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Exploring the potential impact of reciprocal peer tutoring on higher education students' metacognitive knowledge and regulation

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Abstract It is widely recognized that metacognition is an important mediator for successful and high-level learning, especially in higher education. Nevertheless, a majority of higher education students possess insufficient metacognitive knowledge and regulation skills to self-regulate their learning adequately. This study explores the potential of reciprocal peer tutoring to promote both university students' metacognitive knowledge and their metacognitive regulation skills. The study was conducted in a naturalistic higher education setting, involving 67 students tutoring each other during a complete semester. A multi-method pretest–posttest design was used combining a self-report questionnaire, assessing students' metacognitive knowledge and their perceived metacognitive skilfulness, with the analysis of think-aloud protocols, revealing students' actual use of metacognitive strategies. Results indicate no significant pretest to posttest differences in students' metacognitive knowledge, nor in their perception of metacognitive skill use. In contrast, significant changes are observed in students' actual metacognitive regulation. At posttest, students demonstrate significantly more frequent and more varied use of metacognitive regulation, especially during the orientation, monitoring, and evaluation phases. Furthermore, our findings point to an increase in more profound and higher-quality strategy use at posttest.

Keywords Peer tutoring · Collaborative learning · Metacognitive knowledge · Metacognitive regulation · Higher education

Introduction

Contemporary education has shifted from a focus on knowledge transmission to knowledge construction, aiming at self-regulated and lifelong learning (Cornford 2002). Central to self-regulated learning is the concept of metacognition (Efklides 2008). Empirical evidence shows that metacognitive skillfulness corresponds with meaningful, deep-level learning

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and often results in higher achievement (e.g. Prins et al. 2006; Van der Stel and Veenman 2010). Especially in higher education contexts, learners' metacognitive awareness and ability to regulate (meta)cognitive strategies are crucial to be successful (Cornford 2002). However, only a few higher education programmes succeed in effectively preparing students for metacognitive self-regulation (Maclellan and Soden 2006).

Recently, metacognition has been considered from the theoretical perspective of socially shared cognition, in which metacognition is conceptualised as a social activity that can be developed through interaction with teachers and/or other students (Hurme et al. 2006). The potential of collaborative learning to foster students' metacognitive development is currently highlighted (Iiskala et al. 2011; Volet et al. 2009). By regulating peers' learning and cognition, students question, reconstruct, and control their own cognitive processes and strategies. Empirical evidence exploring the influence of collaborative learning on higher education students' metacognitive development is, however, rather limited. The present study contributes towards filling this gap by exploring the potential of reciprocal peer tutoring (RPT), as a specific type of collaborative learning, to promote university students' metacognition.

Most research to date has either engaged in a theoretical discussion of the benefits of metacognition in general, or merely reported on the effects of metacognitive training on learning performance without assessing its influence on students' metacognitive activities (Veenman et al. 2006). By contrast to these studies, this research is concerned with the assessment of metacognitive behaviours as such. Moreover, the focus is not exclusively on either metacognitive knowledge (e.g. Antonietti et al. 2000; Pintrich 2002; Schraw 1997) or metacognitive regulation skills (e.g. Bannert and Mengelkamp 2008; Desoete 2007; Moos and Azevedo 2009; Veenman and Beishuizen 2004), but on both components.

Theoretical framework

Metacognition

Metacognition refers to the ability to reflect upon, understand, manipulate, and regulate one's cognitive activities during learning (Efklides 2008; Meijer et al. 2006). In line with Brown's (1987) theoretical framework, we conceptualise metacognition as being comprised of two components: knowledge and regulation.

Metacognitive knowledge

Metacognitive knowledge refers to how much learners understand about the way people process information while engaged in academic tasks (Perfect and Schwartz 2002). This kind of knowledge is relatively stable, statable, fallible, and late-developing, because it requires learners to step back and to consider their own cognitive processes (Brown 1987). Within metacognitive knowledge, declarative, procedural, and conditional knowledge can be distinguished (Schraw 1998). Declarative knowledge concerns the insight into one's processing abilities and factors influencing one's performance. Procedural knowledge refers to knowledge of successful methods (heuristics and strategies) for achieving specific learning goals, and the awareness of how certain cognitive skills are to be employed in learning. Conditional knowledge concerns knowledge about the external conditions in which particular strategies are appropriate, including the reasons for their effectiveness.

