JOS BEISHUIZEN

FOSTERING SELF-REGULATED LEARNING IN TECHNOLOGY ENHANCED LEARNING ENVIRONMENTS: EVIDENCE FROM EMPIRICAL RESEARCH

INTRODUCTION

In the Netherlands, computers have been used in education since 1970. Two research projects, funded by the Dutch Foundation for Educational Research, provided a major stimulus. At Leiden University, a project focused on Computer Managed Instruction for primary education and secondary vocational education (Van de Perel, 1979). At the Vrije Universiteit Amsterdam, a research group developed Computer Assisted Instruction, also for primary education and secondary (vocational) education (Dirkzwager, Fokkema, Van der Veer, & Beishuizen, 1984). The latter project included research on the differential effects of learner controlled and program controlled instruction, in which the concept of self-regulated learning already showed up. Bernaert (1977) showed that students tended to adopt a more risky learning strategy, skipping explanations and immediately jumping to assignments and exercises, when they have the freedom to find their own way. They performed worse on learning and transfer tests than students for whom the learning path had been determined by the program in advance. This detrimental effect of learner control turned out more striking for students with low cognitive abilities.

These pioneering projects were soon followed by a lot of various research projects, especially after the introduction of the desktop computer in 1975. The switch from “mainframe” to “microcomputer” meant a major change in the potentials and functionalities of computers. Fokkema, Van der Veer, Beishuizen, and Dirkzwager observed in 1984 that microcomputers were cheap. For less than 5000 Dutch guilders (approx. 2300 Euros) microcomputers with limited capacity were available. For less than 10000 Dutch guilders one could purchase a microcomputer with standard characteristics like 64 kB internal memory, a conventional microprocessor like the Z80 and two external drives for floppy disks. Like other governments, the Dutch Ministry of Education started to provide money to schools to buy equipment and train the teachers. This led once again to large scale research projects, like the Technology-Enriched School Projects (Beishuizen & Moonen, 1993; Beishuizen & Versteegh, 1993). Gradually, computers became less expensive and more advanced, which exponentially increased their use in education. Since 1995, research into the use of computers in education became more specific, focusing on various applications, like simulation and gaming, and integrating the computer as an instrument in a larger learning environment, the Technology Enriched Learning Environment.

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In this review, we focus on research into the development of self-regulation strategies and skills in technology enhanced learning environments. Steffens (2006) defined three steps in self-regulation: '(1) planning the learning activity, (2) executing and monitoring the execution of the learning activities and (3) evaluating the outcome of the learning activity' (Steffens, 2006). Technology enhanced learning environments can be arranged and equipped in such a way that students are supported to actively regulate their own learning processes. Planning can be supported by providing instruments to choose and sequence learning activities out of a list of learning objectives, assignments to be completed or subjects to be studied. Monitoring the execution of learning activities can be facilitated by keeping a log of all activities to be opened for inspection and review, by displaying progress indicators showing what has been done and what lies ahead of the student, or by checking the assignments completed on a list of all tasks to be done.

In order to describe and characterize recent developments in Dutch educational research into self-regulated learning in technology enhanced learning environment, we distinguished four factors influencing the process of self regulated learning in technology enhanced learning environments: (1) the student, (2) the teacher, (3) the community of learners and (4) the learning environment.

The student

We were interested in the effect of learning styles, expertise, prior knowledge, interest, motivation, age, and cognitive abilities on self-regulated learning.

The teacher

The role of the teacher in technology enhanced learning environments is often underestimated. In this review, we wanted to explore whether Dutch research clarified the contributions of teachers to self-regulated learning in technology enhanced learning environments.

The learning environment

Technology is part of the physical learning environment. Computer programs provide *learning tools* to support self regulation. In a hypermedia environment, an interactive map or table of contents may serve such a purpose. Another example is a progress indicator in an exercise with a number of tasks to complete. However, many programs offer more sophisticated support. Students may use a hypothesis scratchpad to formulate their expectations in a simulation environment. An interactive decision tool may help them to develop a particular learning strategy. These examples all have in common that the learner is in control of the learning process. The learning tools help the learner to regulate the learning process. However, in an environment where the program or the teacher is in charge of learning process, the *learning materials* may be arranged in such a way that students are supported to develop their own regulation strategies. Assignments may be arranged in an order of progressive complexity to keep the cognitive load of each task at a level which is optimal for this particular student in this particular stage of learning. Various subskills may be trained in a consecutive order to enable the student to gradually compose the target skill.

The community of learners

Recent views on learning as a social and constructive process make clear that peers influence the learning of individual students and that learning itself is often the result of a joint effort to solve a problem or to complete an assignment. Therefore, we explored the results of Dutch research into computer supported collaborative learning in which self-regulation (both individually and group wise) was taken into account.

In this review, we were interested in collecting samples of Dutch research on the role of learning tools and learning materials in fostering self-regulated learning in technology enhanced learning environments. This review had two general questions as its main focus:

– Which research programs have been carried out in the Netherlands during the period of 1997 – 2007 in the area of self-regulated learning in technology enhanced learning environments?
– What are the major outcomes of recent Dutch research into self-regulated learning in technology enhanced learning environments?

