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Cognitive effects of an authentic computer-supported, problem-based learning environment

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Abstract. The present study describes the redesign of a Problem Based Learning (PBL) course in a Business curriculum and the effects of this approach on students' cognitive learning outcomes. The goal of the research was to explore the extent to which this new approach would yield better cognitive learning outcomes, when compared to a regular PBL setting. Three main aspects of the regular PBL course were redesigned. Firstly, the authenticity of the case studies was optimized. Authentic problem descriptions and company information were used for the acquisition, application, and assessment of knowledge. Ill-structured real-life information was used, from real companies. Secondly, control aspects between students and tutors were modified. Students were given increased control over their tasks as they worked more independently from their tutors in small, self-steering teams. Thirdly, the students' ways of social collaboration were adapted to resemble teamwork in business practice. Apart from one regular PBL tutorial meeting, students worked in very small teams. Student collaboration on problem solving and information delivery was supported through electronic communication tools.

In order to measure the effects of the redesign on students' cognitive learning outcomes, a quasi-experimental comparative design was set up. Subjects were second-year students who were enrolled in a marketing course at the Faculty of Economics and Business Administration. They completed a case study at the end of the course. The scores on this knowledge application test indicated that the redesigned PBL-format contributed significantly to improved cognitive gains, compared to the regular PBL-setting.

Keywords: authentic case, computer-mediated communication, constructivist pedagogy, problem-based learning, small-group collaboration, student control

Introduction

In the workplace of the 'Age of the Mind' (Heilprin, 1989; Todd, 2000), knowledge becomes the major force in society. In order to be successful in today's dynamic and competitive society, the use of existing knowledge and the development of new knowledge becomes a prominent prerequisite for solving the complex problems which are faced. Accordingly, working in teams supplants working alone. For education, this implies there is a growing need for graduates who are able to reason with and apply knowledge to efficiently identify and resolve complex problems (Segers, 1997; Tynjälä, 1999). Additionally, functioning as part of a team and working together to keep knowledge up to date is considered to be another key issue in education (Hmelo & Evensen, 2000).

In order to cope with societal challenges and their educational implications, the use of problem-based learning approaches in higher education has been promoted by many educators (Bowden & Marton, 1998; Taplin & Tsui, 1999; Tynjälä, 1999). In general, PBL refers in many ways to contextualized approaches of instruction, which take on different forms and are used in different domains (e.g., Williams, 1992; Wilkerson & Gijselaers, 1996). In PBL, it is essential that a problem initiates free inquiry by students working together in a group (Barrows & Tamblyn, 1980). PBL creates opportunities for students to work in groups to seek and acquire knowledge for problem solving, based on the use of authentic problems. To realize the full potential of PBL, teachers and course designers grounded their educational development in modern constructivist theories (Savery & Duffy, 1995; Tynjälä, 1999), or in research on collaborative learning (e.g., Slavin, 1997).

Nevertheless, up-to-date comparative research on the effects of PBL on learning outcomes does not present conclusive results (Hmelo et al., 1997; Norman & Schmidt, 2000). On one hand, empirical research on the effects of design variables in PBL curricula suggests some explanations of these results (Gijselaers & Schmidt, 1990). Additionally, as Koschmann et al. (1994) suggest, the way in which problem-based learning is implemented in various studies can itself produce a number of new issues and challenges. On the other hand, there is plenty of research on co-operative learning which offers insights into the different aspects of the social dimension of learning environments such as PBL. Using this research as background, a number of design variables for optimizing a PBL environment can be formulated. The present study explores to what extent a redesigned learning environment, taking into account these design variables, enhances cognitive learning outcomes, when compared to a regular PBL environment. To date, only a few theory-grounded course intervention studies, measuring cognitive outcomes within a PBL context, have been carried out (Norman & Schmidt, 2000). The majority of them only investigate the effects of the manipulation of a single course element. Research, however, suggests strong interrelations between different learning dimensions (Brown et al., 1989; Kirschner et al., 2001; Williams, 1992) that may affect various outcomes of PBL, making it difficult to interpret outcomes unambiguously. The present study can be referred to as a ‘design experiment’ (Brown, 1992) as it is an attempt to explore cognitive effects as a result of a coherent set of changes (in the task, control and social dimensions of a PBL environment). The central idea in design experiments is to capture the design process of creating and evaluating an innovation in education by uniting cognitive research and concurrent design of learning technologies.

Research on the effects of design variables in PBL curricula

PBL, as initially developed by Barrows and Tamblyn (1980), typically involves students working on problems in small groups of five to twelve, with the assistance of a faculty tutor. Problems serve as a starting point for new learning activities. The analysis of these problems results in the acquisition of knowledge and of problem-solving skills. Problems are encountered before all relevant knowledge has been acquired, rather than after reading texts or attending lectures about the subject matter underlying the problems. This feature reflects one of the essential distinctions between PBL and other problem-oriented methods (Albanese & Mitchell, 1993). The teacher, called the tutor, coaches the group by monitoring the group process and helping the students to identify the knowledge which is needed to resolve the problem. The learning process starts with a preliminary analysis of the problem, based on the students' prior knowledge (the problem analysis phase). It results in the formulation of the students' learning goals or of the unexplained issues which students need to investigate during self-study before follow-up meeting(s). After completing the problem-solving cycle, students will start to analyze a new problem, again following the described problem solving procedure (e.g., Williams, 1992).

Over the past few years, empirical research has been conducted to identify effective design variables in PBL environments. Basing their studies on empirical work, Gijselaers and Schmidt (1990) attempted to identify a set of key variables in PBL that explain cognitive and motivational learning outcomes. These researchers identified three main input variables: the quality of PBL-problems; student characteristics; and the skills of the tutor. These three variables influence the tutorial group process, which in turn directs self-study, resulting in cognitive and motivational outcomes. The model of Gijselaers and Schmidt (1990) demonstrated the importance of problem descriptions and social interaction for determining students' behavior and learning outcomes. More recent empirical studies, using causal PBL models, have led to similar conclusions. Schmidt and Moust (2000), for instance, showed that, apart from the social functioning of the group, the quality of PBL-problems substantially affects the amount of self-study that is needed and the level of the students' interest. These researchers concluded that problems seem to influence almost all aspects of learning and are, therefore, central to learning in PBL curricula (Schmidt & Moust, 2000).

In analyzing curricula from a theoretical point of view, researchers cast social and task related aspects in a similarly prominent role. Based on the implications of research into learning and instruction, researchers such as Brown et al. (1989), Kirschner et al. (2001) and Williams (1992) have unified various key instructional design variables into coherent instructional design frameworks. These frameworks generally contain three dimensions that can be manipulated in order to influence cognitive outcomes: the task, control, and social dimensions. They are relevant tools for the analysis of PBL curricula.