Metacognitive regulation

Metacognitive regulation refers to skills used to orchestrate and oversee learning and performance (Efklides 2008). In contrast to metacognitive knowledge, metacognitive regulation is assumed to be relatively unstable, unstatable, and age-independent (Perfect and Schwartz 2002). Brown (1987) distinguishes between planning, monitoring, and evaluation as the major skills before commencing an academic task, during task execution, and upon completion of the task, respectively. In line with Pressley (2000) and Veenman et al. (1997) a fourth metacognitive regulation skill can be added to this theoretical framework, namely orienting. Metacognitive orientation takes place prior to problem solving and aims at a preparation of the sequential planning and execution of cognitive activities (Meijer et al. 2006; Veenman et al. 2005). The learner explores task demands and learning objectives, activates prior knowledge, and estimates task difficulty (Butler 1998; Pressley 2000). Related to orientation is metacognitive planning: thinking how, when, and why to anticipate during learning, resulting in the selection of appropriate strategies, the allocation of resources, and the development of an action plan to attain learning goals (Desoete 2007; Veenman et al. 1997). When learners monitor their learning, they engage in on-line control of their cognitive strategies. Monitoring aims at the identification of inconsistencies and the modification of learning activities if needed (Meijer et al. 2006; Moos and Azevedo 2009). Finally, evaluating involves learners' self-judging activities upon completion of a learning cycle (Veenman et al. 2005). They can concentrate on either the outcomes or the process of learning (Meijer et al. 2006).

Metacognition as a socio-cognitive construct

Metacognition is essential in the strategic self-regulatory application of knowledge and skills to achieve learning goals. Metacognitive self-regulation is thought to be crucial for academic success, especially in higher education (Cornford 2002). Nevertheless, a majority of higher education students possess insufficient metacognitive knowledge and skills to spontaneously self-regulate their learning (Maclellan and Soden 2006). However, empirical research leads us to be optimistic that metacognitive knowledge, and especially metacognitive skills, are trainable and teachable (Kuhn 2000). In this respect, Hartman and Sternberg (1993) suggest a multi-dimensional approach of (1) promoting metacognitive awareness by learning from modelling; (2) improving metacognitive knowledge and skills by confrontation with and reflection upon a variety of heuristics and self-regulatory skills; and (3) fostering a powerful learning environment challenging learners to judge, control, and manage their learning. With regard to the latter, Hurme et al. (2006), Puntambekar (2006), and Roscoe and Chi (2008) stress the potential of interaction and constructing socially shared knowledge.

The above can be linked to the current research interest about metacognition as a socio-cognitive construct (Iiskala et al. 2011; Volet et al. 2009). According to this view, metacognition has a social dimension and is best promoted through social interactions, in which metacognitive insights and strategies are modelled and consequently internalised. Early research in this field explored the potential of metacognitive modelling by teachers. Recent studies focus on collaborative learning and mediation or modelling by peers (e.g. Hurme et al. 2006; Molenaar et al. 2010; Volet et al. 2009). During collaborative learning, students ask questions, provide explanations, and discuss different viewpoints. Their thinking is compared with their peers', requiring both the knowledge and regulation of their own cognitive processes (Iiskala et al. 2011; Puntambekar 2006). They start monitoring and controlling how peers are working (Volet et al. 2009). In other words, during collaborative learning metacognitive activity is mediated among students.

Since it is assumed that higher-level learning, and more specifically metacognitive competence, can best be accomplished through an exchange of experiences and insights on an equal-ability basis (King 1997; Volet et al. 2009), literature shows an actual call for empirical research on metacognition and collaborative learning. In this respect, the present study takes an interest in studying the influence of RPT on higher education students' metacognitive knowledge and regulation skills.

Reciprocal peer tutoring

Peer tutoring is a type of collaborative learning, aimed at the acquisition of knowledge and skills through active helping and supporting among peers in small groups or student pairs (Falchikov 2001; Topping 2005). Students in a peer tutoring programme take specific roles as a tutor and tutee. The tutor is a more knowledgeable student supporting and directing the learning processes through active scaffolding, questioning, and explaining (Roscoe and Chi 2008). The tutee is a less experienced student receiving help and guidance from the tutor. RPT, in particular, is characterised by the structured switching of the above-mentioned roles at strategic moments during peer learning (Topping 2005). RPT reaps the specific benefits derived from teaching (tutor) and being taught (tutee). RPT is mostly associated with same-age settings, in which tutors and tutees are from the same class group.

Research lists multiple benefits for both tutees and tutors on cognitive, metacognitive, affective, and social levels (e.g. Falchikov 2001; Topping 2005). With regard to the metacognitive effects, Roscoe and Chi (2007, 2008) illustrate tutoring activities having a positive influence on reflective knowledge-building. The tutor role, especially, reflects improvement in comprehension-monitoring and elaborated explanations. King (1997) stresses the promotion of metacognitive reflection. Her research reveals significant effects on students' metacognitive monitoring and regulation, both when tutoring and being tutored. This is confirmed by Ismail and Alexander (2005), stating that—especially scripted—peer tutoring programmes prompt learners to generate more higher-level thinking questions and responses, contributing to their metacognitive awareness. The available research helps us to conclude that peer tutors can function as metacognitive role models and can take ownership of their own and their peers' learning (Falchikov 2001). Thus it appears promising to approach RPT as a pathway to optimize students' metacognitive self-regulation and knowledge.