These research questions were answered by collecting a number of 20 representative articles from international and national scientific journals in which empirical studies were reported into self-regulated learning in technology enhanced learning environments. We did not include theoretical contributions or review studies. Only original empirical research was included in the sample. We took into account that three major research institutes in the Netherlands are active in the area: (1) the Department of Instructional Technology of the University of Twente (Ton de Jong, Jules Pieters, Tjeerd Plomp, Ard Lazonder, Pascal Wilhelm); (2) the Educational Technology Expertise Centre of the Open University of the Netherlands (Jeroen van Merrienboer, Paul Kirschner, Tamara van Gog, Frans Prins), and (3) the Department of Educational Sciences of Utrecht University (Gellof Kanselaar, Jerry Andriessen, Gijsbert Erkens, Paul Kirschner, Frans Prins). We wanted these three research group to be included in our sample. Therefore, we actively sought for publications from these groups and added them to our sample. We used the four factors influencing the process of self regulated learning in technology enhanced learning environments as a framework to describe and interpret the findings reported in the sample.

METHOD

Sample

In order to compose a representative sample of recent Dutch research papers on self regulated learning in technology enhanced learning environments, we chose six journals to extract the papers from:

– Instructional Science (impact factor 2010: 0.92)
– Learning and Instruction (impact factor 2010: 1.44)
– Journal of Computer Assisted Learning (impact factor 2010: 1.01)
– Computers and Education (impact factor 2010: 2.19)
– Interactive Learning Environments (impact factor 2010: 0.94)
– Computers in Human Behavior (impact factor 2010: 1.77)
– Pedagogische Studiën (Pedagogical Sciences, Dutch journal)
– Tijdschrift voor Hoger Onderwijs (Journal of Higher Education, Dutch journal)

These journals were chosen because of their relevance (Journal of Computer Assisted Learning, Interactive Learning Environments, and Computers in Human Behavior), impact factor (Instructional Science, Learning and Instruction, Computers and Education) or local significance (Pedagogische Studiën, Tijdschrift voor Hoger Onderwijs). Our aim was to find 20 to 30 papers which reported empirical research, and shed light on the topic of this review, self regulated learning in technology enhanced learning environments. We were also careful to include some contributions from each of the three major research institutes on the use of computers in education in the Netherlands: (1) the Department of Instructional Technology of the University of Twente; (2) the Educational Technology Expertise Centre of the Open University of the Netherlands, and (3) the Department of Educational Sciences of Utrecht University. Eventually, 26 papers were selected. Table 1 provides a list of the papers.

Table 1. Overview of the sample

#	Reference	Factor
1	Veenman, M.V.J., Wilhelm, P., & Beishuizen, J.J. (2004). The relation between intellectual and metacognitive skills from a development perspective. *Learning and Instruction, 14*, 89-109.	The Learner: Development of Self-regulative Skills
2	Lazonder, A.W. (2000). Exploring novice users' training needs in searching information on the WWW. *Journal of Computer Assisted Learning, 16*, 326-335.	The Learner: Level of Expertise
3	Rienties, B., Tempelaar, D., Van den Bossche, P., Gijselaers, W., & Segers, M. (2009). The role of academic motivation in computers-supported collaborative learning. *Computers in Human Behavior, 25,* 1195-1206.	The Learner: Level of Intrinsic and Extrinsic Motivation
4	Martens, R.L., Gulikers, J. & Bastiaens, T. (2004). The impact of intrinsic motivation on e-learning in authentic computer tasks.	The Learner: Level of

#	Reference	Factor
	Journal of Computer Assisted Learning, 20, 368–376.	Intrinsic Motivation
5	Prins, F.J., Veenman, M.V.J., & Elshout, J.J. (2006). The impact of intellectual ability and metacognition on learning: New support for the threshold of problematicity theory. *Learning and Instruction, 16*, 374-387.	The Learner: Self-regulative Skills versus Intellectual Ability
6	Fisser, P., & De Boer, W. (1999). A decision support tool for web-supported course design. *Journal of Computer Assisted Learning 15*, 255-256.	The Teacher: Authoring Tools
7	Smeets, E., (2005). Does ICT contribute to powerful learning environments in primary education? *Computers & Education, 44*, 343-355.	The Teacher: Attitudes and Skills
8	De Jong, T., & Van der Hulst, A. (2002). The effects of graphical overviews on knowledge acquisition in hypertext. *Journal of Computer Assisted Learning, 18*, 219-231.	The Learning Environment: Learning Tools
9	Swaak, J., De Jong, T., Van Joolingen, W. (2004). The effects of discovery learning and expository instruction on the acquisition of definitional and intuitive knowledge. *Journal of Computer Assisted Learning, 20*, 225–234.	The Learning Environment: Learning Tools versus Assignments
10	Karassavvidis, I., Pieters, J.M., & Plomp, T. (2003). Exploring the mechanisms through which computers contribute to learning. *Journal of Computer Assisted Learning, 19*, 115-128.	The Learning Environment: Effect of Computer Support
11	Kester, L., & Kirschner, P.A. (2009). Effects of fading support on hypertext navigation and performance in student-centered e-learning environments. *Interactive Learning Environments, 17,* 2, 165-179.	The Learning Environment: Fading Support
12	Van Gog, T., Paas, F., & Van Merrienboer, J., (2004). Process-oriented worked examples: improving transfer performance through enhanced understanding. *Instructional Science, 32*, 83-98.	The Learning Environment: Learning Materials
13	Van Drie, J., Van Boxtel, C., Jaspers, J., & Kanselaar, G. (2005). Effects of representational guidance on domain specific reasoning in CSCL. *Computers in Human Behavior, 21,* 575-602.	The Learning Environment: Learning Tools
14	Veermans, K., De Jong, T., & Van Joolingen, W.R. (2000). Promoting self-directed learning in simulation-based discovery learning environments through intelligent support. *Interactive Learning Environments, 8*, 3, 229-255.	The Learning Environment: Learning Tools
15	De Vries, B., Van der Meij, H., & Lazonder, A.W. (2008). Supporting reflective web searching in elementary schools. *Computers in Human Behavior, 24,* 649-665.	The Learning Environment: Learning Tools