In this context, the task dimension includes instructional methods, which can be divided into: instructional (problem solving) procedures; problem descriptions; and information and data sources. The control dimension refers to the degree to which individuals can control learning in terms of influencing content, path, pace, instructional difficulty, and feedback (Barrows & Tamblyn, 1980; Kinzie, 1990). The social dimension refers to collaborative aspects of PBL, or the ways that students interact together and with their tutor.

Apart from these studies, research which has explored models of effective design variables in PBL environments has primarily investigated single variables within the task, control, or social dimensions. Their results indicate potential improvements which could be made to PBL environments.

The PBL task dimension

In the problem analysis phase of PBL problem solving procedures, students brainstorm about a variety of potential explanations for phenomena or problems. It is assumed that, in explaining these phenomena, it is important for students to carry out a thorough problem analysis in order to elaborate on their prior knowledge. Elaboration on prior knowledge (such as exchanging ideas, answering questions and giving explanations) will lead to better knowledge structures, resulting in better understanding and recall of knowledge (Anderson, 1990).

The research of De Grave et al. (1996), however, indicated that in several PBL curricula the brainstorming phase is poor and/or short, resulting in one single problem explanation. The fact that explanations are often not provided, or compared, leads to a rather poor or superficial problem analysis phase, with few elaborations (De Grave, 1998). Additionally, deriving a hypothesis at a too early stage can result in prejudices or misconceptions (Barrows & Tamblyn, 1980). Houlden et al. (2001) described typical behavior of students in PBL-curricula in terms of rapidly focusing on the solution or ‘right answer’. The emphasis in PBL is, however, not necessarily on solving the problem, but rather on analyzing and explaining the possible causes and characteristics of a phenomenon (Hmelo & Evensen, 2000), and the underlying principles. Such learning requires that explicit attention needs to be paid to abstracting knowledge, making generalizations from the problem and reflecting on the problem solving process to understand when the learned knowledge can be applied (Salomon & Perkins, 1989).

How can the problems related to a poor brainstorming phase be explained? Oliver and Omari (1999) argued that one explanation of a short pre-discussion in PBL curricula can be found in the problem descriptions that are used. They stated that problem selection appears to be the most influential component of the learning activity. The fact that students are initially only exposed to a short problem description tends to limit their ability to work in a meaningful manner with this information. The idea of having limited information can therefore limit working with, and understanding of, that information (Oliver & Omari, 1999). Following these arguments, the level of the pre-discussion can possibly be enhanced by offering more information, or by embedding more cues in a problem as a starting point.

Authors like Brown et al. (1989) and Williams (1992) have argued that authentic problems and case descriptions may provide a meaningful context, which may resemble future professional situations. An important implication of learning in authentic contexts, which offer relevant professional situations, is that this can foster the transfer and application of knowledge (Brown et al., 1989). In a review of small group learning, Cohen (1994, p. 3) concluded that 'the relation of the total amount of interaction within a group and achievement differs according to the nature of the task'. Highly structured and closed tasks, which have one fixed answer, lead to low group productivity. By contrast, ill-structured and complex tasks provoked extended elaboration among group members and were associated with 'higher order' conceptual learning. Cohen (1994) concluded that this may be achieved by confronting small groups with ill-structured, complex problems.

Another aspect is the authenticity of the delivery format of problem descriptions. Hoffmann and Ritchie (1997) criticized PBL courses that strongly rely on written problem descriptions and learning resource materials on paper. In their view, transfer between the problem situations presented in a course and similar ones in real life may be adversely affected (Hoffmann & Ritchie, 1997, p. 100). Bransford and Schwartz (1999) made similar comments when noting that sole reliance on written cases or verbal vignettes may have dysfunctional consequences for the learner in professional practice. For example, a business consultant who is solely trained in analyzing written business cases may be ineffective when working in real business practice. Multimedia can, therefore, provide a valuable contribution by offering realistic contexts which contain complex, authentic PBL problem situations (Hoffmann & Ritchie, 1997).

Although problem descriptions are generally considered to be a crucial PBL variable, not much empirical research to date has been carried out on the relationships between the characteristics of problem descriptions and the resulting cognitive outcomes. However, several authors have attempted to develop rules for effective problem formats from a theoretical viewpoint (Barrows & Tamblyn, 1980; Savery & Duffy, 1995), or from an experience-based viewpoint (Gijselaers, 1996; Stinson & Milter, 1996).

Gijselaers (1996) identified several problem formats that he considered to be ineffective. In his view, problem descriptions that include questions for students to answer stimulate them to substitute answering these questions for elaboration on their prior knowledge, resulting in non-productive brainstorming. Using a title for the problem assignment that is similar to the title of chapters in a textbook, or which indicate the assigned readings related to the problem, also leads to poor problem analysis (Savery & Duffy, 1995). If (due to these cues) all students study identical literature and come up with similar analyses, this does not foster a rich problem analysis, which is one of the goals of PBL. The characteristics discussed by Gijselaers (1996) and Savery and Duffy (1995) can be summarized as pre-structured PBL problem descriptions, providing students with too much direction and pre-analysis. Such problem descriptions violate the basic requirements that social learning in groups is associated with ill-structured problems (Cohen, 1994). Savery and Duffy (1995) argued that students need to be engaged in authentic learning activities by confronting them with problems that do not contain pre-specifications. Authentic learning requires, for instance that, as in business practice, students encounter ambiguous data in need of interpretation. When problems already contain obvious conclusions and interpretations, no authentic thinking will occur. Stinson and Milter (1996) made similar arguments, contending that good problems should mirror professional practice, be ill-structured, and contemporary, in order to initiate productive group sessions. In conclusion, effective problem descriptions should be authentic as the use of relevant authentic problems can foster higher order reasoning skills, relevant for practice.

The PBL control dimension

In discussions about the effectiveness of the PBL system, control in PBL environments is gaining more attention (e.g., Albanese, 2000; Vermunt & Verschaffel, 2000). Cognitive researchers have argued that a certain degree of learner control is an essential aspect of effective learning environments (Kinzie, 1990; Vermunt & Verschaffel, 2000; Williams, 1992). The claimed effects of a higher degree of student control (instead of teacher/program control) are intrinsically highly motivated students and more active and autonomous students.

In order to effectively exercise learner control, students should be able to handle autonomy and should possess self-regulation skills (Kinzie, 1990). The study of Vermunt and Verschaffel (2000) about dimensions of student control in learning environments was a case in point. They argued that effective educational systems should gradually offer higher levels of control over the process of learning to students. This implies that effective educational systems provide mature (graduate) students with a higher degree of control than is given to novice students. The researchers further argued that an important control dimension is the degree of 'independent student learning', expressed by all kinds of activities that students carry out by themselves. They described the degree of students' 'independent learning' in PBL settings as high when compared to traditional, lecture-based systems. But when compared to PBL practice, the degree of ownership over the problem and the degree of independent learning is not always developed at an optimum level (Vermunt & Verschaffel, 2000). However, as PBL is implemented in various ways, taking different forms of instruction (e.g., Williams, 1992), the degree of student control is also dependent on the way PBL is actually implemented.