Aim and research questions

The present study aims to explore the potential of a RPT programme for university students on the promotion of their metacognition. Building on the theoretical framework, we put forward the following research questions: What is the evolution in higher education students' (1) metacognitive knowledge and (2) metacognitive regulation skills from pretest to posttest, at the end of a RPT-intervention?

Method

Participants and setting

The present study was conducted in a naturalistic higher education setting at Ghent University, involving 67 first-year Educational Sciences students (10 (15%) males and 57 (85%) females). Students were randomly assigned to twelve RPT groups. The RPT programme was a formal component of a 5-credit course 'Instructional Sciences'. Students received credits for their participation in the RPT programme.

Intervention

During a complete semester, students tutored each other in a face-to-face context, in small and stable groups of four to six tutees per tutor. The intervention consisted of eight successive sessions (each taking 90 min), including a training session. The tutoring programme was same-age and reciprocal by nature (Topping 2005). Within same-age RPT the tutor role is switched between participants, giving equal opportunities to all learners to benefit from the tutor and tutee role (Falchikov 2001). In the present study, the tutor role was changed at each session. As a manipulation check, RPT sessions of all groups were observed weekly, to monitor whether students adequately enacted their tutor and tutee role. In the case of inadequate behaviours, immediate feedback was given to ensure treatment fidelity.

Assignments

During the RPT sessions, tutors supported tutees' knowledge construction and self-directed learning while working on authentic assignments, related to four content-specific themes of the 'Instructional Sciences' course (i.e. class, school, and policy levels within Instructional Sciences; behaviouristic learning theories; cognitivist learning theories; and constructivist learning theories). The assignments were identical for all peer groups and were presented as open-ended tasks, implying no standard approach, nor single right answers. The assignments were complex and extensive, implying group members could not solve the task individually. The tasks demanded a high level of cognitive processing, more specifically critical thinking, problem solving, negotiation, and decision making (Puntambekar 2006). In order to direct students' attention to specific learning content related to the course within these open tasks, each assignment started with an outline of learning objectives. These encouraged students to become acquainted with expectations concerning the focus of peer discussions. Assignments were further divided into two major parts: (1) a subtask aimed at familiarising students with the specific instructional sciences' terminology related to the task and enabling them to gain insight into the relations between these theoretical concepts in the assignment and (2) a subtask in which students were asked to apply these theoretical notions to realistic instructional cases. Appendix A exemplifies the authentic assignments.

Overall tutor training

Building on research evidence that tutors who receive support and training yield better outcomes, all students participated in compulsory preliminary training, organised 2 weeks before the onset of the tutoring programme (Falchikov 2001; Parr and Townsend 2002).The focus of the training was on the acquisition of (meta)cognitive and social skills to moderate group discussions and to facilitate shared knowledge construction (Falchikov 2001; Puntambekar 2006). Participants were introduced to the multidimensional nature of tutoring in order to master a mix of tutoring skills. They were informed about and practiced functional skills, such as establishing a safe learning environment (Parr and Townsend 2002; Topping 2005), managing peer interactions (Roscoe and Chi 2008; Webb and Mastergeorge 2003), asking differentiated and thought-provoking questions (King 1997), giving constructive feedback (Falchikov 2001; Nath and Ross 2001), and scaffolding (Chi et al. 2001). Additionally, these trained tutoring responsibilities were summarised and exemplified in a seven-page manual, which was provided to all students.

Session-specific tutor guide

At each session, the students responsible for the tutor role during a specific week received a session-specific tutor guide, to support and inspire their approach. The function of this tutor guide was twofold. First, it offered additional information regarding the theoretical contents of the specific assignment, for it is assumed that peer support and scaffolding are only appropriate when some difference in knowledge and expertise between the tutor and their tutees exists (Topping 2005). Second, the guide inspired students to tackle the assignments in a stepwise way: exploring the learning objectives, developing an action plan, checking whether requirements are met, and reflecting on the outcomes and the process of peer collaboration. In this way, the guide implicitly stressed the importance of, and elicited, metacognitive activities. This was summarised in a 'tutor card' with a schematic overview of a stepwise problem-solving approach (see Appendix B).

Interim support

In order to provide ongoing support during the intervention, an interim supervision session was organised (Falchikov 2001; Parr and Townsend 2002). This supervision session—directed by a university staff member—was set up in small groups of about twelve students, and focused on sharing experiences and reflecting upon one's tutoring performance. The multiple responsibilities of the tutor, as outlined during the tutor training, served as the starting point. All participants received different statements about specific tutor responsibilities, eliciting self-reflection on one's own performance (e.g. "I go beyond asking knowledge-reviewing questions", "I easily notice silent tutees and know how to activate them"). By discussing these reflections with fellow students (from their own and other RPT groups), students shared experiences and informed each other about personal strengths and weaknesses and about pitfalls concerning managing peer interactions, creating a rich learning environment and stimulating knowledge construction. Additionally, there was room for spontaneous discussion on student-initiated reflections, as well as for questions concerning organisational aspects, encountered problems, or insecurities concerning the preparation for the RPT sessions.

