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The role of scaffolding and motivation in CSCL

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The role of scaffolding and motivation in CSCL

Abstract: Recent findings from research into Computer-Supported Collaborative Learning (CSCL) have indicated that not all learners are able to successfully learn in online collaborative settings. Given that most online settings are characterised by minimal guidance, which require learners to be more autonomous and self-directed, CSCL may provide conditions more conducive to learners comfortable with greater autonomy. Using quasi-experimental research, this paper examines the impact of a redesign of an authentic CSCL environment, based upon principles of Problem-Based Learning, which aimed to provide a more explicit scaffolding of the learning phases for students. It was hypothesised that learners in a redesigned ‘Optima’ environment would reach higher levels of knowledge construction due to clearer scaffolding. Furthermore, it was expected that the redesign would produce a more equal spread in contributions to discourse for learners with different motivational profiles.

In a quasi-experimental setting, 143 participants collaborated in an online setting aimed at enhancing their understanding of economics. Using a multi-method approach (Content Analysis, Social Network Analysis, measurement of Academic Motivation), the research results reveal the redesign triggered more equal levels of activity of autonomous and control-oriented learners, but also a decrease in input from the autonomous learners. The main conclusion from this study is that getting the balance between guidance and support right to facilitate both autonomous and control-oriented learners is a delicate complex issue.

The role of scaffolding and motivation in CSCL

Computer-Supported Collaborative Learning (CSCL) is built on an assumption that Information Communication Technology (ICT) has the power to provide a rich learning experience by using a variety of learning methods (Beers, Boshuizen, Kirschner, & Gijsselaers, 2007; Jonassen & Kwon, 2001; Resta & Laferrière, 2007; Schellens & Valcke, 2006). In particular, most online environments provide considerable autonomy for learners to determine when, where and how to learn, which can enhance the self-direction of actions by learners (K.-C. Chen, Jang, & Branch, 2010; Järvelä, Hurme, & Järvenoja, 2011; Liu, Horton, Olmanson, & Toprac, 2011; Martens, Gulikers, & Bastiaens, 2004).

Despite the increased learning possibilities and autonomy created by ICT-tools, recent findings in research on CSCL indicate that not all learners are able to successfully learn in online settings. It has been found that learners contributions to discourse differ substantially in online settings (Caspi, Gorsky, & Chajut, 2003; De Laat, Lally, Lipponen, & Simons, 2007). For example, Caspi, Gosky and Chajut (2003) analysed a total of 7706 messages for 47 courses at various faculties of the Open University in Israel and found that the majority (80%) of students contributed only a small number of messages. Similar differences between learners have been found with respect to the type (cognitive, affective, metacognitive) of contributions (De Laat, et al., 2007; Järvelä, et al., 2011; Schellens & Valcke, 2005). The lack of persistence shown by some learners to actively engage and contribute to discourse may be one of the factors leading to higher drop-out rates in distance education (K.-C. Chen, et al., 2010; Rovai, 2003).

In a review of Computer-Mediated Communication literature, Luppicini (2007) argues that given the complexity of online learning systems there is a need for research that helps our understanding of learners' characteristics in online learning. Recent research highlights that the degree of self-determination of learners (i.e. the perceived experience that a learner's behaviour is self-determined and autonomous) has a strong impact on learning behaviour in online settings (K.-C. Chen, et al., 2010; Martens, et al., 2004). For example, Martens et al. (2004) found that high intrinsically motivated learners (i.e. autonomous learners with an internal perceived locus of causality) were more active in an online task than low intrinsically motivated learners. In an online economics course using principles of Problem-Based Learning, we found that high intrinsically motivated learners contributed more higher cognitive discourse contributions than extrinsically motivated learners (i.e. learners who have more controlled behaviour with an external perceived locus of causality). Chen et al. (2010) found that perceived autonomy of learners was the most significant factor predicting students' motivation and self-

determination in two online programmes. Finally, recent research in Self-Determination Theory (SDT) has illustrated that in addition to providing autonomy support, teachers who provide more structure, guidance and scaffolding can positively influence students' engagement (Jang, Reeve, & Deci, 2010). According to Hmelo-Silver et al. (2007, p. 100), research in Problem-Based Learning illustrates that “[s]caffolding makes the learning more traceable for students by changing complex and difficult tasks in ways that make these tasks accessible, manageable, and within student’s zone of proximal development”. According to Davis and Miyake (2004), provided appropriate assistance by the teacher, scaffolding allows a learner to attain a goal or engage in a practice that normally would be out of reach. Thus, optimizing the characteristics of autonomy support and scaffolding in CSCL environments to effectively accommodate differences in self-determination of learners may have a profound effect on delivery and quality of online learning.

This paper compares the extent to which a redesign with more explicit scaffolding of the learning phases provided an adequate learning environment for both autonomous and control-oriented learners in a quasi-experimental setting. After a theoretical background of the role of scaffolding and the role of motivation in CSCL, we critically reflect upon the implementation of the initial e-PBL design and rationale as described by our previous research (Author A, 2006). Afterwards, we investigate to what extent the redesigned learning environment with more explicit scaffolding provided a more supportive learning environment for both autonomous and control-oriented learners than the e-PBL design. Finally, we reflect on why the actual results of the redesign were rather different than expected.

THEORETICAL BACKGROUND OF REDESIGN

In CSCL, learners have to construct meaning and co-construct knowledge in a blended or online setting. Learners can be geographically separated and dispersed over many different settings. Several researchers (e.g. Beers, et al., 2007; Kirschner, Beers, Boshuizen, & Gijsselaers, 2008; Schellens & Valcke, 2006) have found that CSCL environments only provide a powerful learning environment if participants actively contribute to discourse and co-construct knowledge together. Nonetheless, participation and continued contribution to discourse in CSCL cannot be taken for granted (Bromme, Hesse, & Spada, 2005; K.-C. Chen, et al., 2010; Kirschner, et al., 2008). In particular when learners are interacting using lean ICT-tools like discussion forums, establishing a critical mass of interaction, whereby (almost) all participants contribute actively to cognitive discourse, is troublesome (Caspi, et al., 2003; Hammond, 2000; Schellens & Valcke, 2005; Schellens & Valcke,

2006) and may be subject to a variety of characteristics both of the environment and of the learner. Hammond (2000) argues that a substantial threshold needs to be crossed before learners start to contribute to discussion forums. In this paper, we will first focus on how teachers can facilitate the learning process by providing appropriate scaffolding, and afterwards focus on the role of student's motivation in online learning.

Scaffolding of the learning phases

Kirschner et al. (2006) suggest that minimal guided instructional approaches, such as Problem-Based Learning, are less effective and efficient for novice students than guided instructional approaches such as direct instruction. In line with Cognitive Load Theory, Kirschner et al. (2006) argue that problem solving of a complex task only becomes effective when learners are sufficiently experienced. Furthermore, learners may become lost in the task when unable to track their plans and monitor their progress (Quintana, et al., 2004). Others have argued that PBL does provide appropriate scaffolds in face-to-face settings for learners to engage in complex tasks that would otherwise be beyond their current abilities (e.g. Hmelo-Silver, et al., 2007; Schmidt, Loyens, Van Gog, & Paas, 2007; Schmidt, Van Der Molen, Te Winkel, & Wijnen, 2009).