Offering more student control is related to the degree of scaffolding (Greening, 1998) and can be expressed by more freedom in the choice of problems, learning-goals, literature and by working more independently from a tutor (Vermunt & Verschaffel, 2000). Authors like Kinzie (1990), Savery and Duffy (1995) and Williams (1992) have expressed similar ideas. Savery and Duffy argued that with authentic problem tasks, a learner should have ownership over the process of problem solving, the problem itself and the learning goals. One way of enhancing ownership is to stimulate students in initiating problems themselves, so that the learner adopts the problem generated as their own (Savery & Duffy, 1995). When students are able to work independently, less scaffolding can be provided. Essential is that optimal levels of challenge (and motivation) in a learning setting are maintained (Greening, 1998). A question that arises is whether students who are working independently and who have more control over the learning process are able to find out for themselves what it is important to learn from PBL problems. A study by Duek et al. (1996) showed that, in a PBL context, second year students who independently met in teams, without their tutor, for the problem analysis, still identified the most important learning objectives, when compared with tutor guided groups. This study demonstrated that second-year students who gained more control over their learning process were at least as effective in identifying learning issues as PBL students who were given less control.

The PBL social dimension

Nowadays, there is a general belief that working in collaborative settings can enhance the learning outcomes of instructional settings (e.g., Slavin, 1997). Research has been conducted on the effects of Collaborative Learning (CL) when compared with individual learning, the effects of group size, and the effects of the use of computers to support the collaborative process.

Review studies of the research on the effect of CL offer major insights: solving learning tasks or problem assignments together with fellow students, rather than in individual situations, has positive effects on student achievement (e.g., Johnson & Johnson, 1989; Slavin, 1997). Researchers like Webb (1992) add that positive learning results of CL depend on the conditions (such as group size) under which CL is implemented (Webb, 1992).

In addition to the effects of collaborative settings, Qin et al. (1995) found that learners who are solving problems in collaborative settings with a common (shared) goal will exchange ideas and correct each others' ideas more frequently and effectively, compared to settings where individuals compete with each other. Research on team processes has consistently shown that the extent to which team members have to rely on each other and must communicate with each other is central to the development of shared goals and shared knowledge (Brannick et al., 1997). The question may be raised as to whether the social and cognitive conditions for PBL groups will result in increased awareness of the importance of sharing knowledge as a strategy for coping with problem materials.

Research by De Grave (1998) on group processes in PBL showed that problem analysis by a group, when compared with individual problem analysis, only had a slightly beneficial effect on remembering problem-related text information. When he tried to explain his research results, De Grave hypothesized that interaction in a group can also have a negative effect on achievement. Research on brainstorming by McGrath (1984) showed that indeed group interaction can have negative effects on the generation of ideas. Individuals not only generate many more ideas, but these ideas are more creative (diverging) than those produced by groups, when intellectual task outputs are considered (McGrath, 1984). Nijstad (2000) argues that, during a brainstorming phase, group members can even disturb individual ideas. The ideas of individual group members should therefore be used at the moment that they have finished their thinking (Nijstad, 2000).

ICT programs can provide help in exchanging information at the moment that individual brainstorming is finished, as such media can be used at any moment. When personal thinking has finished, asynchronous media such as mail and discussion lists can therefore facilitate the process of using the ideas of other group members (Whitworth et al., 2000). Research on brainstorming with computers shows similar results to the studies above. For instance, when comparing face-to-face group interaction with separate brainstorming through computers, Whitworth et al. (2000) argued that face-to-face group interaction is less effective as it generally leads to a gain in the absolute number of 'common' ideas, but a loss in the number of different (divergent) ideas.

Group size is another variable that may affect the PBL process. Research into learning in very small student groups has demonstrated that in general these groups allow not only more intensive, but also more equal opportunities for participation, along with better monitoring of student progress (e.g., Keller, 1983). If students meet together in a small group face-to-face setting to discuss about the ideas generated, then what is an optimum size? According to Lohman and Finkelstein (2000) research suggests that very small student groups (three persons or less) achieved learning outcomes more effectively than medium or large groups. According to Kagan (1989), the ideal number of group members is four, as a higher number of group members tends to lead to greater possibilities of non-participation and 'group production losses'. An example of a 'group production loss' is the time needed for coordination. Oliver and Omari (1999) found similar results. In performing an experiment with small teams in a PBL-setting, they found that five students were too many to enable the members to share and work together, as these groups tended to leave one member overworked. As a result of natural attrition, the groups of three students often became two group members, who were then overworked. The researchers concluded that small teams tend to be most effective when group size is four (Oliver & Omari, 1999).

Research into the effects of Collaborative Learning (CL) supported by computers is mainly dominated by Computer Supported Collaborative Learning (CSCL) research, which investigates technology driven collaborative settings. Research suggests that computer technology increases opportunities for social interactions (Hoyles et al., 1994). The cognitive effects of CSCL environments are often related to the acquisition of higher cognitive skills. For instance, in an overview of CSCL studies, Hoyles et al. (1994) reported that collaborative, computer based tasks lead to higher order thinking. Lehtinen et al. (1999) concluded, in a review on the effects of CSCL environments, that although results were not conclusive, there were a number of experiments which showed the positive learning effects of CSCL, particularly in higher order cognitive processes and skills that are related to information handling (Lehtinen et al., 1999).

Pinsonneault and Kraemer (1989) found that both synchronous and asynchronous systems have the potential to increase a group's depth of analysis of problems, and the quality of decisions, when compared to face-to-face collaborative situations. In general, synchronous systems increased consensus in decision-making and asynchronous systems tended to increase the total group effort (Pinsonneault & Kraemer, 1989).

Oliver and Omari (1999) investigated a problem-based learning environment in which students worked with online learning technologies. Their study provided interesting additional insights concerning the impact of learning technology on the productivity of PBL environments. Students were put into small teams of four or five to work on the analysis of, and solutions to, problems. Internet was used for the presentation of ill-structured problems and to provide access to multiple sources of information for the problem solution. Web technology also offered students communication possibilities by allowing them to post problem solutions within a team, or for others, on a public bulletin board. Finally, within the web environment, students could exchange relevant Internet addresses (URLs) for others to use in their inquiries (Oliver & Omari, 1999). Student responses in their study indicated that the innovative learning environment 'had a substantial impact on students learning and problem solving' (Oliver & Omari, 1999).

These recent studies provide evidence that it is reasonable to expect that students' progress in PBL environments is affected by group size, working procedures, and the use of technology.

Design variables in PBL environments

Based on the results of the studies described, a number of instructional design implications can be suggested for the task, control and social dimensions of the PBL environment.