Design and instruments

A multi-method pretest–posttest design was used to measure students' metacognition, combining the administration of a questionnaire about metacognitive knowledge and studying think-aloud protocols about students' metacognitive regulation. By combining self-report questionnaires with think-aloud protocol analysis, we try to meet the research call for applying multi-method designs when assessing metacognition (Moos and Azevedo 2009; Veenman 2005).

Off-line self-report questionnaire

All students completed the 'Metacognitive Awareness Inventory' (Schraw and Dennisson 1994) before and after the intervention. The MAI is based on Brown's (1987) theoretical framework about metacognitive knowledge and regulation. In the present study, we adopted the MAI subscale 'knowledge of cognition' to assess students' metacognitive knowledge and the subscale 'regulation of cognition' to assess their perceived metacognitive regulation. Both MAI subscales have been shown to be reliable (Schraw and Dennisson 1994). The first subscale consists of 17 items, assessing students' awareness of their declarative, procedural, and conditional metacognitive knowledge. In the present study, Cronbach's α was .78 (pretest) and .81 (posttest). The subscale 'regulation of cognition' comprises 35 items, assessing students' awareness of planning, information management, monitoring, debugging, and evaluation strategies. Cronbach's α in the present study was .90 (pretest) and .89 (posttest). The original scoring system of the MAI was replaced with a six-point Likert-type scale, ranging from 1 (I totally don't agree) to 6 (I totally agree).

On-line think-aloud protocol analysis

Both before and after the intervention, all students individually performed a think-aloud task. The entire task solution process of each individual student was videotaped. By analysing the verbal protocols, students' metacognitive strategies could be tracked and identified (Veenman 2005; Yang 2003). This research method is expected not to disturb, nor to influence, thought and regulation processes significantly (Ericsson and Simon 1993; van Someren et al. 1994; Fonteyn et al. 1993). Nevertheless, it may slightly slow down task performance (Bannert and Mengelkamp 2008; Veenman 2005).

Task

The think-aloud task comprised a text with theoretical background information and a related case relevant to the context of Instructional Sciences. At pretest, the central topic of the think-aloud task concerned evaluation and assessment, its purposes and forms. At posttest, students engaged in a task on inequality in education, its explanations and consequences. Apart from this difference in the content of the topic, all aspects of the think-aloud task and measurement were identical at pretest and at posttest. Students were asked to read the text materials and to solve some thought-provoking questions while verbalizing their thoughts. In case of silence, participants were prompted by the assessor to continue thinking aloud (van Someren et al. 1994). The task was developed taking into account research-based guidelines. First, we paid attention to the complexity of the task and the terminology used, by providing an academically written text that was challenging yet comprehensible for students (Bannert and Mengelkamp 2008; Fonteyn et al. 1993). In this way, we tried to avoid both automated processes (which might arise with academically unchallenging task materials) and cognitive overload (which might arise with overly complex tasks and an abundance of new terminology). Second, the representativeness of the task with regard to the (meta)cognitive processes involved, was taken into account (van Someren et al. 1994). We constructed a task that consisted of multiple parts and questions, in order to create opportunities for students to spontaneously orientate, plan, monitor, and evaluate. Third, students were instructed to think aloud, to report on the cognitive actions taking place, but not to justify them. This approach ensured the avoidance of interpretative verbalizations, explaining reasons for cognitive actions (Ericsson and Simon 1993; van Someren et al. 1994). Last, we adopted mild time constraints, by offering each student a maximum of 30 min for task completion (Veenman and Beishuizen 2004).

Coding scheme

A coding scheme was developed to analyse and code students' verbal protocols. Building on the aforementioned multidimensional nature of metacognition, the coding scheme reflects a variety of skills, activities, and strategies. It mirrors the four basic regulation skills as the main coding categories, each being further specified by multiple components. At the lowest operational level, indicators of metacognitive regulation sometimes take the form of cognitive activities. It is—as stated in the literature—legitimate to infer covert metacognitive activity from overt cognitive actions (Meijer et al. 2006). As a result, the coding scheme specifies how elements of the theoretical framework can be identified in verbal student protocols before commencing the task, during task execution, and upon task completion. Table 3 in Appendix C presents a detailed and illustrated overview of the (sub)categories in the coding scheme.