#	Reference	Factor
16	Akkerman, A., Admiraal, W., & Huizenga, J. (2009). Storification in history education: A mobile game in and about medieval Amsterdam. *Computers and Education, 52,* 449-459	The Learning Environment: Learning Tools
17	Manlove, S., Lazonder, A.W., & De Jong, T. (2009). Trends and issues of regulative support use during inquiry learning: Patterns from three studies. *Computers in Human Behavior, 25,* 795-803.	The Learning Environment: Regulation Tools
18	Martens, R., Bastiaens, Th., & Gulikers, J. (2002). Leren met computergebaseerde authentieke taken: motivatie, gedrag en resultaten van studenten [Learning with computer based authentic tasks: Motivation, behaviour and learning outcomes of students]. *Pedagogische Studiën, 79*, 469-482.	The Learning Environment: Students' Appreciation of Authenticity
19	Van der Meij, H. (2000). The role and design of screen images in software documentation. *Journal of Computer Assisted Learning, 16*, 294-306.	The Learning Environment: Learning Materials
20	De Jong, T., Van Joolingen, W.R., Swaak, J., Veermans, K., Limbach, R., King, S., & Gureghian, D. (1998). Self-directed learning in simulation-based discovery environments. *Journal of Computer Assisted Learning, 14*, 235-246.	The Teacher: Authoring Tools The Learning Environment: Learning Tools
21	De Laat, M., Lally, V., Lipponen. L., & Simons, R.-J. (2007). Online teaching in networked learning communities: A multi-method approach to studying the role of the teacher. *Instructional Science, 35*, 257-286.	The Teacher: Role in the Community of Learners
22	Saab, N., Van Joolingen, W.R., & Van Hout-Wolters, B.H.A.M. (2006). Supporting communication in a collaborative discovery learning environment: the effect of instruction. *Instructional Science, 35*, 73-98.	The Community of Learners: Learning Materials
23	Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007). Visualization of participation: does it contribute to successful computer-supported collaborative learning? *Computers & Education, 49*, 1037-1065.	The Community of Learners: Learning Tools
24	Kirschner, P.A., Beers, P.J., Boshuizen, H.P.A., & Gijselaers, W.H. (2008). Coercing shared knowledge in collaborative learning environments. *Computers in Human Behavior, 24, 403-420.*	The Community of Learners: Learning Tools
25	Van Eijl, P., Pilot, A., De Voogd, P., & Thoolen (2002). Samenwerkend leren of individueel leren met ICT [Collaborative or individual learning with ICT]? *Pedagogische Studiën, 79*, 482-494.	The Community of Learners: Students'

#	Reference	Factor
		Preferences
26	De Laat, M. & Lally, V. (2004). It's not so easy: researching the complexity of emergent participant roles and awareness in asynchronous networked learning discussions. *Journal of Computer Assisted Learning, 20*, 165-171.	The Community of Learners: Analysis Tools

RESULTS

The Learner

Various learner characteristics have been related to learning processes and outcomes in technology enhanced learning environments. In the sample of 26 studies we found five relevant studies: Lazonder (2000) on the influence of level of expertise, Martens, Gulikers, and Bastiaens (2004) on the influence of intrinsic motivation, Prins, Veenman, and Elshout (2006), Veenman, Wilhelm, and Beishuizen (2004) on the relationship between self-regulation skills and intellectual ability, and Rienties, Tempelaar, Van den Bossche, Gijselaers, and Segers (2009) on the relationship between academic motivation and contribution to discourse in a problem based learning group.

Lazonder (2000) compared the search behavior of 7 novice and 7 expert users of the World Wide Web. Fourteen fourth graders had to locate particular sites and specific information on those sites. Differences between both groups did show up during the phase of locating sites, not during the phase of locating information on sites. Lazonder (2000) concluded that novice users could be supported by training them to improve their monitoring skills, evaluating the quality of the information on sites, and by supporting them to use advanced search tools, like Boolean operators.

Martens, Gulikers, and Bastiaens (2004) compared the behavior of 33 higher education students with high and low levels of intrinsic motivation in a game-like realistic simulation. Unexpectedly, high intrinsic motivation students did not show greater effort or persistence than low intrinsic motivation students. Rather, high intrinsic motivation students displayed more variation in exploratory behavior. For instance, they more often consulted senior advisers (in the simulation environment) or traced information in the archive or the mailbox. This more diversified exploration behavior did not pay off in increased level of knowledge on a posttest. Both high and low intrinsic motivation students performed equally well on the knowledge test.

The extent to which self-regulation skills and/or intellectual ability determine the learning process and outcomes of novice and advanced learners who explore a computer simulated inductive-learning environment was studied by Prins, Veenman, & Elshout (2006). First year psychology students with low or advanced levels of domain related knowledge explored an optics lab and, following a series of three assignments, tried to find out underlying rules. The authors concluded that when learners operate at the boundary of knowledge, metacognitive skillfulness is more essential for learning than intellectual ability.