The task dimension:

- Students should be stimulated to perform a more thorough problem analysis in a setting that leads to more than one (diverse) problem explanation;
- The use of authentic (ill-structured, non contrived) problem descriptions and data sources, embedded in a real-life context, can lead to extended elaboration on problems (Cohen, 1994) and therefore stimulate the problem analysis;
- The reflective process of deriving generalizations and making abstractions on the knowledge studied can be more stimulated;
- ICT can be useful in offering students ill-structured, authentic case materials in multi-media formats.

The control dimension:

- The degree of learner control should be adapted to the maturity of the students;
- Learning control can be managed by offering students a setting for independent learning with freedom in time and place and responsibility for solving problems;
- Guidance and scaffolding (through ICT tools) can optimize the tutor's role as facilitator of the learning process.

The social dimension:

- The process of generating ideas or explanations should be carried out by individuals working on their own. The ideas generated can then be discussed in small teams of about four persons, instead of in relatively large tutorial groups;
- After the individual brainstorming is completed, ICT programs can provide help for exchanging ideas and with problem analysis.

The small teams that are created should work with a shared goal and have responsibility for a common product.

An innovative learning environment: Problem-based, with authentic learning materials, small team collaboration, and technology rich

This section contains a description of a modified PBL course, based on the instructional design variables proposed. In the academic year 1999–2000, a regular marketing course at the business school was redesigned in the three previously discussed cardinal dimensions (task, social and control). This new approach was called 'Authentic Learning Environment' (ALE) and was compared in an experiment with a regular (control) PBL setting. In summary, firstly the authenticity of the PBL problem situations was enhanced: ill-structured problems and real-life data resources were used, coming from real companies. Secondly, the students' method of social collaboration was adapted more closely to teamwork in business practice. Apart from during regular PBL tutorial meetings, students worked in small teams of four persons. Thirdly, students were provided with more control over their learning activities as they worked in self-steering small teams, more independently from their tutors.

In designing this ALE, we departed from the standard PBL protocol that most courses at the Maastricht business school usually follow. In the standard protocol, students have two formal meetings with each session lasting for two hours. A tutorial group consists of about 14 students. A tutor coaches each group of students, a student chairperson hosts the discussion and a student secretary minutes the meeting. A typical course has about 200-400 students: hence there are about 20 to 30 tutorial groups.

The ALE Task dimension: authenticity of the learning materials

The problem tasks

In many PBL courses at the Maastricht business school, students are offered problem descriptions that contain rather limited information, next to many cues that provide students with hints for problem analysis. However, looking at the real life of business, graduates must be able to determine what information is needed for problem solving and interpretation of information (Stinson & Milter, 1996). Therefore, in the ALE, the students were offered a problem description and, at the same time, additional authentic business information. Both provided a larger context for brainstorming on problems than the regular PBL problems, with a pre-structured problem description and structured written company information being available after the students brainstormed on the small problem description. The real-company information used in the ALE setting contained non-interpreted sections of annual reports, authentic pictures, internal management presentations and company product information. The company materials were not adapted for educational use. This kind of information allowed students to simulate the real-life process of identifying problems from ill-structured data and required them to use cognitive activities, as in professional practice. In offering these rich problem contexts, computers can be an aid (Koschmann et al., 1994). In business practice, most information is in electronic formats, available from the intranet or Internet, making use of a variety of media such as databases, presentations, commercials, etc. Therefore, in the ALE, authentic company material was offered in a multimedia format via a CD-ROM. Additionally, in the ALE, the use of Internet for searching for resources was an integrated part of education.

Savery and Duffy (1995) argued that for fostering transfer, students should encounter examples of problems from diverse categories and apply knowledge in a variety of situations. On this point, Norman and Schmidt (2000) added that learners should be trained in identifying the features that discriminate an example of one class from another. Therefore, the ALE consisted of ‘sidebar’ information about various companies which was related to the concepts to be learned in the main problem of that week. Students had to relate the main problem of the company under study (on CD-ROM) with an additional company problem, found on Internet. For instance, globalization issues concerning L’Oreal were related to globalization issues concerning

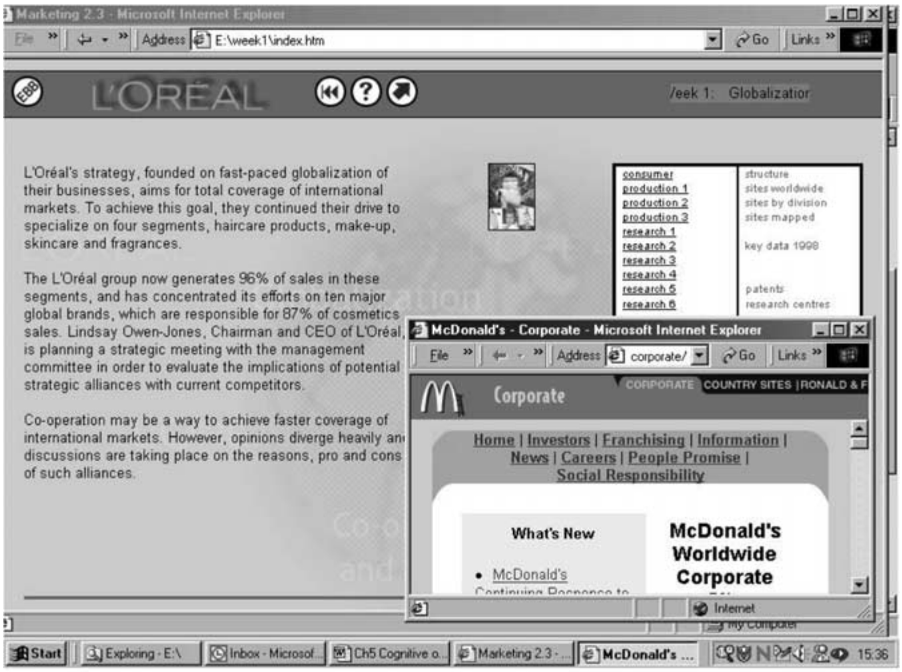

Figure 1. An illustration of a part of the authentic multimedia-company materials.

McDonalds. This comparison was intended to stimulate multiple views on business concepts and to detach and abstract knowledge acquired from one specific case, in order to stimulate transfer. In both the ALE and the regular PBL setting, students worked during one week on one business (marketing) theme on the basis of two problem descriptions.

Figure 1 shows one of the screens of the ALE course materials. It shows a problem situation, as presented in the first week on the subject of globalization, the additional company data available (links to 'consumer information', 'company research 1' etc.), and a link to the (contrasting) McDonald's case on Internet. The data available are only partly relevant for the linked problem situation. It is students' task to select and interpret relevant information, as in a typical authentic activity.

The problem solving process

In order to improve the problem solving process within the ALE, an adapted problem solving procedure was implemented.