Orientation takes place prior to task execution and aims at preparing the latter. When orienting, learners ideally analyse the task in order to get acquainted with learning objectives or task demands (Butler 1998). First, this encompasses exploration of the task subject (Veenman et al. 1997). At a minimum level this involves orientation on the general title (Pressley 2000). Additionally, learners might also consider subtitles or generally screen task or text materials, and consequently explore the task more extensively by taking into account aspects like its constitution or length. Task analysis further consists of reading task instructions (Meijer et al. 2006). Learners who want to ensure their complete comprehension of the task demands normally engage in more profound orientation, by rereading, citing or even paraphrasing task instructions (Artzt and Armour-Thomas 1992; Veenman et al. 2005). For some learners, task analysis will result in awareness of perceptions or feelings about the task (Meijer et al. 2006; Veenman et al. 1997). These perceptions mostly involve a consideration of both task-difficulty and one's self-efficacy in relation to the perceived difficulty. Metacognitive orientation is ideally also focused on exploring the particular content of the academic task involved (Veenman et al. 1997). Content orientation comprises formulating hypotheses about the learning contents to be investigated and/or activation of prior knowledge (Butler 1998; Meijer et al. 2006). Lastly, learners can extend their orientation activities by structuring (for example underlining or schematising) task instructions, indicating they process task requirements (Desoete 2007; Veenman et al. 2005).

Metacognitive planning normally takes place at the onset of problem solving, but can also appear during the course of problem solving, for example before executing the next subtask. Planning activities can be directed at the problem-solving approach and/or at a timeframe for task execution (Bannert and Mengelkamp 2008). Profound planning involves selecting an approach after considering various problem-solving alternatives (Artzt and Armour-Thomas 1992; Veenman et al. 1997). At a more basic level, however, learners will develop a single (reading) plan for reading text materials (for a reading task) or (action plan) for task execution (Pressley 2000; Desoete 2007).

Metacognitive monitoring involves the on-line quality control of one's strategy use, comprehension, and progress (Moos and Azevedo 2009). Monitoring of strategy use encompasses learners' structuring of text or learning materials by means of highlighting information, making notes, and schematising, indicating their intention to make the learning materials manageable (Meijer et al. 2006; Veenman et al. 2005). Further, students engage in selective text navigation when focusing on specific learning contents or scanning text materials (Meijer et al. 2006; Palinscar and Brown 1984). The latter is aimed at regulating and optimizing the efficiency of the problem-solving process. Monitoring of strategy use further includes the purposeful use of reading strategies. In this respect, learners can decide to adapt their reading pace, to reread information (for example after noticing confusion or when becoming aware of essential information), or to read out loud (Palinscar and Brown 1984). Finally, monitoring of strategy use can result in awareness of deficiencies and therefore in modification of the problem-solving strategies being used (Butler 1998; Moos and Azevedo 2009).

Comprehension monitoring refers to control activities focusing on the correctness and comprehensiveness of one's understanding. A first indicator in this respect concerns learners' noting a lack of full understanding (Crain-Thoreson et al. 1997; Veenman et al. 1997). By contrast, students may demonstrate comprehension by summarising or reaching conclusions about learning content, or by asking critical questions concerning the content (Crain-Thoreson et al. 1997; Meijer et al. 2006). Comprehension is also demonstrated by quoting or paraphrasing learning content, since being able to repeat the main ideas within a text indicates a certain level of understanding. More profound comprehension monitoring implies elaboration on learning materials (Bannert and Mengelkamp 2008; Veenman et al. 1997). Possible indicators in this respect are personal interpretations or exploration of relationships between aspects of the learning content.

In addition to monitoring comprehension, students' monitoring activities can also be directed at the progress they make (Butler 1998; Moos and Azevedo 2009). More specifically, they can control and reflect on the problem-solving strategies used, the proposed solution for a (sub)task, the available time left for task execution, and the quality of their perceived progress (Meijer et al. 2006).

Upon completion of problem solving, learners ideally engage in metacognitive evaluation. The latter can be directed at both learning outcomes and at process factors during task execution (Desoete 2007). In the first case, learners can check the correctness, the completeness, and/or the effectiveness of proposed solutions (Artzt and Armour-Thomas 1992). More extensive product evaluation consists of a recapitulation of the search for the provided answers (Meijer et al. 2006; Veenman et al. 2005). In the case of process evaluation, judgements and reflections can be directed towards one's personal efficiency, the perceived task difficulty, and/or one's self-efficacy (Meijer et al. 2006).

Coding strategy

The verbal protocols of all students were transcribed verbatim and coded by means of the coding scheme. Two trained coders performed the coding independently. They double-coded 23% of the protocols. Cohen's kappa ($\kappa = .80$) indicates high overall interrater reliability. Interrater reliability for the main categories of the coding scheme indicate equally good agreement beyond chance (κ orientation = .93, κ planning = .98, κ monitoring = .89, and κ evaluation = .82). Since metacognitive regulation is multidimensional by nature, it is clear that multiple activities can be reflected within a single protocol fragment. Therefore, we opted for units of meaning as the unit of analysis (van Someren et al. 1994). In the present study, a unit of meaning is defined as a unit representing a thematically consistent verbalization of a single metacognitive strategy (Chi 1997). Each unit of meaning received only one code. Table 4 in Appendix D exemplifies the coding strategy.

