.65)
Problem-solving	3.99 (0.34)	4.11 (0.33)	4.08 (0.53)	4.00 (0.41)	4.1 (0.37)	4.05 (0.43)
Certainty	3.35 (0.63)	3.87 (0.33)	3.56 (0.54)	3.05 (0.7)	3.53 (0.56)	3.25 (0.88)

Furthermore, we found that both groups displayed more certainty regarding their answers in the posttest compared to the pretest, but the gain did not differ significantly between both classes. Five weeks later the reported certainty had slightly diminished but was still above pre-test level. The ANOVA revealed no significant interaction regarding kind of treatment (F (2, 43) = 1.54, p=0.23; Eta^2 = 0.07). Table 1 shows all means of dependent variables.

SUMMARY AND DISCUSSION

Comparing the results from our study with results from traditional PBL using adult students we found support that there is no reason not to implement PBL at earlier stages of education. Children in the PBL class showed a higher intrinsic motivation and an equal gain in declarative knowledge than children in the traditional lecture-based class assessed with knowledge tests. Additionally, PBL led to better long-term retention as opposed to LBL. It is not clear whether this result is caused by a deeper elaboration of the learned material or by the additional time spent with the subject due to the higher intrinsic motivation in the PBL-class.

Due to methodological shortcomings we were not able to show that the PBL-condition also led to an enhanced transfer of problem-solving, although the means pointed into such a direction. The multiple-choice question format used in this study seems to be inappropriate to measure pupils' problem-solving skills of that age group. Additional research and methodological alternatives such as, for example, simulation-based testing are needed here.

The outcome of this study is in most respects comparable to studies involving adult students, for instance, as summarized in the meta-analyses by Albanese and Mitchell (1993), or Vernon and Blake (1993). This challenges our traditional view of learning in elementary schools: so far self-directed learning in minor grades has been rarely applied in the German educational system. Traditional lecture-based education with high levels of teacher-directed learning is more wide-spread than a real learner-controlled knowledge acquisition. By using a PBL approach, students were able to acquire and construct knowledge (in this case about the badger) by means of exploration, discussion, and elaboration without direct teacher intervention. Our PBL-program offered children a natural way of learning—a learning by doing and learning by exploration. The computer is an excellent tool in providing the necessary opportunities for doing so: multimedia technology allows free exploration, information on demand, authentic learning, and so forth. By combining technology with an adequate instructional method it is possible to replace parts of traditional lectures with meaningful self-directed learning.

We took a first step in investigating the role of computer-based PBL in elementary school children. Further experiments and long-time studies are necessary to provide a more detailed view on how technology-based PBL affects children's learning, transfer, and motivation. The German government continuously invests in the enhancement of multimedia and internet-based learning in schools. This could help to increase the reasonable use of technology in education. However, many teachers have too little experience in the use of new media. Thus, they themselves are in need of training. Additionally, there often is a lack of adequate software making the use of contemporary instructional approaches impossible. More support for teachers and better software is required to turn the investments in multimedia enriched classrooms into a successful endeavor.

Future research may leave traditional classrooms or national borders and enable the participation of children from all over the world in distributed PBL-environments. Meaningful learning, intercultural exchange and an intrinsic motivation are some of the benefits that may derive from such developments.

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