The brainstorm phase starts with individual preparation, followed by a discussion in small teams (three to five students), carried out face-to-face and/or via electronic communication tools. The meeting in small groups was

Form for the problem 'Pre-analysis' *"For analyzing all problem situations, perform the following steps":*
1a Derive problem statements: → Identify problems or phenomena in the problem situations and in the case information. *Example: Firm x is not big enough to invest in country y.*
1b Provide relevant facts: → Provide factual evidence (symptoms) supporting the problems perceived. *Examples: 1. The sales of shampoo x are very low. 2. The turnover of unit A is high.*
2 Brainstorm about the explanation of the problem: → Give *tentative* explanations (hypothesis) for the problems found in the case information. Use your prior knowledge. Provide *more* than one tentative explanation for the problems found. *Example: Firm x is too small to be able to invest. The company is not specialized enough.*
3 Define learning goals: → Formulate learning goals for the phenomena you can not explain. *Example: What kinds of strategic alliances exist?*

Figure 2. The form the teams submitted to their tutor containing the results of the pre-discussion.

intended to allow the exchange of ideas and to enrich the problem analysis. As the members of these small teams all performed their brainstorm separately, it was assumed that this method of problem analysis would lead to more diverse problem explanations than a problem analysis in one large group. As an outcome of the brainstorm phase, the student teams were asked to schematize their analysis of the business case study information on a form (see Figure 2).

The form in Figure 2 was designed in such a way that students were forced to focus thoroughly on the problem analysis, not on solutions. The purpose of this structured format was to encourage students to state some explanations (causes) for problems, to explicate their arguments, and to formulate learning goals. The form was mailed to the tutor, who checked problem explanations and verified whether major goals were formulated. After revising the problem analysis, the tutors provided feedback by e-mail. After receiving the tutor feedback, students were expected, if necessary, to further reflect on their problem analysis and explanations. Next, the tutor brought together the results of the separate small teams and returned it as one integrated document to all teams, in order to stimulate the idea of multiple perspectives on a problem explanation. At the time when the small teams received the results of the pre-discussions of the other teams, all teams were assumed to be converging in the problem solving process. On the basis of this initial problem analysis process and the learning goals formulated, the students studied literature and prepared discussion points for the next meeting. In the mean time, students in the ALE, as in the regular (control) setting, all attended a lecture where they had the possibility of interacting with speakers from businesses. Next, the ALE students' answers to the learning goals were

	ALE	Regular PBL
Monday	• Small students teams meet face-to-face and/or on the web for the pre-analysis of the case information	• Regular tutorial group meeting under supervision of a tutor
Tuesday	• Student teams hand in a 'pre-analysis form' and receive feedback from their tutors	• Individual self-study
Wednesday	• Self-study for the Thursday discussion (individual or in collaboration with team members) • Lecture • Preparation 'discussion points' for the Thursday post-discussion	• Individual self-study for the Thursday discussion • Lecture
Thursday	• Regular tutorial group meeting in presence of the tutor (post-discussion of 2 problems)	• Regular tutorial group meeting in presence of the tutor

Figure 3. Activity schedule in the ALE compared to the regular PBL-setting.

discussed during a tutorial meeting, which took place in a regular PBL setting. In this meeting, the members of the various small teams came together, into a group of about 14 members. In this meeting, the various student teams presented their findings to the whole group for discussion. The students also considered the *discussion points* that they had prepared. An example of a discussion point was: 'How does a different (competing) company cope with the phenomenon discussed?' The discussion points had two main purposes. Firstly, learning goals in a post-discussion (in the PBL reporting phase) are normally focused on explaining concepts that have arisen from the literature. The discussion points were, however, meant to go beyond comprehension of knowledge in order to bring the discussion to a more general level. For instance, the discussion points highlighted the differences and links between two course themes. Hence, the discussion points aimed to foster reflection through abstraction and could be considered as an important link at the end of the PBL learning circle to integrate more deeply the strategic use of the knowledge acquired. Secondly, discussion points were intended to foster the application of knowledge in contexts other than the current problem situation. For instance, students derived implications of phenomena studied for companies other than the one in the actual problem under study. Figure 3 shows the activities of students in the ALE setting, as compared to the regular PBL-setting.

The ALE control dimension

In the regular PBL setting, the problem analysis is carried out within a fixed time span, at a fixed place, under the guidance of a tutor during all meetings. Students receive feedback from both their peers and their tutor during problem analysis in their tutorial group.

One purpose of the ALE was to provide students with a higher degree of student control related to aspects such as contents, instructional path, pace and feedback. This was addressed in different ways.

Firstly, when analyzing the problem situations and company information, the student could make decisions about which parts of the interactive material to use and to manipulate electronic (Internet) sources. The control of the learner over the company materials was facilitated by using electronic information with a non-linear hypertext structure to give access to all the case information. This implied that students had control over the sequence of the information, as the paths through the company information were non-linear (Reeves, 1993).

Secondly, the degree of control by the tutor was adapted, when compared to a regular PBL course. In the regular PBL setting, the pre-analysis and the post-discussion of two problems were divided over two tutorial meetings. In the ALE, students had only one weekly two-hour tutorial meeting, facilitated by a tutor. This meeting was only used for the post-discussion (reporting phase) of problems, and two problems were discussed. Additionally, in the ALE, students worked independently from their tutor in small student teams for the analysis of their problems. Students were responsible for the group process as well as for assigning the team roles.

The small teams could meet at any time, anywhere, and this was facilitated by electronic communication tools. The tutors acted as facilitators and, to a lesser extent than in a regular PBL setting, as a source. For the brainstorm during the problem analysis, tutors provided guidance at small-team level by giving feedback and hints on the results of the brainstorm. This implies that the scaffolding of the student learning process had a 'Just In Time' format, with students taking the initiative and defining the moment when they needed help. As soon as the student teams had completed their brainstorm and pre-analysis, they could send it to their tutor to ask for and receive feedback. Eventually, students could also communicate any other questions to their tutor. Although the small teams were given more control over the problem analyzing process in terms of place, pace and time, the teams had to respect the requirements of the problem analysis, and an accompanying deadline, strictly.

The ALE social dimension

In regular PBL settings, most interactions and problem solving activities take place in relatively large tutorial groups.

A purpose of the ALE was to improve the quality of interaction in collaborative problem solving. This collaborative aspect was addressed in different ways. Firstly, students were allotted to small teams of three to five students to perform the brainstorm phase. The small team setting offered students a collaborative setting to experience authentic cases derived from professional practice. It was explained to students that they were working on a collaborative assignment, not an individual assignment. It was assumed that students in small teams had more individual participation than students in medium-sized or large tutorial groups. By working in small student teams with characteristics such as equal opportunities for success of all participants (e.g., Slavin, 1997), it was expected that this would lead to stronger links between the students. This would lead to mutual and positive interdependence (Johnson & Johnson, 1989), and the taking of responsibility for accomplishing a common task (e.g., Slavin, 1997). It was further assumed that, in these self-directed small team settings, students developed a greater sense of ownership, commitment and responsibility for the problem analysis than in larger PBL groups. For instance, the problems and learning goals that the small teams generated themselves could result in strong ownership (Savery & Duffy, 1995). All our claims on the changes in group processes intended to lead to higher cognitive outputs.