In blended and online settings, an increasing number of researchers have found that ICT can provide appropriate scaffolding to reduce the cognitive load for students and facilitate the process management of the task (Quintana, et al., 2004). A large number of researchers have argued that appropriate scaffolding in PBL, and CSCL in general, can make disciplinary thinking and strategies explicit (Quintana, et al., 2004), help to structure complex tasks (Weinberger, Reiserer, Ertl, Fischer, & Mandl, 2005), ensure that learners are actively engaged with the learning environment (Beers, Boshuizen, Kirschner, & Gijsselaers, 2005), reduce cognitive loads of students (Hmelo-Silver, et al., 2007; Schmidt, et al., 2007), and facilitate the learning processes in small groups (Beers, et al., 2005; Quintana, et al., 2004). For example, previous research in experimental settings (Beers, et al., 2007; Weinberger, et al., 2005) has found that more explicit scaffolding of the cognitive learning process leads to more engagement, discourse and interaction.

In a review of a range of scaffolding designs for ICT, Quintana et al. (2004) developed a scaffolding design framework for inquiry learning for science. It goes beyond the scope of this paper to elaborate on the entire framework and guidelines for software design. However, given the focus of PBL in our context, in particular the process management and articulation and reflection guidelines are relevant. Quintana et al. (2004) recommend that tasks should be structured to a level and complexity in which learners can focus on the most relevant parts of the task. For example, Nadolski et al. (2005) showed that explicit process worksheets to

students in law, which provide explicit descriptions on the phases learners should go through when solving a problem as well as hints or rules of thumb, improved learning task performance. Segers et al. (2003) showed that by providing process worksheets to students in economics working and learning in PBL, their performance scores increased significantly in comparison to students who used the standard PBL instructional approach (Schmidt, et al., 2007; Schmidt, et al., 2009). Finally, Quintana et al. (2004) recommend scaffolds that facilitate ongoing articulation and reflection, which can for example be established by providing reminders and guidance for planning and monitoring. In other words, research from face-to-face and experimental settings indicate that using explicit scaffolds of the learning phases that learners go through to solve a task may enhance performance.

The role of motivation in CSCL

The impact of motivation of learners to engage with online discussions has been found to significantly influence active participation in online discussions (Järvelä, et al., 2011; Martens, et al., 2004; Renninger, Cai, Lewis, Adams, & Ernst, 2011). However, Martens et al. (2004) argue that our understanding of how motivation influences learning behaviour in CSCL is rather limited. As motivation is a multidimensional and multilevel construct (Boekaerts & Minnaert, 2006), a wide variety of definitions and instruments are discussed and used in educational psychology research in order to understand the role of motivation on learning. Given the openness, flexibility and freedom of most online collaborative settings, learners have (relatively) more autonomy to determine their learning actions in comparison to classroom settings (Boekaerts & Minnaert, 2006; K.-C. Chen, et al., 2010; Mazzolini & Maddison, 2007). At the same time, given that in online collaborative settings it is (relatively) more difficult to provide immediate guidance (Beers, et al., 2007; K.-C. Chen, et al., 2010; Kirschner, et al., 2008; Van der Pol, Admiraal, & Simons, 2006; Weinberger, et al., 2005), emotion control (Järvelä, et al., 2011), rapid and appropriate feedback (Bromme, et al., 2005; De Laat, et al., 2007; Mazzolini & Maddison, 2007), interaction (Anderson, Rourke, Garrison, & Archer, 2001; Hammond, 2000), and trust (Rusman, Bruggen, Cörvers, Sloep, & Koper, 2009), creating an autonomy supported learning environment that provides sufficient guidance may not be straightforward.

Given the complex nature of CSCL to provide autonomy-support and structure to learners, in this paper we adopt the concept of motivation developed in Self Determination Theory (SDT) by Deci and Ryan (1985). According to Ryan and Deci (2000, p. 58), “[SDT] is specifically framed in terms of social and environmental factors that *facilitate* versus *undermine* intrinsic motivation”. SDT distinguishes between intrinsic and extrinsic motivation. Intrinsically motivated learning can be defined as the drive to learn. This drive is based on the

satisfaction and pleasure of the activity of learning itself; no external rewards come into play. Intrinsically motivated learners show autonomous behaviour and have an internal perceived locus of causality (Black & Deci, 2000). Externally motivated learning refers to learning that is a means to an end, and not engaged for its own sake and behaviours are more controlled. SDT proposes that extrinsic motivation is a construct with different factors that influence how autonomous or self-directed a learner is (Deci & Ryan, 1985; Ryan & Deci, 2000).

Three factors facilitate or undermine intrinsic motivation of learners: feelings of competence, sense of autonomy, and sense of relatedness (K.-C. Chen & Jang, 2010; K.-C. Chen, et al., 2010; Ryan & Deci, 2000). The interactions between learners, teachers or the course material can impact on the task performance and influence how learners perceive their competence and sense of relatedness. This can be enhanced by providing timely, positive feedback and support (Sadler, 1989). However, if a learner does not perceive a sense of autonomy in performing a task or action, feelings of competence are less likely to increase and it is argued intrinsic motivation is not enhanced (Jang, et al., 2010; Ryan & Deci, 2000). In other words, both feelings of competence and sense of autonomy are needed for intrinsic motivation of learners to be sustained or enhanced during a course.

According to Schmidt et al. (2007, p. 83), “[o]ne of the basic tenets of PBL can be summarised as scaffolding for student independence”. Within the boundaries provided by the scaffolds and teacher, in PBL learners are free to decide their own learning goals and explore how and the way in which to solve an authentic problem (Hmelo-Silver, et al., 2007). In other words, PBL offers the opportunity for learners to explore their own learning goals but at the same time provides structure or guidance to learners, in the form of the task, interaction with other learners, scaffolding of the learning phases, and tutor feedback. A crucial challenge for teachers in PBL is to balance autonomy and support to enhance feelings of competence and sense of relatedness of learners.

Given the nature of CSCL, the degree of self-determination of learners might explain why some learners contribute more to discourse than others (K.-C. Chen, et al., 2010; Martens, et al., 2004). At the same time, research has highlighted that autonomy support (K.-C. Chen & Jang, 2010; K.-C. Chen, et al., 2010; Jang, et al., 2010) and guidance provided by the learning environment (Beers, et al., 2007; Van der Pol, et al., 2006) positively influence engagement of students. Therefore, a crucial question is whether and how a CSCL environment can be designed in an autonomy supportive and scaffolded way that stimulates both intrinsically and extrinsically motivated learners to actively participate.

RESEARCH DESIGN

Online Collaborative learning environment

The present study took place in an online summer course for prospective bachelor students of an International Business degree program at an Institute for Higher Education in the Netherlands. The primary aim of this course was to bridge the gap in economics prior knowledge with the requirements for the degree program (Author A, 2006). This online course was given over a period of six weeks in which learners were assumed to work for 10-15 hours per week. The participants never met face-to-face before or during the course and had to learn economics using the virtual learning environment “on-the-fly”, that is learners had to learn how to use the VLE and PBL learning phases while doing it.

The course was based upon principles of Problem-Based Learning (PBL). PBL typically involves learners working on problems and learning tasks in small groups with the assistance of a tutor (Hmelo-Silver, et al., 2007; Schmidt, et al., 2009). Tasks were constructed in a real-world setting but in an ill-structured manner in a simple-to-complex sequence (Schmidt, et al., 2007), whereby the learners themselves could decide their learning actions and future directions. Although there is a wide variety of iterations of PBL, the learning process within PBL is commonly scaffolded according to the seven-jump method (Schmidt, et al., 2007). That is, problems serve as the context for new learning, whereby learners’ prior knowledge is activated (Schmidt, et al., 2009; Segers, et al., 2003). It results in the formulation of so-called learning goals by learners (rather than the tutor), which guide learners to issues that they were unable to solve and therefore requires further investigation (Segers, et al., 2003). Their analysis and resolution result in the acquisition of knowledge and problem-solving skills.