By presenting inductive learning tasks in a computer supported simulation environment to fourth-, sixth-, and eighth-graders and to university students, Veenman, Wilhelm, & Beishuizen (2004) showed that metacognitive skills are domain-independent characteristics which develop partly independent of intelligence. According to the authors, training of metacognitive skills across domains may be successful, as long as the same approach is chosen across disciplines.

The position and behavior of students in a problem based learned group may be determined by the academic motivation of individual students. Rienties, Tempelaar, Van den Bossche, Gijselaers, and Segers (2009) studied six groups of students entering university education. The students met in a summer school and practiced the problem based learning method in their domain of international business administration. In groups of 11 to 17 participants, they solved six problems. After analyzing the content the students produced, the social networks in which they operated and the academic motivation of the students the authors concluded that highly intrinsically motivated students provided central and prominent contributions to the academic discourse. Extrinsically motivated students, however, contributed on average and were positioned in various places throughout their social network. The authors do not interpret their findings in terms of causes and effects. One can imagine that extrinsically motivated students feel less secure than intrinsically motivated students and, consequently, hesitate to post contributions to the discussion forum.

The studies reported all showed that student characteristics are an important source of differences in learning processes and learning outcomes in technology enhanced learning environments. Novices differ from experts, children differ from adults, and high intrinsically motivated students differ from low intrinsically motivated students or from extrinsically motivated students. Students with extrinsic academic motivation may have to cope with problems how to survive in the group, whereas students with intrinsic academic motivation may act in a more content oriented way. Therefore, students with extrinsic academic motivation may be less secure and less flexible in choosing their strategy than students with high academic motivation. The better equipped the student is, the more he or she can choose between strategies, particularly when the constraints are tight. This calls for fostering diversity in cognitive strategies, whenever instruction can be invoked to promote students' ability to cope with complex learning environments.

The Teacher

Dutch research into the role of the teacher in technology enhanced learning environments relates to the various roles of novice and experienced teachers (De Laat, Lally, Lipponen, & Simons, 2007) , the relevant expertise of Dutch teachers (Smeets, 2005) and the development of authoring tools for teachers (De Jong et al., 1998; Fisser & De Boer, 1999).

De Laat, Lally, Lipponen, and Simons (2007) studied the behavior of an experienced and a novice teacher in a networked learning community with mid-career professionals working on their Masters in Education. The students participated in five on-line workshops during a period of two years aimed at establishing a research learning community. The teachers tried to coach and support the groups, carefully seeking a balance between too much control and too much freedom. The experienced teacher allowed the group to gradually create a mode of collaboration which was in tune with the group's character. The teacher made use of advance organizers to create a zone of proximal development for the group. This teacher was successful in providing appropriate scaffolding and fading tuned to the development of the group. The novice teacher was insecure about her role and did not consider herself able to cope with the complex technology enhanced learning environment. She did not anticipate the specific needs of the learning group. The project showed that the role of the teacher in establishing a virtual learning community is very important and demanding, requiring specific teaching and pedagogic skills.

Smeets (2005) asked more than 300 upper primary school teachers about their pedagogical views in relation to the use of ICT in education. Although more than 70% of the teachers regularly or often paid special attention to information handling skills, discussed recent events during the lessons, or referred to the application of acquired knowledge and skills outside the school, and 93% of the teachers reported that they did apply ICT in their classrooms, the use was in general restricted to skill-based applications, which matched traditional views on teaching and learning. In this way, existing pedagogical practices were confirmed, not changed. Smeets (2005) advocated fostering the awareness and skills of teachers with respect of the use of ICT to enhance learning environments.

De Jong et al. (1998) developed an authoring tool for designing and creating simulation-based learning environments, SimQuest. Finding a proper balance between guiding students in the process of discovery learning and providing them with enough tools to regulate their own learning process was an important aim of the design. Teachers can prepare various types of assignments to guide the students. Students are asked to explore or investigate a simulation, to formulate rules or predict phenomena, or to optimize a certain process. The actual characteristics of the learning environment are determined by a set of rules, based on students' behavior and their preferences. One of the problems the authors have experienced during the process of implementing SimQuest is students' general tendency to follow the assignments without developing an independent and self-regulated way of discovery learning. Because feedback is connected to assignments students need complete assignments in order to receive feedback on their work. Since then, the authors have been developing feedback procedures which can be used to coach students during free exploration of the environment.

Fisser and De Boer (1999) developed a decision support tool for university teachers to re-design courses and curricula on the basis of the seven principles of good education, as proposed by Chickering and Gamsom (1987). Good education encourages contacts between students and faculty, develops reciprocity and co-operation among students, uses active learning techniques, gives prompt feedback, emphasizes time on task, and communicates high expectations and diverse talents and ways of learning. Fisser and De Boer's (1999) decision support tool comprises three major decisions about the feedback the teacher provides to the student: (1) is the feedback structured or open? (2) Is the focus of the feedback the process or product of learning? (3) What is the extent of the feedback (short, long)? Teachers are able to use the instrument on-line and can compare their choices with those of other teachers.

Both De Laat, Lally, Lipponen, and Simons (2007) and De Jong et al. (1998) emphasized the importance for teachers to find a proper balance between guidance and support. The fact that De Jong et al. (1998) found that students tend to rely on assignments makes the task of finding the balance even more crucial. Too much guidance makes students dependend, too much freedom prevents the students from making progress. This balance problem is not new, but the introduction of technology in the learning environment makes the dilemma more articulate (see also Karassavvidis, Pieters, & Plomp, 2003). The balance problem pertains to both the level of cognitive operations and self-regulative control. Both De Jong et al., (1998) and Fisser and De Boer (1999) offered guidelines for teachers to structure the technology enhanced learning environment in accordance with their teaching strategy. Smeets' (2005) rather alarming findings that there exists a large gap between Dutch primary school teachers' views on learning and their ability to give concrete form to these views in computer supported learning environments underlines the need to both train teachers and provide them with on-line authoring tools to establish an efficient and effective technology enhanced learning environment.