For the post-discussion, students met in a regular tutorial group of about 14 members, coached by a faculty tutor.

Secondly, the interaction of team members was facilitated and supported by electronic discussion tools. Students had the possibility of using both synchronous (chat rooms) or asynchronous tools (discussion lists) for exchanging brainstorm ideas, arguments or Internet addresses (URLs). Students were free to use the (synchronous) chat tool, although they were encouraged to meet virtually at times to be fixed by their teams. The asynchronous tool, the discussion list, contained topics related to the main themes of the course. The discussion on these topics was initiated by the tutors, after that the tutors did not intervene in the discussions. This electronic discussion list was during and after the course available 24 hours a day, so students also had access to it during self-study and re-sits. This offered the possibility of ongoing collaboration between the teams.

Expected cognitive outcomes of the ALE

Based on the results of previous research, as discussed above, it was hypothesized that the ALE students would perform better in a number of cognitive aspects than those on a regular PBL course.

With regard to the task dimension of the ALE, it was expected that the use of more authentic problems would lead to extended elaboration on problems and would therefore foster higher order reasoning skills (Cohen, 1994). Furthermore, it was hypothesized that learning in authentic contexts, requiring the cognitive activities that are used in professional practice, would foster the transfer and application of knowledge to novel problems (Brown et al., 1989). The use of 'sidebar' problem situations was also assumed to foster transfer of knowledge into new situations. Additionally, the use of 'discussion points', implemented at the end of the PBL-cycle, was assumed to stimulate comprehension and transfer of knowledge.

Concerning the control dimension, it was hypothesized that a higher degree of control over the problem tasks would stimulate students in performing their tasks and, accordingly, improve students' learning outcomes.

Concerning the social dimension, it was hypothesized that the use of small teams and the use of electronic discussion tools would lead to more elaboration and a higher interaction level. More elaboration on information can lead to better understanding of knowledge (Anderson, 1990).

Methods

Research questions

The present research investigates the cognitive effects of the designed authentic, problem-based and computer supported learning environment (the ALE). The goal of the study is to examine whether the experimental ALE, when compared with a regular PBL environment, would yield different learning outcomes in terms of the applicability and the transferability of the knowledge acquired. The research question is therefore: 'Does the new learning environment (when compared to a regular PBL situation) lead to a better application of knowledge in new and authentic problem solving situations?'

Subjects

Second year students from the Maastricht business school participated in the present experiment. Out of the 429 students that enrolled for the marketing course under study, 114 students participated in the experiment. This sample comprised 68 male and 46 female students, with a mean age of 21.5.

Table 1. Design for the evaluation of the Authentic Learning Environment

Group:	Pre-knowledge analysis (GPA)	Control pre-test	Treatment: The experimental ALE	Treatment test: case study	Control post-test
Experimental ALE group	O_0	O_1	X	O_3	O_2
Control group 1	O_0	O_1		O_3	O_2
Control group 2	O_0	O_1		O_3	O_2

Design

A quasi-experimental, comparative design was set up, consisting of three randomized student groups: one experimental and two control groups (see Table 1).

In order to measure the main effects on the outcome of the course, an authentic case study was used as a post-test. It would not make sense to give a pre-experimental test to students who have never studied an international marketing course. Also, using a pre-test at the beginning of the experiment, could influence the outcomes of the experiment (Cook & Campbell, 1979). Therefore, we used an 'Untreated control group design with proxy pre-test measures'. In such designs a post-test is the main measure of treatment, and proxy measures should be found that correlate with the post-test scores. An example of such a pre-test is a general aptitude test in the subject area that is being investigated. Statistical power increases if the scores of the proxy pre-test are related to the post-test (Cook & Campbell, 1979). In the present study, as a proxy pre-test, students' GPAs (their performances on seven courses with a PBL-format) were used as a general measure of business aptitude. The correlation between the GPA and the post-test turned out to be 0.421 (Pearson, 2-tailed, significant at 0.01 level). This correlation is acceptable for using the GPA as proxy pretest measure.

Sampling

Before the start of the experimental course, a survey was administered to all students to investigate whether or not they were familiar with web-based technology. Out of all students who enrolled for the course (429), 70% of the students (300) showed to be familiar with Internet technology. Both the ALE group and control group 1 were randomly selected from this sample of 300 students with Internet familiarity. Differences in familiarity with the Internet could potentially confuse the results. For instance, students with

<table>
<tr><th></th><th>ALE-setting</th><th>Control group 1</th><th>Control group 2</th></tr>
<tr><td>Task Dimension</td><td>- Problem descriptions, not pre-analyzed.
- Ill-structured information from real companies.
- Brainstorm on problem description and company materials.
- Real company information in audiovisual, electronic format.</td><td colspan="2">- Pre-analyzed problem descriptions.
- Company information, structured for educational use.
- Brainstorm on the problem description only.
- Paper information.</td></tr>
<tr><td>Control Dimension</td><td>- Students work independently from their tutor in self-steering small teams.
- Students assign roles themselves.
- Tutors act as facilitators, students take the initiative in communication.</td><td colspan="2">- Tutorial meetings of groups of about 14 students.
- Roles assigned by tutors.
- Tutors act as facilitators.</td></tr>
<tr><td>Social dimension</td><td>- One tutorial group meeting a week, for the post-discussion only.
- Self-directed small student teams for the PBL pre-discussion.
- Electronic tools: discussion list & chatting to facilitate communication in small teams and with tutor.</td><td colspan="2">- Two tutorial group meetings a week
- The tutorial groups consisting of about 14 students.</td></tr>
<tr><td>Sampling</td><td>Sample of students familiar with Internet.</td><td>Sample of students familiar with Internet.</td><td>Random sample of students out of the course population of 429 students.</td></tr>
</table>

Figure 4. Key differences between the three instructional conditions.

Internet experience may possibly be more highly motivated to seek additional learning resources. A second control group (N = 39) was created by randomly selecting students out of the *total* student course population of 429 students. To summarize, the three groups in the experiment were:

- The experimental group, receiving the ALE treatment (N = 36);
- Control group 1, participating in a regular PBL-setting (N = 39).

All members of this control group and the experimental group were familiar with the Internet.

- Control group 2, also participating in a regular PBL-setting. Control group 2 was created by randomly selecting students out of the *total* student course population of 429 students.

For a summary of key differences between the three conditions, see Figure 4.