In comparison to a typical application of PBL in face-to-face classroom settings, in e-PBL the phases of the traditional seven jump are less obvious as learners interact with the materials and discourse with peers at various times during a week. That is, the mutual brainstorming, analysing the problem, synthesising and formulation of learning goals in the pre-discussion phase occurs simultaneously in e-PBL, as illustrated in Appendix 1. In other words, in e-PBL learners have a large degree of autonomy in the way how, what and when to contribute which may lead to greater fragmentation of the progress being made.

The two settings that are subject to this study were both based on the principles of e-PBL where the second was a redesign of the first offering more explicit scaffolding of the various learning process phases, as well as the more explicit articulation and reflection of activities within the various phases in order to support

higher levels of knowledge construction. For reasons of clarity, the first setting is referred to as the 'e-PBL design' and the second optimised setting is referred to as the 'Optima design'. The virtual learning environment, tasks, course materials, and assessments were identical in both settings. The role of the tutors/teachers in both designs was to provide a clear instructional design, facilitate discourse and provide rapid feedback in line with recommendations of CSCL and SDT research (Anderson, et al., 2001; K.-C. Chen, et al., 2010; De Laat, et al., 2007; Jang, et al., 2010; Vonderwell, Liang, & Alderman, 2009). Both designs included a lead tutor and back-up tutor and each group was mentored and facilitated several times each day. No obligatory meetings were scheduled. At the end of each week, the lead tutor made a suggestion on how to proceed with the next task, thereby focusing on process rather than on content. In the e-PBL design, four tutors were responsible for teaching six groups, while in the Optima design two tutors taught five groups. One tutor, who was course conveyor and who was the most experienced tutor in terms of years of teaching economics in PBL, led three groups in the e-PBL design and all five groups in the Optima design.

Discussion themes and tasks

Learners participated in a collaborative learning environment using eight discussion forums. There was one cafe-forum where learners could share non-task related info, get to know each other and develop a sense of relatedness (K.-C. Chen, et al., 2010). In addition, there was a "how does PBL work Task 0?" forum, whereby tutors replicated a discussion to illustrate how e-PBL/Optima works. The remaining six forums were task-related forums. The first two tasks were introductory and addressed basic terminology to get a feel for the domain. The tasks were designed to relate to the prior knowledge of students, as recommend by Schmidt et al. (2007), whereby the first task focussed on an international student from North-Korea coming to the institute and realising that the way markets function in Western Europe are different, while the second task focussed on explaining a graph of longitudinal Gross Domestic Product growth differences between Europe and the U.S. The following four tasks addressed authentic tasks within micro-economics and macro-economics with increasing complexity. The results of three interim-tests and a final summative test combined with graded participation in the discussion forums were used to make a pass-fail decision.

Two cohorts of learners in quasi-experimental research setting

1) Reflection on e-PBL implementation

Author A (2006) found that all learners participating in the e-PBL format were satisfied with the overall course and support provided by the tutor. 83% of the learners indicated that the goals of the module were clear, 82% indicated that the internet application was easy to use, 70% were satisfied about the knowledge and skills learned in the module, and 62% were satisfied about the group in which they participated. However, only 43% of the learners indicated that they actively participated in the discussions. During semi-structured interviews conducted two months after the completion of the course with two groups of four learners they indicated that they had found it difficult to understand the structure and scaffolding process of the online course. In particular they noted they had difficulty with understanding the functioning of the e-PBL five jump. Some learners indicated that it was sometimes unclear in which phase of the learning process the discussions were, which might influence their feelings of competence and perceived autonomy. Furthermore, some of the more active learners complained about the lack of participation by other learners in their group. Follow-up research (Author A, 2009; 2010) showed that successful participants in the e-PBL setting were high intrinsically motivated learners, while low intrinsically motivated learners contributed significantly less higher cognitive discourse and were more likely to drop-out of the course.

2) *Optima design*

Based upon the above results and follow-up discussions with experts in the field of PBL and SDT, we redesigned the e-PBL course in line with the so-called Optima model. Segers et al. (2003) proposed a new seven-jump procedure that consisted of a more explicit scaffolding and explanation of the activities learners were expected to perform in order to reach the desired learning outcomes. By providing more explicit scaffolding of the learning phases and by providing explicit reminders and guidance to facilitate productive planning, monitoring and articulation, more learner control over the learning process was provided (Segers, et al., 2003), in line with recommendations from research promoting scaffolding as a process within learning (Nadolski, et al., 2005; Quintana, et al., 2004). In addition, research in economics and medical education found that the Optima model led to improved learning satisfaction (L. S. Chen, Cheng, Weng, Lin, & Tan, 2005) and learning outcomes (Segers, et al., 2003).

In comparison to the e-PBL design, the Optima design was adjusted in four ways. First, the five-jump process was extended to a seven-jump process (See Appendix 1). For example, an explicit “Step 4 Elaboration on findings in Step 3” was added to encourage more interaction, elaboration and higher cognitive discourse. Learners were encouraged to print out a so-called Optima card, or process overview (i.e. a schematic overview

showing the concrete steps in the seven-jump process), and use this card when looking at the discussion forums (Nadolski, et al., 2005).

Secondly, specific scaffolds were given to provide an easy visual overview for learners to understand in which part of the seven-jump learning process a discussion was positioned. For example, learners could only proceed to the third phase of answering a particular learning goal when at least three (25% of group members) learners agreed (by using a “thumbs-up” button) with the formulation and relevance of the learning goal (LG) as illustrated by number 1 in Figure 1. Only the third learning goal in the marked box 1 (i.e. LG. Negative and Positive Externalities) received at least three thumbs-ups, thereby the learners did not have to focus on the first two. This provided a visual prompt to show which phase the discussions were in, which provided learners more opportunities to control their learning.

➔ Insert Figure 1 about here

Thirdly, in the Optima design clearer guidelines were given to learners over what to do in each of the seven phases in comparison to the e-PBL design, in line with the process and articulation principles of Quintana et al. (2004). For example, in Step 4 learners were asked to elaborate on their findings by making a mind-map, thereby providing a conceptual overview of the concepts discussed in the task and how they related to each other. Alternatively, learners could question the assumptions of the arguments given before or provide other examples where the respective theory discussed did not hold, which is illustrated by the two posts marked by number 2 in Figure 1. In this way, more scaffolding was provided to learners on how to proceed within the learning process. However, they remained autonomous in directing their actions over how to proceed.

Fourthly, the worked-out example of “how does PBL work Task 0” was redesigned in order to illustrate how Optima worked in practice, as illustrated in Figure 1. By providing a worked example of interactions between nine teachers to the participants, the various steps required to solve the problem were visually illustrated, thereby providing more explicit training and support before the learners embarked on the problems set (Schmidt, et al., 2007). The examples given on the Optima card also related to the worked example, in an attempt to demonstrate to the learners in which phase of the Optima model the experts were.

Participants

Participants were selected based upon their scores on an entry assessment in economics (see Author A (2006) for more detail). In total 82 participants were randomly assigned to one of six teams in the e-PBL design, while 61 participants were randomly assigned to one of five teams in the Optima design. The eleven teams had an average of 13.00 members (SD= 2.68, range = 9-17). The average age was 19 years and 48% of the learners were female.