The Learning Environment

Although the learning environment as a domain of study encompasses a rather wide scope of potentially interesting research questions, two issues stand out in our sample of Dutch studies into fostering self-regulated learning in technology enhanced learning environments. The first issue is complexity. Martens, Bastiaens, and Gulikers (2002) questioned the need for authenticity in technology enhanced learning environments. Karassavvidis, Pieters, and Plomp (2003) compared a traditional environment with a technology enhanced learning environment. Van der Meij (2000) studied the effects of various arrangements of text and images in a computer supported learning environment. De Vries, Van der Meij, & Lazonder (2007) provided a portal as a restricted set of websites to help children to localize information. De Jong and Van der Hulst (2002) manipulated the representation of the content of a hypertext in order to reduce complexity. Van Drie, Van Boxtel, Jaspers, and Kanselaar (2005) provided various tools to represent historical arguments. Task complexity caused a high cognitive load. Manlove, Lazonder, & De Jong (2009) observed that lack of domain knowledge prevented high school students to benefit from regulative support in a simulation-based learning environment. Akkerman, Admiraal and Huizenga (2009) used computers and cell phones to enable secondary school students to play an authentic history game in the historical center of Amsterdam. The complex real life environment of downtown

Amsterdam both enhanced the narrative force of the game and increased the cognitive load of the game. Van Gog, Paas, and Van Merrienboer (2004) argued that the transfer value of worked examples could be enhanced by adding explanations.

The second issue is interactivity, the extent to which the technology enhanced learning environment can be adapted to students' learning processes. Swaak, De Jong, and Van Joolingen (2004) compared the effects of providing assignments versus providing learning tools. Veermans, De Jong, and Van Joolingen (2000) designed computer generated feedback procedures to support discovery learning in a technology enhanced learning environment. Kester and Kirschner (2009) studied the effects of fading conceptual and strategic support to studying a hypertext document in a distance learning course.

Martens, Bastiaens, and Gulikers (2002) studied competency based computer supported learning environments (CCLEs). The authors varied the degree of authenticity of the learning environments. Psychology students had to discover why in a transport company so many bus drivers often fall ill. Three versions of the environment were compared: an authentic version with full learner control, a text-only version, and an authentic version with restricted learner control. Students' reports were evaluated. They also completed a knowledge test and a questionnaire about the experienced authenticity and clarity of the learning environment. The text-only version turned out to produce the best learning outcomes. Moreover, students did not perceive the authentic learning environments as more authentic or more motivating than the text-only version. The authors concluded that high expectations of the authentic learning environments were not corroborated by the learning outcomes. However, the authors did not advocate a restoration of traditional principles of instruction. Rather, they suggested to further explore the nature of student motivation in learning environments.

In perhaps one of the most explicit studies into self-regulated learning in technology enhanced learning environments of this review, Manlove, Lazonder and De Jong (2009) devised a so-called Process Coordinator (PC+) to provide regulative support to upper secondary students inquiring a fluid dynamics problem in a simulation environment called Co-Lab. PC+ provided a goal tree or a representation of goals in an inquiry cycle. This feature was heavily and successfully used by the students. Monitoring tools like a note pad, question prompts, timed cues and hints did not improve students' inquiry behavior. A lab report template clearly helped students to report and evaluate the outcomes of their inquiry. The authors emphasized the influence of domain related knowledge and experience on the efficacy of the regulative tools in PC+. Students were reported to have ample experience with lab experiments which made the goal tree instrument for planning useful. However, due to lack of knowledge about fluid dynamics they could not take advantage of the monitoring tool which was embedded in the problem space. In line with Moreno and Mayer (1999) the authors suggested to pretrain student on subject matter knowledge and skills before admitting them to complex simulation based learning environment.

Studying the effects of authenticity on the motivation of secondary school students was one of the aims of the FM1550 Project, in which students explored the medieval center of Amsterdam and enacted various historical events. Field teams were guided by colleagues in the headquarters of the game. Akkerman, Admiraal and Huizenga (2009) collected data about the extent to which authentic context contributed to the acquisition of history knowledge and understanding and to the motivation of the students. The authors observed that the field teams were less able to grasp the story line and, consequently, focused on the practical issues related to locating assignment spots in the city, communicating through cell phones and recording video sequences. Students working the headquarters of the game were better able to create a narrative organization of all game elements representing the historical context of medieval Amsterdam.

A fine-grained analysis of teaching and learning protocols in a computer supported and a paper and pencil learning environment was conducted by Karassavvidis, Pieters, and Plomp (2003). Participants were two groups of 10 15 years-old secondary school students. They learned to solve correlational problems in the domain of geography, either with paper and pencil or by using a spreadsheet program. All lessons were videotaped, transcribed and analyzed. The most important finding was that both the teacher and the students set more explicit goals in the computer supported environment than in the paper and pencil environment. The authors attributed this difference to the increased opportunities for making task relevant decisions which a computer supported environment offers.