Course context and content

The specific context was a marketing management course, part of the International Business Studies degree program. The experimental course was structured around seven major themes, each lasting for one week. The course concerned international marketing issues such as globalization, standardized marketing strategies, competitive positioning etc. The course contents (books, articles) and all content assessments were identical for all three experimental settings.

Table 2. Actual student numbers in the three experimental conditions

	Experimental (ALE) group	Control group 1	Control group 2
Tutor A	13 students	13 students	13 students
Tutor B	11 students	13 students	13 students
Tutor C	12 students	13 students	13 students
Total (114)	N = 36 (17 male, 19 female)	N = 39 (26 male, 13 female)	N = 39 (24 male, 15 female)

Tutors

For each of the three conditions, three tutorial student groups were set up, leading to nine tutorial groups in total. Tutors were crossed with the three conditions to apply a control for any 'tutor effect' during education. Table 2 presents the actual number of students in the three research groups, divided between the tutors.

Initially, it was planned to use 39 students for each of the three conditions. However, as the experiment was carried out in an ecological context, natural attrition of students occurred. For instance, some students did not show up for the final course test. This explains the variance in the number of participants in the tables presented.

Instruments

For the three groups, several cognitive measures were used (see Table 1). Firstly, the effects of the treatment (ALE) were measured by open-ended questions related to a case study, which was novel to the students. The subject of the case study concerned the European marketing strategies of tire manufacturers. The test was a problem-based test in that students were confronted with a problem description based on real cases, accompanied by data resources which consisted of original market survey tables from the tire companies concerned. The problems in the case studies have possibilities for different solutions, so they require divergent thinking abilities. In that sense, this resembled the characteristics of the ALE company case studies. The test part of the case study consisted of six large essay questions, each counting for a maximum of 10 credits. Two experts in the field constructed the case study, as well as the questions. The instrument measured the cognitive outcomes in terms of knowledge application and transfer. Typical questions were: '*Explain how the different companies can achieve competitive advantages*'. '*How appropriate is a franchise system in the market in the case study? Explain*'. Individual answers to each item were checked against a standard scoring key, by a team of 10 tutors. To enhance the reliability of scoring, each tutor rated one question for all students. An evaluation session was organized in order to eliminate differences in interpretations in cases where tutors rated more than one question.

Secondly, to provide a control for the probability that the experimental students had a higher level of prior knowledge than the control group students, a proxy measure was used that correlated with the post-test that was used with the treatment groups (Cook & Campbell, 1979). As proxy measure, the GPA was estimated on the basis of the students' performances on seven courses with a PBL format that the students had followed prior to the experiment.

Thirdly and finally, the students' prior knowledge was measured by means of a control pre-test and post-test. The pre-test and post-test were identical, containing 25 multiple-choice questions with a maximum score of 25. The questions had the format of 2 (true-false), 3, or 4 choices. The test reliability (Cronbachs alpha) was 0.58. The pre-test and post-test were related to 'research methodology' which was a part of the course and was studied by all students. The content of this control test was not changed by the instructional intervention. A typical question in this test was: '*Marketing interviewers were told to select a fixed number of women and men from city areas. What kind of sample is this?*' (*Choose answer: simple random, quota, stratified or cluster*).

The (identical) pre-test and post-test were administered to different random samples of the three groups (ALE, control group 1, control group 2). From the 114 students that participated in the experiment, 80 randomly chosen students were asked to take either the pre-test or the post-test. From this group, 70 students actually participated in either the pre-test or the post-test.

Data analysis

To provide an answer to the research question, mean differences in achievement between the studied groups were compared by using ANOVA analysis of variance.

Results 1: Main treatment effects

Table 3 shows the mean scores of the three students groups for the essay questions in the case study test (results are collapsed over three tutors). These essay questions concerned the application of marketing knowledge.

A two-way ANOVA analysis was performed with three fixed levels for both tutors and instructional condition. The mean scores of the three conditions revealed significant differences between the means of the three groups

Table 3. Mean student scores for the case study test

Group	Essay questions score for case study test		
	N	Mean score (max = 60 pt)	Sd
Experimental group	31	35.50	7.21
Control group 1	35	31.01	6.86
Control group 2	28	32.00	6.91

Sd = Standard deviation

[F(2,86) = 4.10; Mse = 45.14, p = 0.020]. A post-hoc analysis (Tukey) showed that the mean score in the experimental ALE condition differed only from the first control PBL condition (p = 0.028) and not significantly from the second PBL control group. The post-hoc analysis showed that the mean scores of the two control groups did not differ significantly. This implies that the two control groups did not substantially differ in cognitive performance. This result contradicts the earlier hypothesized idea that students having access to and experience with the Internet (control group 1) would perform differently from a group made up of less experienced Internet users (control group 2).

Analysis of variance showed no significant tutor effect on the course exam results [F(2,86) = 0.08, MSe = 45.14, p = 0.923]. A significant interaction effect was found between tutor and the three instructional conditions [F(4,86) = 3.402, MSe = 45.142, p = 0.012]. Comparison of cell means showed that interaction was caused by one tutor cell in control setting 2 with relative low cognitive outcomes at the final exam.

In general, researchers argue that when measuring knowledge gains, results need to be interpreted with caution. Additional measures like the 'Effect Size' of a treatment need to be calculated (e.g., Albanese, 2000). Therefore, the Effect Size (*ES*) was calculated for the ALE and the control conditions. The results confirmed and strengthened the differences found between the three mean scores. The effect size between the ALE group and control group 1 is stronger (*ES* = 0.65) than the effect size between the ALE group and control group 2 (*ES* = 0.43).

Table 4. Students average score on all PBL-courses in year 1 and 2 (GPA)

Group	N	Mean (range: 1–10)	Sd
Experimental group	33	6.88	0.78
Control group 1	37	6.76	0.63
Control group 2	39	6.62	0.57

Sd = Standard deviation

Results 2: Control studies

Control study 1: A comparison of the GPA of the three groups in the experiment

This control test was designed to assess whether, at the start of the experiment, the three groups in the experiment were equal with regard to prior knowledge of business related to the treatment. The GPA of the students was expressed by the average scores of the students in the three groups on the PBL tests in the first and second years (see Table 4).

Table 4 shows that the three groups which participated in the experiment did not differ in business knowledge, acquired from PBL courses they had followed prior to the start of the experiment [$F(2,106) = 2.150$; Mse = 0.459, $p = 0.142$]. This suggests that, at the start of the experiment, the three student groups were equal with regard to relevant prior knowledge scores.

Control study 2: Analysis of the (non-treatment related) pre-test and post-test results

The purposes of the pre-test and post-test were twofold. Firstly, the pre-test was used to measure differences in prior knowledge of a marketing subject (‘marketing research’) related to the course content under study. Secondly, the tests were used to estimate differences in students’ cognitive *abilities* by assessing differences between the three groups in *gaining* knowledge about marketing research by the end of the course.