Research questions and hypotheses

Based upon on theoretical framework, we expected that learners in the Optima cohort would reach higher levels of knowledge construction and subsequently complete the course more successfully. In addition, we expected that the differences in contributions to discourse in the Optima model based on motivation would be reduced in comparison to the e-PBL model. Therefore, the following research questions were formulated:

1. Does providing more explicit scaffolding of the learning phases in CSCL lead to more active learning, as measured by contributions to higher cognitive discourse?
2. Does providing more explicit scaffolding of the learning phases in CSCL lead to a more inclusive learning environment, whereby intrinsically and extrinsically motivated learners more equally contribute to discourse?
3. Does the Optima model result in a lower drop-out rate?

Instruments

Academic Motivation Scale (AMS)

Individual motivation was measured by the Academic Motivation Scale (AMS), which is an adjusted version of the SDT model (Deci & Ryan, 1985) specifically focussing on college/university learners (Vallerand, et al., 1992). Recent research by Chen et al. (2010) and our own research shows that AMS can be a powerful instrument to help understand the influence of motivation in online learning. The instrument consists of 28 items whereby learners respond to the question stem “Why are you going to college?”. There are seven subscales on the AMS, of which three belong to the intrinsic motivation scale, three to the extrinsic motivation scale and one for amotivation. Intrinsic motivation subscales are intrinsic motivation to know (IMTK), learning for the satisfaction and pleasure to understand something new; intrinsic motivation to accomplish (IMTA), learning for experiencing satisfaction and pleasure to accomplish something; and intrinsic motivation to experience stimulation (IMES), learning to experience stimulating sensations.

The three extrinsic motivation subscales are identified regulation (EMID), introjected regulation (EMIN), and external regulation (EMER). The three extrinsic motivation scales constitute a motivational continuum reflecting the degree of self-determined behaviour, ranging from identified regulation as the component most adjacent to intrinsic motivation, to externally regulated learning, where learning is steered through external means, such as rewards. The last scale, amotivation (AMOT), constitutes the very extreme of the continuum: the absence of regulation, either externally directed or internally. The response-rate on the AMS-questionnaire among the summer course participants was 83%. The Cronbach alpha reliability for the seven scales ranged from .760 to .856, which is in line with previous studies (K.-C. Chen & Jang, 2010; Vallerand, et al., 1992).

Content Analysis of non-task and task-related discourse by learners

The aim of content analysis techniques (De Wever, Schellens, Valcke, & Van Keer, 2006; Schrire, 2006; Strijbos, Martens, Prins, & Jochems, 2006) is to reveal evidence about learning and knowledge construction from online discussions. When comparing a range of content analysis schemes, Schellens and Valcke (2005) conclude that the Veerman and Veldhuis-Diermanse (2001) scheme is particularly suited for analysing knowledge construction among novice undergraduate students (i.e. as is in this setting). Veerman and Veldhuis-Diermanse (2001) make a distinction between non-task related (1 planning; 2 technical; 3 social; 4 non-sense) and task-related discourse activity (5 facts; 6 experience/opinion; 7 theoretical ideas; 8 explication; 9 evaluation). An elaborate description of the nine discourse activities and specific examples in our context can be found in Author A (2009).

Three independent coders (two economists, one educational psychologist), who were blind to the study's purpose and hypotheses, were trained to use the CA instrument and independently coded all messages. A random sample of 100 messages was used as a test case but the Cronbach alpha was rather low (0.6). Therefore, an additional meeting with the three coders was established and the divergent results were discussed and consensus on the method agreed. The coding took 120-160 hours per coder, who received financial compensation in return.

As a unit of analysis, the complete message was chosen as recommended by Schellens and Valcke (2006). A message was "codeable" when two or more coders used the same category. If this was not the case, the coders discussed until there was agreement on the coding of the message. Learners posted 3186 messages of which 60 were considered as uncodeable (2%). The Cronbach alpha (α) for these 3186 messages was 0.903.

Most studies have set the minimum α at 0.7 and recommend setting $\alpha > 0.8$. The Cohen's kappa of the coder inter-reliability (coders agreeing with each other) between Coder 1 – 2, 2 – 3 and 1 – 3 was 0.62, 0.63 and 0.61 respectively. De Wever et al. (2006) argue that Cohen's kappa values between 0.4 and 0.75 represent fair to good agreement beyond chance.

Positioning of individuals within social network using Social Network Analysis

Social Network Analysis (SNA) provides us with several tools to analyse interaction patterns among individual learners (De Laat, et al., 2007; Martinez, Dimitriadis, Rubia, Gomez, & De la Fuente, 2003; Wassermann & Faust, 1994). Two frequently used measures in SNA were employed in order to determine the position of the learners in each social network. First, Freeman's degree of Centrality measures whether learners are central in or more peripheral to the social network (Wassermann & Faust, 1994). If a learner contributed actively to discourse and most other learners responded to the activities of this learner, s/he became a central learner in the network and therefore had a high degree of centrality. Second, the ego network density (Size) of each individual within the network was used, which measures to how many other learners a learner is directly connected. In a cohesive learning environment (i.e. most learners are connected to each other), most learners will have a large ego network density and the differences in degree of centrality between learners are small.

Statistical analyses

Motivational profiles were determined by first calculating a Relative Autonomy Index (Black & Deci, 2000; K.-C. Chen & Jang, 2010; Ryan & Deci, 2010) based upon the scores of the AMS scales, and afterwards conducting a median split, whereby we distinguished between learners relatively low in autonomy (Low RAI) and learners relatively high in autonomy (High RAI). To compare the difference in discourse over the two designs in general, T-tests were used. Second, MANOVAs were used to analyse the data on a deeper level by taking into account high and low levels of autonomy. ANOVAs and correlational analysis were conducted to make sure we did not miss any information that could be hidden in the aggregated scores. Finally, social network analysis consisted of calculating centrality and ego-density measures by using UCINET 6.158.

RESULTS

In order to test whether the cohort participating in the Optima design was similar to the cohort participating in the e-PBL design at the start of the course, we compared the participants' scores on the entry test, prior education, gender, and academic motivation using independent sample T-tests for quantitative measures and Chi-square analysis for categorical measures. No significant differences were found between the two cohorts with respect to their entry assessment scores, prior education, gender, or the seven subscale scores of AMS. In other words, the division of prior knowledge and motivational profiles of participants was similar at the start of the course for the two designs.

Comparing contributions to discourse

On average, learners in the e-PBL design contributed 28.46 (SD= 28.52) messages, while in the Optima design learners contributed 14.44 (SD= 14.24) messages during the course. If we look into the different categories that are discerned by Veerman and Veldhuis-Diermanse (2001), using independent sample T-tests we found evidence of significant differences in the two designs with the exception of categories 2 (technical), 7 (theoretical) and 9 (evaluation). However, with the exception of category 3 (social) the direction of the difference was in the opposite direction than we expected. That is, in the Optima design learners posted significantly fewer non-task related messages and fewer task-related messages in comparison to the e-PBL design, as is illustrated in Table 1.

➔ Insert Table 1 about here

When comparing higher cognitive messages by aggregating the number of messages in categories 7-9, learners in the e-PBL design contributed on average 7.99 (SD= 9.85) messages, while learners in the Optima design contributed on average only 4.10 (SD= 5.27), which is significantly different at 1% confidence level. In other words, in contrast to our prior expectations, providing more explicit scaffolding of the learning phases did not lead to more contributions of higher cognitive discourse. In contrast, the learners in the Optima design contributed significantly lower amounts of (higher) cognitive discourse with the effect size being small to moderate.