Van der Meij (2000) carefully compared three design formats for software documentation. The manuals differed on the use of full screen versus partial screen images, and on the layout of the text: a two-column layout, in which instructions were located either in the left column and images in the right column, or a layout with images in the left column and instructions in the right column. Participants were 48 inexperienced adult users. Participants read the manual, carried out the assignments, and were tested afterwards. The use of full screen images (instead of partial screen images) which were located in the right column of the page (instead of in the left column) produced shortest training times and best retention outcomes. The author interpreted the results in terms of cognitive load theory (Sweller, 1994; Van Merrienboer, Kirschner, & Kester, 2003).

De Vries, Van der Meij, & Lazonder (2007) developed a portal with a small set of websites to help children aged ten to twelve to find answers to particular questions as part of a writing assignment. In order to be an effective tool, the arrangement and presentation of the links was crucial. A simple listing of sites in two categories did not suffice. A hierarchical presentation together with short descriptions of the information in a particular website did help the children to localize information which contained an answer to their question.

The often documented "lost in hyperspace" phenomenon was tackled by De Jong and Van der Hulst (2002). They created a "visual" layout of a hypertext on fuel supply systems, in which the basic structure of the domain was presented in such a way that learners were "unobtrusively encouraged" to follow a predesigned path through the text. Left-to-right ordering of nodes indicated either a temporal or a causal relationship between the nodes. Vertical ordering indicated specification relationships, in which lower nodes specified upper nodes. This layout was compared with two random arrangements of nodes. In the hints condition highlighting was used to indicate a proper reading path through the text. In the control condition, no help was offered at all, student simply received the random layout of the nodes in the text. Assignments were completed by 46 first year undergraduate psychology students. After having been trained students worked in the experimental hypertext environment and received three posttests: a propositional test which assessed the relations between the concepts, a definitional test which tapped knowledge of the individual nodes, and a configural test which measured the extent to which students had grasped the structure of the text. The data showed that students in the enriched conditions used the information provided and followed the paths which were suggested by the layout of the overview. There were no differences in exploration routes between students in both enriched conditions, but only in the visual condition did students produce a significantly better representation of the structure of the text and better knowledge of the propositional relations between the nodes than students in the control condition. As expected, there were no differences in knowledge of the individual nodes between the three conditions. De Jong and Van der Hulst (2002) concluded that presenting an overview of a hypertext which displays the relationships between nodes adds important informant to the content of the text, from which readers take advantage.

Van Drie, Van Boxtel, Jaspers, and Kanselaar (2005) compared three representational formats in a CSCL environment, in which 65 pairs of secondary school students had to complete a historical writing assignment. The participants had to collect information from textbooks, photos, views of historians, tables, and interviews and had to prepare a 1000 words essay on the issue whether the changes in the behavior of Dutch youth in the nineteen sixties were revolutionary or not. The pairs worked in separate rooms and had to communicate through the CSCL environment. Three tools were compared: an argumentative diagram, in which students could place and arrange arguments to be included in the essay, a simple linear list of arguments to be used in the essay, or a matrix in which arguments can ordered on various characteristics like the source from which the argument was taken or the domain (e.g., sports, economy, culture) to which the argument belonged. Chat interactions were analyzed, as well as the quality of the constructed representations, the final essay, and the outcomes on an individually taken knowledge test. The various tools facilitated various reasoning structures. Using the matrix produced more interactions about historical changes, whereas the diagram focused students more on the balance of arguments. However, these differences did not result in different essay or leaning outcomes. Students in the matrix condition and students in the control condition (no tools available) spend more interactions on discussing the approach to be taken to carry out the task. The authors attributed this lack of effect on the outcome variables to the cognitive load which the task imposed on the students.

In the domain of cognitive load theory (Sweller, 1994) the worked example effect has often been reported: novice student learn more from studying worked examples than from solving problems, because of the heavy cognitive load of solving these problems. Van Gog, Paas, and Van Merrienboer (2004) argued that worked examples might function better when they are accompanied by an explanation which clarifies why and how the steps to solve the problem were taken.

The question whether inquiry learning in a simulation learning environment leads to quantitatively and qualitative better learning outcomes than expository instruction in a hypertext environment was studied by Swaak, De Jong and Van Joolingen (2004). They tested the performance on various posttests by 112 16-17 years old secondary school participants preparing for university education. Participants were randomly assigned to either a simulation environment or a hypertext environment. Both environments contained a considerable number of assignments. The hypertext environment led to better learning outcomes than the simulation environment in terms of knowledge of definitions and relations between concepts. It turned out that participants in both conditions closely followed the assignments without using the facilities for self-regulated learning. The authors concluded that simulation based learning environments should only be developed and implemented when they provide clear advantages to the students, when the domains are really complex, and when students receive considerable amount of freedom to explore and self-regulate their learning process.

Veermans, De Jong, and Van Joolingen (2000) compared two methods of providing computer-generated feedback in a simulation-based discovery environment. The first method was based on the current hypothesis of the learner and the current experiment in which the hypothesis was put to the test. According to the second method, students received predefined feedback on the basis of the student's hypothesis, without taking the student's experiment into account. Secondary school students, 15 to 16 years of age, experimented in a simulation environment on collisions. Students' experimenting behavior was recorded, as well as their performance on various knowledge tests. Both groups performed equally on the posttest. However, participants who received feedback according to the first method developed a more inquiry-based learning strategy than students who received predefined feedback. The authors conclude that relating hypotheses to experiments is a powerful form of feedback which fosters the development of inquiry skills, rather than encouraging students to complete given assignments.