ANOVA analysis showed that the mean scores on the pre-test at the beginning of the experiment did not differ significantly [$F(2,32) = 0.89$; Mse = 6.174, $p = 0.915$] between the three groups. This implies that the three groups did not differ in their independent prior knowledge.

With regard to the post-test, a one-way ANOVA analysis showed that the mean scores on the post-test at the end of the experiment did not significant differ [$F(2,32) = 0.061$; Mse = 10.403, $p = 0.941$] between the three groups.

Table 5. Comparison of scores on the pre-test and post-test during the experimental course

Group in experiment	Pre-test scores		Post-test scores		Relative cognitive gain
	N = 35	Mean (Sd)	Mean (Sd)	N = 35	
Experimental group (Condition 1)	10	9.30 (2.83)	11.00 (3.36)	13	+18.1%
PBL control group 1 (Condition 2)	13	9.53 (2.50)	11.27 (3.46)	11	+18.3%
PBL control group 2 (Condition 3)	12	9.75 (2.13)	11.45 (2.77)	11	+17.5%

Sd = Standard deviation

This implies that all three groups benefited equally from course content that was offered in a regular format. Table 5 shows the scores of the three groups on the pre-test and post-test. The table shows only marginal differences between the three groups in cognitive gain. This indicates a comparable ability for the three groups in the acquisition of knowledge in a domain of marketing.

A general conclusion concerning the control tests is that the three groups in the experiment did not differ in cognitive measures before the experiment. This result strengthens the idea that the three groups were equal in their possession of prior knowledge. A second conclusion is that students did not differ in an independent post-test measure after the treatment. This implies that students' abilities to acquire knowledge did not differ between the three groups. Overall, it can be concluded that the three student groups are comparable.

Discussion and conclusion

Comparative research on the effects of PBL on learning outcomes does not present conclusive results. This could indicate that PBL has more potential than has been actually realized. A redesigned learning environment was therefore created, taking into account research on several design variables. The purpose of this study was to explore whether the redesigned instructional approach, when compared with a regular PBL environment, would lead to a better application of knowledge in new and authentic problem solving situations.

In the present experiment, scores on the case study instrument were analyzed for the measurement of treatment effects. This analysis showed that the students who experienced the redesigned PBL format had significantly better scores, compared to the control group with the same student background variables (control group 1). Comparisons between the scores of the experimental ALE group and control group 2 (students with limited Internet experience) did not differ significantly. The effect size (*ES*) between the experimental ALE group and control group 1 was found to be large (0.65); the *ES* between the ALE group and control group 2 was lower (0.43). In general, it can be concluded that the redesigned PBL format contributed significantly to better student learning when compared with the regular PBL setting.

Concerning effect sizes in intervention studies in general, Albanese (2000) argued that an *ES* between 0.80 and 1.0 is extremely high, and an unreasonable expectation from curriculum studies. The average *ES* reported in PBL studies is about 0.50 (Albanese, 2000). It can be concluded that the ES of *0.65* found between the experimental group and control group 1 in this study is satisfyingly high. The ES between the ALE group and the control group with Internet experience is lower (*0.43*). Typically, the experimental ALE group performed significantly better than control group 1, but not significantly better than control group 2. This result is difficult to explain, especially as all control tests on student selection showed no significant differences between students at the start of the experiment. Comparison of cell means showed that one tutor cell in control setting 2 showed relative low cognitive outcomes at the final exam. Further research might determine differences in students' characteristics that were not examined (e.g. students' cognitive style differences).

Another issue is the validity of the instrument used. From the viewpoint of experimental validity, it can be argued that students should be assessed in a similar (real-life) setting to the one in which they acquired the knowledge. This would imply that students should have been confronted with an authentic technology test case, performed in a team setting, similar to the treatment setting, instead of an individual paper test case. In such an assessment setting, the transfer from knowledge acquisition to application would be optimal (see also Bransford & Schwartz, 1999). Bransford and Schwartz argued that tests which limit students to what they have in their heads, can provide a limited, low sensitivity measure of transfer. But as Honebein et al. (1993) argued, authentic environments are the ones which engage learners in activities that require the same type of cognitive thinking as the workplaces for which we are preparing the learner. It can, therefore, be assumed that a paper test case is a valid test instrument for assessing cognitive performances in authentic settings. Additionally, authors such as Johnson and Johnson (1989) argued that group-to-individual transfer occurs when individuals who learned within a cooperative group demonstrate mastery on a subsequent test, taken individually. In other words: what individuals learn in a group today, they are able to do alone tomorrow. Therefore, the individual paper test that was used (with authentic features such as ill-structured and real-life resource information) should be a valid measure.

In a similar discussion, Salomon (1996) argued that implementing new constructivist learning environments should also be accompanied by the assessment of new cognitive learning goals. For example, in designing a learning environment that assumes different group knowledge construction processes, one should also investigate process outcomes related to aspects such as shared understandings, as well as cognitive tests. Future research could investigate process related outcomes of the ALE. An analysis of the PBL process could also possibly reveal which components of the ALE were responsible for producing the cognitive gains.

A related issue to be discussed is the preparation of students for 'future learning', as addressed by Bransford and Schwartz (1999). The current case study measured students' cognitive outcomes as performances at one particular moment: that is, at the end of one particular course. However, Bransford and Schwartz (1999) argued that such knowledge tests do not capture the process of preparation for future learning. In the context of the present study, it may be that students in authentic (experimental) settings have acquired skills for more effective future learning. Future research into the processes of learning could demonstrate whether the students from the experiment can induce knowledge more effectively when confronted with authentic problem situations.

Two issues in the area of measurement are related to this discussion.

One issue, related to 'future learning', concerns the short-term effects that were measured in this study. As is known from earlier research, educational innovations such as PBL often do not lead to cognitive gains in the short term, but do so in the long term (Norman & Schmidt, 2000). Further research could indicate to what extent the ALE leads to long term effects in our curriculum.

A second issue is related to the scope of the measurement outcomes of the ALE that were studied. It is well known, from former intervention studies within the CSCL research domain that, next to cognitive achievement, affective or motivational changes may occur, along with changes in interaction. Although we collected subjective data, such as students' opinions, it was not within the scope of the main research question to report these qualitative data in this study.

A general implication of the results of this study for educators is that this new instructional design has the potential to improve the applicability of marketing knowledge in practical settings. This may encourage educators in marketing, or related social studies, to use elements of the redesigned PBL format and to further improve their educational settings. Suggested elements that can enhance learning are what Albanese (2000) referred to as the 'active ingredients' of constructivist settings.

Basically, the active ingredients in the ALE were that students worked in small, self-steering team settings, using real-life problems, procedures and information sources. More research is necessary to examine how the positive results from the present experiment can be transferred to larger instructional settings. Studies replicating the current ALE setting and focusing on how dimensions interact are necessary to develop a better understanding of exploiting instructional potentials of PBL.

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