Comparing contributions to discourse by self-determination

The second research question addresses whether the learning environment was equally supportive for both sets of identified learners; those relatively low or high in autonomy. In the e-PBL design, learners relatively low in autonomy contributed on average 25.18 (SD = 25.06) messages, while learners relatively high in autonomy contributed 34.70 (SD = 32.13) messages. In the Optima design, learners relatively low in autonomy contributed 14.50 (SD = 15.07) messages, while learners relatively high in autonomy contributed 13.60 (SD = 12.53) messages, which implies that both types of learners contributed in a similar manner.

When we compare the type of contributions to discourse using our Content Analysis results, in the e-PBL design learners relatively high in autonomy contributed significantly more category 6 (own experience) and category 7 (theoretical ideas) contributions in comparison to learners relatively low in autonomy using an independent sample T-test and a 5 % significance level. In addition, in the e-PBL design learners relatively high in autonomy contributed more to higher cognitive discourse than learners relatively low in autonomy at a 10 % significance level. In the Optima design, all significant differences in quantity of contributions to discourse between the two levels of learning autonomy disappeared. In other words, learners in the Optima design contributed in a more balanced manner to discourse (irrespective of their motivational profile) in comparison to learners in the e-PBL design.

A subsequent MANOVA of the nine categories of discourse, with two sub-groups of learners based on median-splits of RAI, confirmed the results and a significant effect for Optima ($\Lambda(9, 116) = 3.961, p < .001$) but not for e-PBL ($\Lambda(9, 116) = 1.402, p > .05$). Follow-up univariate ANOVAs indicated significant differences in contributions to discourse in six of nine content analysis categories, which was primarily attributed to the large differences in contributions between the two designs, as illustrated by the F-values in Table 2.

→ Insert Table 2 about here

As median split analysis of RAI may disguise patterns present in individual variables but lost in the aggregated index, separate correlation analyses of the seven subscales of the AMS, the RAI and scores for the nine content analysis categories for both designs were calculated. Results indicate that the role of the learner's motivational profile on the level of learner activity, as measured by contributions to discourse, was very different for the two course designs. In Table 3, it is evident that being high intrinsically motivated positively correlated with discourse activity in all categories: all correlations were positive in the e-PBL design. However, the strongest contribution to being high intrinsically motivated was for the categories of task-related discourse:

correlations in this category were generally higher in value than correlations with non-task related discourse. High intrinsically motivated learners excelled mostly in contributing their own experiences, theoretical ideas and explications. The significant positive correlations of the RAI with six of nine categories confirmed the above findings.

➔ Insert Table 3 about here.

A rather different picture emerges when looking at the correlations of AMS subscales and the RAI with the various learning indicators in the Optima model, as illustrated in Table 4. Learners high on intrinsic motivation contributed only above average to non-task related activities, with marginally significant positive correlations in planning and nonsense. With respect to task-related messages, in contrast to the e-PBL design, significant negative correlations were found for explication and evaluation. In other words, in contrast to the e-PBL design learners high on intrinsic motivation contributed less to higher cognitive discourse in the Optima design.

➔ Insert Table 4 about here.

Learners high on identified regulation (EMID), that is the extrinsic motivation component most adjacent to intrinsic motivation, contributed significantly more to all types of discourse in the Optima model with the exception of technical messages and evaluation. In particular, positive correlations between the level of identified regulation were especially strong with task-related messages and higher cognitive discourse. Learners high on the other two subscales of extrinsic motivation (EMIN, EMER) contributed close to the average, as none of the correlation coefficients of AMS and CA were significant at a 5% significance level. Finally, the Relative Autonomy Index score did not correlate significantly with any of the learning indicators. In sum, the Optima design appeared to have changed how learners with various motivational profiles contributed to discourse. In contrast to the e-PBL design, where intrinsically motivated and autonomous learners contributed significantly more to (higher) cognitive discourse, in the Optima design, intrinsically motivated learners could not be distinguished from other learners in terms of actively contributing to cognitive discourse. At the same time, in the Optima design learners high on identified regulation are actively contributing to discourse, both for non-task and task-related messages.

Comparing social network structures between Optima and e-PBL

While the above analysis captures how differences in levels of the several facets of motivation are related to differences in the contributions to the different types of discourse, the analysis does not allow us to investigate whether the learning environment became more cohesive. When comparing the degree of centrality between the e-PBL and Optima design, there was a significant difference at a 1% confidence level. That is, in comparison to the Optima design there were more learners in the e-PBL that occupied a central position in the learning network. At the same time, the average number of peers a learner was connected to was almost identical in the two designs, as is evident from Table 5. In other words, in both designs learners were connected to a similar number of other learners within their social network, but in the e-PBL design some learners occupied a more central role in their social network. Thus, the Optima model suggests a more equitable cohesive environment.

Subsequent correlational analyses indicate that intrinsic motivation was positively correlated with the centrality and ego-density measures from our social network analysis in the e-PBL design. This implies that high intrinsically motivated learners distinguished themselves from extrinsically and amotivated learners not only in terms of how actively they contributed, but also with respect to their position in the network. That is, intrinsically motivated learners in the e-PBL design were more likely to be central contributors to discourse, whereby they interacted with more learners. In the Optima design, learners who scored highly on identified regulation were more likely to be central contributors to discourse. Furthermore, learners high on identified regulation had more connections to other learners. Thus, combining the results from Table 3 and the position of learners in their social network we found that with respect to the second research question, the Optima model provided a more inclusive learning environment, whereby intrinsically and extrinsically motivated learners both contributed similarly to discourse.

➔ Insert Table 5 about here

Comparing learning outcomes

In Table 6, the final exam scores (consisting of 20 multiple choice questions and one essay question) and pass rating of the e-PBL and Optima design are illustrated. In the Optima design learners who sat the final exam obtained significantly higher scores. However, while in the e-PBL design 70% of the learners made the final exam, only 41% of the learners in the Optima design completed the final exam. Indeed the end grade for the course in the Optima design is significantly lower than in the e-PBL design. Furthermore, the overall passing rate has fallen to 41%, which according to the result on a Chi-Square test is significantly lower than in the e-PBL

design (χ^2 (df= 1 N= 172) = 7.409 , $p < .01$). In particular, 64% of the learners relatively low in autonomy in the e-PBL design and 38% in the Optima design passed the course, which is significantly different (χ^2 (df= 1 N=65) = 4.127, $p < .05$). 69% of the learners relatively high in autonomy in the e-PBL design and 48% in the Optima design passed the course, which is marginally significantly different (χ^2 (df= 1 N=64) = 2.885, $p < .10$). In other words, the dropout from the Optima cohort was significantly higher and learners relatively low in autonomy were more likely not to complete the course than those in the e-PBL cohort, therefore we have to reject hypothesis 3.

→ Insert Table 6 about here

DISCUSSION

In this study we found that providing more explicit scaffolding of the learning phases in Computer-Supportive Collaborative Learning has a profound impact on learners' engagement, behaviour and learning outcomes. In the original design, we found that autonomous learners contributed more task-related and higher cognitive discourse than control-oriented learners. In the redesigned learning environment, the differences in contributions to cognitive discourse depending on the level of autonomous learning disappeared. That is, learners in the Optima design contributed in a more balanced manner to discourse, irrespective of their motivational profile, in comparison to learners in the e-PBL design. Follow-up correlation analyses with the seven subscales of AMS indicate that learners high on intrinsic motivation contributed only actively to non-task related activities in the Optima design. In contrast to the e-PBL design, significant negative correlations were found for the two highest cognitive discourse categories (explication and evaluation) for learners high on intrinsic motivation. Learners high on identified regulation (EMID), that is the extrinsic motivation component most adjacent to intrinsic motivation, contributed with greater frequency to almost all types of discourse in the Optima design than learners low on this scale.