Data analysis

The questionnaire data regarding students' self-reported metacognitive knowledge and regulation were analysed quantitatively. Pretest and posttest scores on both subscales of the MAI were compared by means of paired-samples *t*-tests. The verbal protocols, revealing students' actual use of metacognitive regulation skills, were first coded qualitatively. Next, the occurrence of metacognitive skills and strategies at pretest and posttest was analysed and compared quantitatively (Chi 1997). Paired-samples *t*-tests were used to test for significant changes in both the frequency of students' use of metacognitive skills and the type of strategies employed to control and regulate their learning (see Table 2). Cohen's *d* is reported to study the effect size of significant differences in the occurrence of metacognitive skills and strategies.

Results

Descriptive analyses

Descriptive analyses of the MAI-based data show that students report a relatively high amount of metacognitive knowledge, both at pretest ($M = 4.31$, $sd = 0.39$) and at posttest ($M = 4.37$, $sd = 0.44$). Furthermore, relatively high levels of metacognitive strategy use are reported at pretest ($M = 4.17$, $sd = 0.44$) as well as at posttest ($M = 4.21$, $sd = 0.44$). However, this level of self-reported metacognitive regulation has to be linked to the results of the think-aloud protocol analysis. With regard to the latter, 1273 units of meaning were identified in the pretest, and 2303 units were isolated in the posttest transcripts. This increase in metacognitive utterances can be considered as an indication of the pretest to posttest evolution.

Table 1 presents the frequencies of students' metacognitive skill use during think-aloud problem solving for the entire sample. Analyses of the verbal protocols collected at pretest demonstrate a dominant use of monitoring strategies (83.4%). In contrast, a very limited adoption of metacognitive orientation (7.4%), planning (5.4%), and evaluation (3.8%) is shown at pretest. Measurement of students' actual metacognitive regulation at posttest reveals some important shifts. First, students pay considerably more attention to metacognitive orientation (12.5%). Second, students are considerably more involved in metacognitive evaluation (8.9%). In contrast, we observe a decrease in metacognitive monitoring (74.9%) and in metacognitive planning (3.8%). It is nevertheless important to examine the second level coding categories. For instance, within the types of monitoring activities, there is an increase of particular metacognitive regulation strategies: comprehension monitoring and monitoring of progress play a considerably more important role at posttest.

Table 1 Occurrence of students' actual use of metacognitive skills (frequencies and percentages)

Metacognitive skills	Pretest		Posttest	
	Frequency	%	Frequency	%
Orientation	94	7.4	286	12.5
Task analysis	89	6.9	229	9.5
Exploring text subject & constitution	30	2.3	113	4.9
Detecting task demands	59	4.6	104	4.5
Becoming aware of task perceptions	0	0.0	12	0.5
Content orientation	5	0.5	49	2.4
Generating hypotheses	3	0.2	16	1.0
Activating prior knowledge	2	0.3	33	1.4
Structuring task instructions	0	0.0	8	0.6
Underlining core concepts	0	0.0	8	0.6
Schematizing task instructions	0	0.0	0	0.0
Planning	69	5.4	88	3.8
Planning in advance	37	2.9	62	2.7
Planning problem solving approach	34	2.7	58	2.5
Making a time-schedule	3	0.2	4	0.2
Interim planning	32	2.5	26	1.1
Planning problem solving approach	31	2.3	26	1.1
Making a time-schedule	1	0.1	0	0.0
Monitoring	1062	83.1	1729	74.8
Monitoring of strategy use	722	56.5	858	36.7
Text structuring	171	13.4	254	10.7
Selective text navigation	262	20.5	297	12.8
(Re)reading	232	18.2	258	11.1
Adapting strategy use	57	4.4	49	2.1
Comprehension monitoring	255	20.0	632	27.8
Noting lack of comprehension	50	4.1	38	1.6
Claiming understanding	88	7.0	155	6.7
Demonstrating comprehension by repeating	90	7.2	188	8.6
Demonstrating comprehension by elaborating	27	2.2	251	10.9
Monitoring of progress	85	7.1	239	10.3
Reflecting on strategy use	30	2.3	90	3.9
Reflecting on the proposed solution	51	4.2	101	4.4
Reflecting on the available time and time-schedule	3	0.4	5	0.2
Reflecting on the quality of the progress made	1	0.2	43	1.8
Evaluation	48	3.8	200	8.9
Evaluating learning outcomes	41	3.3	163	7.4
Checking the correctness of the solution	7	0.5	57	2.5
Checking the completeness of the solution	26	2.0	49	2.1
Checking the effectiveness of the solution	0	0.0	44	1.9
Recapitulating the solution	1	0.1	17	0.6
Evaluating learning process	7	0.5	33	1.5
Reflecting on personal efficiency	0	0.0	17	0.8

Table 1 continued

Metacognitive skills	Pretest		Posttest	
	Frequency	%	Frequency	%
Reflecting on task-difficulty	4	0.3	13	0.6
Reflecting on self-efficacy	3	0.2	3	0.1

Evolution in students' self-reported metacognitive knowledge and regulation

Results of the paired-samples *t*-test on students' self-reported metacognitive knowledge reveal no significant difference between pretest and posttest scores ($t = -1.25$, $df = 58$, $p = .215$). The changes in students' awareness of metacognitive strategy use appear not to be significant either ($t = -0.65$, $df = 58$, $p = .515$). However, the results point at a discrepancy in our findings when comparing the questionnaire-based analyses with the actual metacognitive regulation as derived from the think-aloud protocols.