In a distance course on instructional design Kester and Kirschner (2009) presented a hypertext document to 41 adult students, together with conceptual support in the form of concept map, and strategic support with the help of a flow chart displaying the main steps to be taken and heuristic advice on each of the steps. In the fading condition, the concept map was tuned to the particular problem students had to solve, whereas the heuristic advice was gradually removed from the strategic flow chart. Students benefited from fading, navigation accuracy increased under fading conditions. However, task performance did not improve. The authors contended that students did not invest enough time and effort to complete the assignment.

Dutch research into complexity in technology enhanced learning environments showed that complexity as such does not exist. Rather, complexity is related to the student’s level of expertise or available self-regulation and/or cognitive strategies. As Martens, Bastiaens, and Gulikers (2002) and Akkerman, Admiraal, and Huizenga (2009) showed, authenticity is not always functional. Again, the level of expertise of the student determines the educational value of authenticity. Novice learners should be supported by worked examples, as Van Gog, Paas, and Van Merrienboer (2004) underlined. In general, complexity should be tuned to the level of expertise of the learner. Studies into the characteristics of interactivity in simulation based learning environments showed that feedback should be based upon both the student's hypotheses and his or her experiments (Veermans, De Jong, & Van Joolingen, 2000). A similar conclusion was drawn by Kester and Kirschner (2009): conceptual and strategic support during a hypertext studying task should be faded along with increasing experience with the task.

The Community of Learners

We have collected five studies under the heading of community of learners, because in these studies the relationships between students in a technology enhanced learning environment played an important role. To a certain extent, the factors highlighted above, the learner, the teacher, and the learning environment, all return in research into the community of learners. Apart from De Laat and Lally (2004), who developed an analysis tool for studying group dynamic processes, all studies reported technological enhancements of a learning environment to foster the work of a community of learners. Van Eijl, Pilot, De Voogd, and Thoolen (2002) paid attention to the learner's preferences, Janssen, Erkens, Kanselaar, and Jaspers (2007) studied a particular learning tool in an environment for collaborative learning, and Saab, Van Joolingen, Van Hout-Wolters (2007) focused on the effect of providing guidelines to foster collaboration, and Kirschner, Beers, Boshuizen, and Gijselaers (2008) instructed teams of three students to elaborate on individual contributions to the solution of a common problem.

De Laat and Lally (2004) asked mid-career professionals, working on their masters in education, to join asynchronous Networked Learning discussions, and applied content analysis to the recorded interactions to explore emergent role development and group awareness processes. Three individual student participants were interviewed to analyze critical events, a "task-focused completer/finisher", a "group-focused facilitator", and a "task-focused ideas contributor". The authors concluded that their methods of observing and analyzing role development and group awareness processes has helped them to understand the processes of teaching and learning of professionals in a community.

Van Eijl, Pilot, De Voogd, and Thoolen (2002) asked university students, enrolled in a course on 19th century English literature how they preferred to work in the course's electronic learning environment: alone or in groups of two to four students. High achieving students preferred to work in groups. Collaborating students benefited from group work.

Janssen, Erkens, Kanselaar, and Jaspers (2007) developed a software tool to visualize participation in a computer supported collaborative learning environment. Each participant was represented by a sphere, connected to a central circle, the size of which reflected the length of the messages sent by the group. The distance between a sphere and the central circle was an indicator of the number of messages sent by the participant. The tool was actively used by small groups (3 or 4 students) of 16 years old secondary school students in a collaborative learning task. Groups in which the tool was available more actively engaged in collaborative work and issued many planning messages through which the social activities of the group were coordinated and regulated. Although the group awareness and the quality of the group product were not higher in the experimental group as compared with the control group, the authors concluded that visualization of participation can contribute to successful CSCL.

Saab, Van Joolingen, and Van Hout-Wolters (2007) developed an instruction for students working in a technology enhanced collaborative learning environment. Four rules were included in the instruction: respect ("everyone will have a chance to talk", "everyone's ideas will be thoroughly considered"), intelligent collaboration ("sharing all relevant information and suggestions", "clarify the information given", "explain the answers given", "give criticisms"), deciding together ("explicit and joint agreement will precede decisions and actions", "accepting that the group, rather than the individual, is responsible for decisions and actions"), and encouraging ("ask for explanations", ask until you understand", "give positive feedback"). Pairs of 76 tenth grade secondary school students (age 15 - 17) were randomly assigned to either an instruction or a control condition. The students had to discover the rules behind a simulation about collisions, implemented in SimQuest (De Jong et al., 1998). The instruction improved the quality of communication (describing and recognizing relations), discovery activities (drawing conclusions) and regulative interaction between the pairs, but the learning outcomes of instruction group and control group did not differ.

In a series of four experiments, Kirschner, Beers, Boshuizen and Gijselaers (2008) tested a script which forced three participants in a group problem solving assignment to contribute to the common discussion platform and to discuss all contributions before deciding on the acceptance of the contribution as a step in the process of solving the problem. Not surprisingly, the stricter the protocol, the more contributions each participant posted to the discussion platform. This more intense collaboration improved the common ground at which the problem solving group arrived. The authors concluded that coercion helps a community of learners to increase goal-directed interactions.

The studies on collaboration in a technology enhanced learning environment showed that not all students equally prefer to work in a collaborative learning environment (De Laat & Lally, 2004). Therefore, freedom of choice is appreciated by students and may in fact add to the beneficial effect of computer supported collaborative learning environments. Collaboration can be actively fostered by providing tools and or guidelines. The good news is that the quality of the collaborative processes increases. The disappointing news is that these process-oriented measures do not always enhance learning outcomes.