A second important finding was that in the redesigned learning environment learners contributed less to higher cognitive discourse. These results indicate that the more explicit scaffolding of the PBL learning phases primarily had a negative impact on the behaviour of autonomous learners. That is, while in the e-PBL design learners relatively high in autonomy contributed on average 18 cognitive messages per learner, in the Optima design learners relatively high in autonomy contributed only 6 cognitive messages per learner. In other words,

autonomous learners were less likely to contribute actively to cognitive discourse in the redesigned learning environment.

A possible explanation for the lower engagement of learners in the Optima design is that the more explicit scaffolding of the Optima seven jump learning process may have narrowed the freedom and autonomy of learners relatively high in autonomy to self-determine their learning actions. While research in face-to-face settings (Segers, et al., 2003), blended (L. S. Chen, et al., 2005; Van der Pol, et al., 2006) and experimental settings (Beers, et al., 2005, 2007; Weinberger, et al., 2005) show that explicit scaffolding of the learning phases enhances interaction and task performance, in our CSCL environment, whereby learners work and learn at a distance for a sustained period of time, increased scaffolding reduced discourse. One possible explanation of the lower engagement may be found in the fact that learners in the Optima setting had to wait for approval by peers before continuing their learning actions (e.g. discussing a learning goal they were interested). In the e-PBL design learners could (technically) start and complete the learning phases without their peers, that is they could start with a learning goal and provide a set of answers/solutions without receiving approval or feedback from their peers. A drawback of this approach is that learners are not co-constructing knowledge together, which may inhibit the contributions of learners to the discourse. The explicit timing in Optima might have negatively influenced the engagement of autonomous learners, while it was beneficial for control-oriented learners, who had more time to actively engage with the task. In addition, while Jang et al. (2010) found a strong positive relation between structure and autonomy of teachers and the respective learning environment with behaviour engagement of students during a one-hour face-to-face lesson, perhaps a sustained scaffolding in our online setting may have delayed and/or interfered with the natural flow of interaction of autonomous and control-oriented learners. Also Quintana et al. (2004) argue that our understanding of how teachers can effectively fade the scaffolding of the learning phases over time needs more research.

A third important result is that the behaviour of control-oriented learners in the Optima design was similar to those of autonomous learners, which was one of the main reasons for the redesign. That is, control-oriented learners contributed equally to discourse as autonomous learners. Nonetheless, in comparison to the e-PBL design learners relatively low in autonomy in the Optima design were less engaged and contributed less to discourse, despite more explicit scaffolding of the learning phases. A possible explanation is that due to the (relatively) lower engagement of autonomous learners, the “engines” that spark social interaction and engagement in the discussion forums were missing in the Optima design to “push the group forward”. Given that learners high on identified regulation contributed significantly more to (higher) cognitive discourse, the

redesigned learning environment seemed to be well-suited for these types of learners. However, their enhanced participation did not compensate the significantly reduced contributions by more autonomous, intrinsically motivated learners.

The main conclusion from this study is that getting the balance between guidance and support right in minimal guided environments such as (online) PBL to facilitate both autonomous and control-oriented learners is a complex and delicate issue. Not being content with the very different positions of students of different motivational profiles in our e-PBL design, we chose a redesign that provided more explicit scaffolding of the learning phases for learners seemingly most in need for it. Our redesign indeed triggered more equal levels of activity, but that was achieved at a substantial cost of “de-activating” those who may have been instrumental to the collaborative learning process: the autonomous learners.

Limitations

The results of this study are based on a redesign of an authentic, real environment using quasi-experimental research. A first limitation of this study is that we did not introduce a classical experiment-control research design. However, given that there were no significant differences between the two cohorts with respect to their entry assessment scores, prior education, gender, or the seven subscale scores of AMS, we argue that our participants were similar at the start of the course for the two designs.

A second limitation is that we did not measure the interactions between individual and mutual conceptions, emotions and shared regulation among participants (Järvelä, et al., 2011; Järvelä, Volet, & Järvenoja, 2010). In groups that have more autonomous learners, one may expect that more (higher) cognitive discourse activities would be present than groups with more control-oriented learners. However, the number of groups (six and five) in both conditions was too small to conduct a group-level analysis. Furthermore, methodologically it is difficult to measure interaction patterns on group level when CA and SNA-measures are combined. Further research should assess whether group-level effects and dynamic learning processes during discourse of autonomous and control-oriented learners also influence behaviour of individual learners in CSCL settings. Given that our study analysed the learning behaviour of 142 learners in two designs during an online course for six weeks using a mixed-method approach, whereby almost 3200 messages posted were reliably coded by three independent coders and linked to social network analysis, our study provides a comprehensive and rather unique insight into how learning behaviour of autonomous and control-oriented learners may be influenced by the scaffolding of the learning phases in a CSCL environment.

Future research and implications for practice

Future research should investigate how autonomy support and structure can be manipulated in such a way that the key drivers of social interaction (i.e. autonomous learners) are able to actively engage and push the vehicle of discourse forward without over-dominating the discussions, while at the same time ensuring that more control-oriented learners are able to actively contribute as well, and over time become more intrinsically motivated learners. We intend to redesign the Optima model so that the progression between stages becomes less restrictive, whereby the first two weeks are explicitly scaffolded to allow all learners to contribute on equal terms, but over time more freedom is given to learners to explore individual learning goals within the task, thereby providing more space for autonomous learners to explore alternative solutions. At the same time, we recommend that researchers explore the recent discussions on assigning specific roles to learners (Strijbos & De Laat, 2010), whereby individual learners may be supported to overcome initial resistance in contributing to discourse. In addition, by analysing how learners mutually influence each other in collaborative learning, future research should assess how the type of motivation of one learner influences the behaviour of other learners. These findings are relevant for teachers, managers, admission officers and schedulers as the results imply the scaffolding of the learning phases has a strong impact on the engagement of students. Appropriate strategies to deal with various types of motivation should be designed to assist each type of learner.