Evolution in students' actual use of metacognitive skills

As revealed in Table 2, multiple significant differences in learners' actual metacognitive regulation are observed at posttest. Students not only apply metacognitive skills more frequently, they show a more varied use during problem solving as well.

Metacognitive orientation

Paired-samples *t*-tests confirm that students orient themselves significantly more towards problem solving at posttest ($t = -18.39$, $df = 58$, $p < .001$, $d = 3.12$). This general tendency of increased metacognitive orientation is moreover reflected in second-level strategies. At posttest, students pay significantly more attention to analysing the task ($t = -14.76$, $df = 58$, $p < .001$, $d = 2.55$), structuring the task instructions ($t = -3.02$, $df = 58$, $p < .001$, $d = 0.75$), and orienting themselves to the specific content of the learning task ($t = -7.81$, $df = 58$, $p < .001$, $d = 1.52$). The changes in metacognitive orientation ($d = 3.12$) are mainly due to the significant increase of students' engagement in task-analysis. Moreover, a more varied use of task-analysis strategies can be observed. First, students explore the subject and constitution of the task significantly more ($t = -10.97$, $df = 58$, $p < .001$, $d = 2.03$). This is evidenced by significantly more attention being paid to both the general title ($t = -11.19$, $df = 58$, $p < .001$, $d = 2.30$) and the subtitles ($t = -7.52$, $df = 58$, $p < .001$, $d = 1.40$) of the task and text given, implying a more profound orientation. Second, the results demonstrate that students' actions are significantly more aimed at detecting specific task demands ($t = -8.06$, $df = 58$, $p < .001$, $d = 1.31$). In this respect students reread ($t = -3.30$, $df = 58$, $p < .001$, $d = 0.56$), quote ($t = -3.82$, $df = 58$, $p < .001$, $d = 0.77$), and paraphrase ($t = -4.10$, $df = 58$, $p < .001$, $d = 0.86$) task instructions more frequently at posttest. It has to be stressed, however, that the overall occurrence of the above-mentioned strategies remains rather limited. Third, participants engage significantly more in reflection on task characteristics by verbalizing their task perceptions ($t = -3.85$, $df = 58$, $p < .001$, $d = 1.32$). Although an increase in reflections about task difficulty is observed ($t = -3.02$, $df = 58$, $p = .004$, $d = 0.77$), the actual frequency of this regulation type remains marginal ($M = 0.13$, $sd = 0.34$).

Table 2 Results of pre- and posttest think-aloud protocol analysis: occurrence of metacognitive skills