DISCUSSION

Recent Dutch research into self-regulated learning in technology enhanced learning environments has disclosed important relationships between the arrangement of the learning environment, the learning process and the learning outcomes. The conclusions can be arranged under four key characteristics of technology enhanced learning environments: complexity, interactivity, articulation, and balance. Although self-regulated learning is in many studies not explicitly mentioned, the issue is often inexplicitly addressed or implied.

Complexity

The complexity of technology enhanced learning environments is both an advantage and a potential threat to successful learning. The advantage has to do with the possibility to create authentic contexts which resemble the real life situations for which we educate our students. Authentic conditions may foster students' intrinsic motivation to learn. Various studies explored authentic and complex technology enhanced learning environments, not only simulation based learning environments (Swaak, De Jong, & Van Joolingen, 2004; Manlove, Lazonder, & De Jong, 2009; Saab, Van Joolingen, & Simons, 2007) but also authentic learning tasks (Martens, Bastiaens, & Gulikers, 2002; Akkerman, Admiraal, & Huizenga, 2009). These studies highlighted the threats of complex environments. They may create a cognitive overload preventing the student from using the tools provided or from any learning whatsoever.

As explained above, complexity as such does not exist. The concept of cognitive load relates the objective complexity of the learning environment to the learner's perceived complexity. Reducing the cognitive load of the learning environment enables the student to focus on the learning process by deploying and further developing self-regulation skills (Martens, Bastiaens, & Gulikers, 2002; Van der Meij, 2000; Van Gog, Paas, & Van Merrienboer, 2004).

Interactivity

Increasing the interactivity of the learning environment by means of technological support is a successful way to foster learning processes (Karassavvidis, Pieters, & Plomp, 2003; Swaak, De Jong & Van Joolingen, 2004). However, time and again it has been shown that fostering learning processes does not necessarily lead to improved learning outcomes (Martens, Gulikers, & Bastiaens, 2004; De Jong et al., 1998; Van Drie, Van Boxtel, Jaspers, & Kanselaar, 2005; Swaak, De Jong, & Van Joolingen, 2004; Veermans, De Jong, & Van Joolingen, 2006).

Articulation

An important beneficial effect of technology enhanced learning environment is that often the structure of the learning task and the learning process is made transparent by visual tools. This was illustrated in two recent studies on collaboration between students in a Community of Learners (Janssen, Erkens, Kanselaar, and Jaspers, 2007; Saab, Van Joolingen, & Van Hout-Wolters, 2007). As Van Drie, Van Boxtel, Jaspers, and Kanselaar (2005) and De Jong and Van der Hulst (2002) made clear, various visual tools have various effects on the learning process, but the articulation characteristic is itself an important asset of technology enhanced learning environments, fostering both learning processes and regulative behavior.

Balance

Too much structure in the technology enhanced learning environment creates dependent learning behavior (De Laat, Lally, Lipponen, & Simons, 2007; De Jong, et al., 1998; Fisser & De Boer, 1999; Swaak, De Jong, & Van Joolingen, 2004; Kirschner, Beers, Boshuizen, & Gijselaers, 2008). Therefore, teachers play an indispensable role in technology enhanced learning environment. They should develop and apply a powerful repertoire of design and support strategies to enrich the learning environment with both technological tools and personal support and feedback (De Laat, Lally, Lipponen, Simons, 2007; Smeets, 2005; De Jong, et al., 1998; Fisser & De Boer, 1999). The principal role of teachers in a technology enriched learning environment is establishing a balance between structure and freedom to learn in self-regulated way.

In many ways students display different learner characteristics. In the studies reported here, we have encountered differences in search skills (Lazonder, 2000), in domain-specific knowledge (Prins, Veenman, & Elshout, 2006), in motivation (Martens, Gulikers, & Bastiaens, 2004; Rienties, Tempelaar, Van den Bossche, Gijselaers, & Segers, 2009), in metacognitive skillfulness and in intelligence (Veenman, Wilhelm, & Beishuizen, 2004). The existence of technological support creates opportunities for adapting the learning environment to learner differences, both in complexity (De Vries, Van der Meij, & Lazonder, 2007) and in interactivity. Moreover, by adapting instruction in a technology enhanced learning environment to varying learner characteristics, a proper balance may be found between structure and freedom to learn in a self-regulated way (Martens, Gulikers, & Bastiaens, 2004; Van Eijl, Pilot, De Voogd, & Thoolen, 2002; Veermans, De Jong, & Van Joolingen, 2006; Kester & Kirschner, 2009).

The study by Manlove, Lazonder, and De Jong (2009) may serve as a basis for a general conclusion regarding the gearing of regulative support to students' expertise and experience in a technology enhanced learning environment. First, regulation tools are used to the extent that students recognize the value of the tool. Recognition is based on a match the strategic basis of the tool and the strategic approach of the student. Secondly, because cognitive load is a serious problem in many technology enhanced learning environments, students should be pretrained and prepared as much as possible in order to enable them to take full advantage of the enhanced learning environment.

Together, the studies reported in this paper provide a realistic evidence based account of the effects of technology enhanced learning environments. Teachers, learning tools and appropriate assignments all help to improve the quality of learning and self-regulation. Further research is necessary to explore the relationship between quality of learning and self-regulation on the one hand and learning outcomes on the other.

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AFFILIATIONS

Jos Beishuizen
Centre for Educational Training, Assessment and Research
Vrije Universiteit Amsterdam, The Netherlands