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APPENDIX 1

Traditional PBL 7-Jump	e-PBL 5-Jump	Optima 7-jump
<p>The seven-jump procedure, where 1-5 is pre-discussion and, 6 is self-study and 7 post-discussion.</p> <p>1) Understand all terms</p>	<p>Step 1: Read the task and see if there are any difficult words and check whether somebody else has already defined such words on Polaris;</p> <ol style="list-style-type: none"> If not, state the difficult word in Polaris; If yes, see if you agree with the definition of the difficult word and use the “thumbs up” button ; If others have stated difficult words that are not difficult for you, try to explain their meaning to your fellow students. 	<p>Step 1: Read the task and see if there are any difficult words?</p> <ol style="list-style-type: none"> Check whether somebody else has already defined the difficult word(s) on Polaris. If not, state the difficult word in Polaris by clicking on “start new thread”; Click on “start new thread” and start with difficult word in the subject line. For example, ‘Nationalisation’. Afterwards, fill in the remaining text boxes so that others can understand why you chose this difficult word. Check whether you agree with the definition of the difficult word and use the “thumbs up” button ; If you do not agree with the definition given by others or if a fellow student has stated a difficult word that is not difficult for you, try to explain its meaning to your fellow students.
<p>2) Define the problem</p>	<p>Step 2: What are the main problems of the task according to you and check if somebody else has already defined these problems on Polaris;</p> <ol style="list-style-type: none"> If not, state the problem(s) in a question-type form (learning goals); If yes, see if you agree with the formulation of the learning goal(s). 	<p>Step 2: What are the main problems of the task?</p> <ol style="list-style-type: none"> Check if somebody else has already defined these problems on Polaris. If not, state the new problem(s) in a question type form (learning goals); Click on “start new thread” and start with abbreviation LG in the subject line, followed by key terms of your learning goal. For example, ‘LG: Why nationalisation OPEC disappointing?’. Afterwards, fill in the remaining text boxes so that others can understand why you chose this problem. For convenience, use for each learning goal a separate new thread. In this way, in the overview everyone can see the main questions raised. See if you agree with the formulation of the learning goal(s) and use the “thumbs up” button  if you agree with learning goal. As soon as 3 or more of your fellow students have agreed with the formulation of the learning goal without that somebody else has rephrased the learning goal, you can proceed to step 3 for this particular learning goal.
<p>3) Analyse the problem -brainstorm -activate prior knowledge -discuss</p> <p>4) Synthesise (arrange ideas)</p> <p>5) Define learning objectives</p>	<p>Step 3: Try to answer one (or more) learning goal(s):</p> <ol style="list-style-type: none"> By common sense, prior knowledge and/or experience; Referring to (additional) literature; Referring to the videos/animated graphs; 	<p>Step 3: Try to answer one (or more) learning goal(s) once Step 2c has been completed:</p> <ol style="list-style-type: none"> Using your prior experience/ knowledge; By referring to the literature of Bade & Parkin (2006); By referring to other sources (internet, videos, graphs, etc);
		<p>Step 4: Elaborate on the findings found in step 3:</p> <ol style="list-style-type: none"> Make a scheme by determining the main points and concepts mentioned at Step 3; MS Powerpoint is a helpful tool to link various ideas, concepts and theories together. For example, the question why nationalisation of OPEC was not as profitable as expected has not one unique answer. There are multiple concepts that explain the failure. By first visualising the main points, important relationships can be distinguished. State difficulties in question and answers given thus far; At this point of the 7 JUMP, several answers and opinions have been given by yourself and your fellow students. However, most answers make assumptions that can be questioned. For example, your experience about a problem might be different than others, or you have read different articles which say the opposite as mentioned thus far. Bring these different points-of-view into the discussion.




		<p>c. Give other examples; By giving other examples and trying to explain how these different examples relate to the learning goal, important (general) concepts can be identified. For example, the problems faced by OPEC are not unique for OPEC. Dutch beer-brewers were recently accused of forming a cartel. However, the beer-brewers stated that the market was not conducive for cartels. In addition, many problems faced by OPEC are similar to problems faced by governments.</p>
	<p>Step 4: See if you agree with the answers of the learning goals:</p> <p>a. If not, state why you do not agree with the answer;</p> <p>b. If you partly disagree/agree, state what should be added to the answer to receive your complete approval.</p> <p>c. If yes, use the “thumbs up” button  ;</p> <p>d. If 3 or more students have agreed with the answer (without that anyone has disagreed), the learning goal is answered sufficiently and you can proceed with the remaining learning goals.</p>	<p>Step 5: Do you agree with the answers of the learning goals?</p> <p>a. If not, state why you do not agree with the answer;</p> <p>b. If you partly disagree/agree, state what should be added to the answer to receive your complete approval.</p> <p>c. If yes, use the “thumbs up” button  ;</p> <p>d. If 3 or more students have agreed with the answer (without that anyone has disagreed), the learning goal is answered sufficiently and you can proceed with the remaining learning goals.</p>
		<p>Step 6: Check whether all learning goals and questions are answered:</p> <p>a. If not, go back to step 3;</p>
<p>6) Self-study 7) Report back</p>	<p>Step 5: Try to summarize the main points of the entire discussion and see whether all learning goals and questions are answered:</p> <p>a. If not, go back to step 3;</p> <p>b. If yes, close the discussion by making a short summary and continue with the next task.</p>	<p>Step 7: Try to summarize the main points of the entire discussion and:</p> <p>a. Make a short summary of the main points of the entire discussion</p> <p>b. If you partly disagree/agree, state what should be added to the answer to receive your complete approval.</p> <p>c. See if you agree the short summary given by others by using the “thumbs up” button  .</p>

Table I Comparison of contributions to discourse per learner in e-PBL vs. Optima

	e-PBL		Optima		T-test	d-value
	M	SD	M	SD		
<i>Non-task related</i>	13.17	15.21	7.13	6.66	2.899**	0.51
Planning (Cat. 1)	1.65	2.23	0.80	1.48	2.580**	0.45
Technical (Cat. 2)	1.14	2.14	0.69	1.01	1.511	0.27
Social (Cat. 3)	0.88	1.59	1.82	3.16	-2.325*	-0.38
Nonsense (Cat. 4)	9.51	11.50	3.82	2.77	3.776**	0.68
<i>Task-related</i>	14.31	17.21	7.30	9.53	2.867**	0.50
Facts (Cat. 5)	4.75	5.98	2.33	3.94	2.747**	0.48
Experience (Cat. 6)	1.57	2.42	0.87	1.56	1.965*	0.34
Theoretical Ideas (Cat. 7)	2.41	3.43	1.49	2.23	1.814	0.32
Explication (Cat. 8)	5.28	6.58	2.16	3.22	3.406**	0.60
Evaluation (Cat. 9)	0.30	0.58	0.44	1.13	-1.002	-0.16

Independent Sample t-test for e-PBL (n=82) and Optima (n=61)

**Coefficient is significant at the 0.01 level (2-tailed).

*Coefficient is significant at the 0.05 level (2-tailed).

Table 2 Contributions to discourse per learner in e-PBL vs. Optima condition depending on Relative Autonomy Index median split.

	e-PBL				Optima				F-value
	Low RAI		High RAI		Low RAI		High RAI		
	M	SD	M	SD	M	SD	M	SD	
<i>Non-task related</i>	12.31	15.31	15.59	15.56	6.85	5.96	7.20	7.37	3.421*
Planning (Cat. 1)	1.49	1.99	2.00	2.55	0.65	1.09	0.88	1.56	2.994*
Technical (Cat. 2)	0.82	1.37	1.62	2.76	0.58	0.70	0.88	1.33	2.097
Social (Cat. 3)	0.69	1.49	1.19	1.75	1.65	3.12	1.88	3.55	1.461
Nonsense (Cat. 4)	9.31	12.72	10.78	10.63	3.96	2.51	3.56	3.00	4.805**
<i>Task-related</i>	11.44	13.65	18.49	20.58	7.62	10.83	6.40	7.59	4.375**
Facts (Cat. 5)	3.85	4.36	6.03	7.47	2.46	5.04	1.72	2.03	4.002**
Experience (Cat. 6)	1.08	1.61	2.22	3.07	0.85	1.26	0.76	1.51	3.525*
Theoretical Ideas (Cat. 7)	1.72	2.72	3.35	4.05	1.62	2.50	1.16	1.49	3.473*
Explication (Cat. 8)	4.41	5.83	6.65	7.47	2.04	3.22	2.44	3.56	4.484**
Evaluation (Cat. 9)	0.38	0.59	0.24	0.60	0.65	1.50	0.32	0.85	1.126

ANOVA F-Test for low RAI (n=39) and high RAI in e-PBL (n=34), low RAI (n=26) and high RAI in Optima (n=25).

**Coefficient is significant at the 0.01 level (2-tailed).

*Coefficient is significant at the 0.05 level (2-tailed).

Table 3 Correlations of learning indicators and academic motivation in e-PBL design

	IMTK	IMTA	IMES	EMID	EMIN	EMER	AMO	RAI
<i>Non-task related</i>	.192	.201	.191	-.008	.035	.017	.120	.140
Planning (Cat. 1)	.290*	.308**	.292*	.086	.063	.056	-.003	.215 ¹
Technical (Cat. 2)	.236*	.178	.215 ¹	-.073	.020	-.097	.007	.235*
Social (Cat. 3)	.275*	.167	.151	-.259*	.075	-.228*	-.198 ¹	.235*
Nonsense (Cat. 4)	.115	.148	.133	.023	.020	.061	.185	.066
<i>Task-related</i>	.273*	.248*	.229*	.027	.007	-.047	-.094	.269*
Facts (Cat. 5)	.228*	.214 ¹	.203 ¹	-.001	-.049	-.074	-.008	.285*
Experience (Cat. 6)	.274*	.214 ¹	.212 ¹	-.003	-.027	-.069	-.175	.282*
Theoretical Ideas (Cat. 7)	.262*	.265*	.275*	.098	.024	-.006	-.073	.267*
Explication (Cat. 8)	.263*	.234*	.196 ¹	.014	.052	-.036	-.117	.212 ¹
Evaluation (Cat. 9)	.072	.023	-.039	.099	.094	.119	-.215 ¹	-.110

IMTK, intrinsic motivation to know; IMTA, intrinsic motivation to accomplish; IMES, intrinsic motivation to experience stimulation; EMID, identified regulation; EMIN, introjected regulation; EMER, external regulation; AMO, a-motivation; RAI, relative autonomy index; **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). ¹Correlation is significant at the 0.10 level (2-tailed).

Table 4 Correlations of learning indicators and academic motivation in Optima design

	IMTK	IMTA	IMES	EMID	EMIN	EMER	AMO	RAI
<i>Non-task related</i>	.257 ¹	.133	.037	.386**	.105	.203	.008	.009
Planning (Cat. 1)	.245 ¹	.173	.141	.242 ¹	.060	.124	-.083	.087
Technical (Cat. 2)	.035	-.058	-.164	.221	-.104	-.008	-.001	.070
Social (Cat. 3)	.184	.126	.055	.346*	.057	.209	.112	.003
Nonsense (Cat. 4)	.267 ¹	.108	.018	.313*	.196	.181	-.075	-.051
<i>Task-related</i>	-.024	-.136	-.186	.400**	-.032	.171	-.091	-.092
Facts (Cat. 5)	.024	-.019	-.028	.321*	.052	.233 ¹	-0.03	-.120
Experience (Cat. 6)	.063	-.083	-.175	.376**	-.042	.116	-.022	-.014
Theoretical Ideas (Cat. 7)	.055	.028	-.008	.329*	.209	.202	-.158	-.147
Explication (Cat. 8)	-.103	-.236 ¹	-.278*	.311*	-.183	-.001	-.122	.020
Evaluation (Cat. 9)	-.142	-.277*	-.355*	.201	-.213	.096	.032	-.114

IMTK, intrinsic motivation to know; IMTA, intrinsic motivation to accomplish; IMES, intrinsic motivation to experience stimulation; EMID, identified regulation; EMIN, introjected regulation; EMER, external regulation; AMO, a-motivation; RAI, relative autonomy index; **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). ¹Correlation is significant at the 0.10 level (2-tailed).

Table 5 Centrality, ego-density, and correlations with academic motivation

	M	SD	IMTK	IMTA	IMES	EMID	EMIN	EMER	AMO	RAI
<i>e-PBL</i>										
Reply degree	26.25	24.29	.228*	.210 ¹	.181	-.002	-.007	-.029	.048	.214 ¹
Size	6.44	6.36	.240*	.213 ¹	.218 ¹	-.014	.038	.046	-.021	.139
<i>Optima</i>										
Reply degree	11.89	11.71	.166	-.023	-.072	.483**	.007	.155	-.111	.166
Size	6.36	3.81	.232 ¹	.125	-.013	.424**	.168	.174	-.115	-.011

IMTK, intrinsic motivation to know; IMTA, intrinsic motivation to accomplish; IMES, intrinsic motivation to experience stimulation; EMID, identified regulation; EMIN, introjected regulation; EMER, external regulation; AMO, a-motivation; RAI, relative autonomy index; **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). ¹Correlation is significant at the 0.10 level (2-tailed).

Table 6 Comparison of final exam score & pass rate

	e-PBL		Optima		T-test	χ^2	d-value
	M	SD	M	SD			
Score on final exam	7.26	1.42	8.14	1.14	-2.709**		-0.68
End grade of the course	5.88	2.62	4.21	3.02	3.474**		0.59
Pass rate (in %)	64		41			7.409**	

Note: Independent Sample T-test and Chi-Square test for e-PBL (n=82) and Optima (n=61).

Figure 1 Exemplary Task 0 of Optima model

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Forum: Task 0 Innovations and Externalities

Subject	Author	Date	? ! 🔊 & 0 🗑️ 📄 #
Thanks so much for that	Trust	21-06-08 13:43	🗑️ 📄 0
announcement	J Hon	23-05-07 16:12	🗑️ 📄 0
Thank you for your update	Online	23-05-07 21:51	🗑️ 📄 0
I will also take a short weekend of	Bart F	24-05-07 22:07	🗑️ 📄 0
Moving	Maart	25-05-07 14:03	🗑️ 📄 0
why do international oil companies better than national oil co...	J Hon	23-05-07 9:03	🗑️ 📄 1
LG: why do international oil companies better than nationa...	Online	23-05-07 13:21	🗑️ 📄 2
LG: Negative and Positive Externalities	Maart	21-05-07 21:59	🗑️ 📄 4
I found something	Maart	23-05-07 8:58	🗑️ 📄 0
another example for positive externalities	Keeti	23-05-07 15:51	🗑️ 📄 3
summary	Keeti	31-05-07 11:45	🗑️ 📄 4
Excellent summary	Online	04-06-07 9:18	🗑️ 📄 0
LG: How may environmental regulations generate competitive adv...	Martir	21-05-07 17:27	🗑️ 📄 3
LG: What are environmental regulations	Bart F	22-05-07 8:57	🗑️ 📄 5
two types of regulations	Keeti	24-05-07 9:26	🗑️ 📄 3
LG: What are competitive advantages	Bart F	22-05-07 8:58	🗑️ 📄 3
lg externalities	J Nijh	22-05-07 13:24	🗑️ 📄 1
comparative advantage	Keeti	24-05-07 9:38	🗑️ 📄 0
comp	Piet E	24-05-07 16:50	🗑️ 📄 0
Competitive advantage vs comparative advan...	Bart F	24-05-07 22:00	🗑️ 📄 0
I have a competitive advantage	J Nijh	24-05-07 22:45	🗑️ 📄 2
Try to link the concepts :-)	Online	29-05-07 14:41	🗑️ 📄 0
A mindmap to link business dec...	Bart F	29-05-07 20:06	🗑️ 📄 0

1

Concrete scaffolds to encourage elaboration

2

At least 3 learners have to agree with learning goal