Metacognitive skills	Frequency				*t (df)*
	Pretest		Posttest		
	M[a]	SD	*M*	SD	
Orientation	1.59	0.85	4.85	1.19	−18.39 (58)***
Task analysis	1.49	0.75	3.73	0.98	−14.75 (58)***
Exploring text subject & constitution	0.51	0.68	1.91	0.70	−10.97 (58)***
Detecting task demands	1.00	0.49	1.76	0.65	−8.06 (58)***
Becoming aware of task perceptions	0.00	0.00	0.20	0.40	−3.85 (58)***
Content orientation	0.08	0.28	0.83	0.70	−7.81 (58)***
Generating hypotheses	0.05	0.22	0.27	0.44	−3.34 (58)***
Activating prior knowledge	0.03	0.18	0.56	0.50	−8.01 (58)***
Structuring task instructions	0.00	0.00	0.14	0.34	−3.02 (58)*
Underlining core concepts	0.00	0.00	0.13	0.34	−3.02 (58)*
Schematizing task instructions	0.00	0.00	0.00	0.00	
Planning	1.17	0.93	1.49	0.73	−2.14 (58)
Planning in advance	0.63	0.55	1.05	0.22	−5.01 (58)***
Planning problem solving approach	0.57	0.49	1.00	0.00	−6.53 (58)***
Making a time-schedule	0.05	0.22	0.07	0.25	−0.37 (58)
Interim planning	0.54	0.62	0.44	0.67	0.90 (58)
Planning problem solving approach	0.49	0.59	0.42	0.67	0.60 (58)
Making a time-schedule	0.02	0.13	0.00	0.00	1.00 (58)
Monitoring	11.30	4.62	20.81	5.48	−10.28 (58)***
Monitoring of strategy use	5.54	2.37	6.30	3.04	−1.64 (58)
Text structuring	0.13	2.36	6.30	3.03	−2.47 (58)*
Selective text navigation	4.44	2.23	5.03	2.42	−1.45 (58)
Adapting strategy use	0.96	0.85	0.83	0.98	0.81 (58)
Comprehension monitoring	4.49	3.32	10.76	3.98	−9.88 (58)***
Noting lack of comprehension	0.88	1.24	0.64	0.86	1.50 (58)
Claiming understanding	1.51	1.38	2.64	1.14	−4.93 (58)***
Demonstrating comprehension by repeating	1.72	2.14	3.22	1.81	−4.44 (58)***
Demonstrating comprehension by elaborating	0.47	0.91	4.27	2.39	−11.22 (58)***
Monitoring of progress	1.51	1.33	4.05	1.71	−8.78 (58)***
Reflecting on strategy use	0.51	0.73	1.52	0.99	−7.27 (58)***
Reflecting on the proposed solution	0.89	1.02	1.71	1.26	−4.07 (58)***
Reflecting on the time and time-schedule	0.84	0.33	0.85	0.28	0.01 (58)
Reflecting on the quality of the progress made	0.02	0.13	0.73	0.74	−7.13 (58)***
Evaluation	0.81	0.71	3.49	1.43	−12.67 (58)***
Evaluating learning outcomes	0.71	0.62	2.93	1.13	−12.16 (58)***
Checking correctness of the solution	0.10	0.30	0.97	0.55	−10.56 (58)***
Checking completeness of the solution	0.42	0.49	0.83	0.62	−4.07 (58)***
Checking effectiveness of the solution	0.00	0.00	0.74	0.51	−11.19 (58)***
Recapitulating the solution	0.00	0.00	0.29	0.49	−4.49 (58)***
Evaluating the learning process	0.12	0.33	0.58	0.65	−5.00 (58)***
Reflecting on personal efficiency	0.00	0.00	2.88	0.45	−4.84 (58)***

Table 2 continued

Metacognitive skills	Frequency				t (df)
	Pretest		Posttest		
	M^a	SD	M	SD	
Reflecting on task-difficulty	0.07	0.25	0.22	0.41	−2.42 (58)*
Reflecting on self-efficacy	0.05	0.22	0.05	0.22	0.01 (58)

M refers to how often an individual student on average uses a metacognitive skill or strategy during think-aloud problem solving at pretest and at posttest

* $p < .05$, *** $p < .001$

At posttest, students perform significantly more activities related to content orientation ($t = -7.81$, $df = 58$, $p < .001$, $d = 1.52$). The related effect size is large ($d = 1.52$). On the one hand, students generate significantly more hypotheses ($t = -3.34$, $df = 58$, $p < .001$, $d = 0.64$). On the other hand, there is a significant increase in students' activation of prior knowledge ($t = -8.01$, $df = 58$, $p < .001$, $d = 1.52$).

Students also bring more structure to the task instructions ($t = -3.02$, $df = 58$, $p = .004$, $d = 0.77$), by underlining core concepts. However, this does not seem to be common practice.

Metacognitive planning

Although participants engage in metacognitive planning, the results outline that their planning behaviour is rather scarce, both at pretest and at posttest. No overall difference is discerned in metacognitive planning ($t = -2.14$, $df = 58$, $p = .063$). Nevertheless, a promising significant evolution regarding the planning of the problem-solving approach was found ($t = -6.53$, $df = 58$, $p < .001$, $d = 1.60$). No other sub-skills seemed to be affected in a significant way.

Metacognitive monitoring

A considerable part of the problem-solving process is populated by metacognitive monitoring, both at pretest and at posttest. The t-test results reveal significant shifts in students' monitoring of comprehension ($t = -9.88$, $df = 58$, $p < .001$, $d = 1.72$) and progress ($t = -8.78$, $df = 58$, $p < .001$, $d = 1.67$). No significant change could be distinguished in monitoring the use of problem-solving strategies ($t = -1.64$, $df = 58$, $p = .106$). Nevertheless, students do show a tendency to structure the contents of the text and task significantly more at posttest ($t = -2.47$, $df = 58$, $p = .016$, $d = 0.46$), by making significantly more notes ($t = -2.44$, $df = 58$, $p = .017$, $d = 0.49$) instead of merely underlining important text parts (see Table 2). Again, however, these effects mirror only marginal increases.

With regard to comprehension monitoring, more important changes are observed. At posttest, participants significantly claim more understanding ($t = -4.94$, $df = 58$, $p < .001$, $d = 0.90$). Instead of merely summarising text content, they tend to ask and answer significantly more critical questions concerning the text ($t = -10.16$, $df = 58$, $p < .001$, $d = 2.07$). Additionally, there is an increase in demonstrating comprehension by paraphrasing relevant information ($t = -12.36$, $df = 58$, $p < .001$, $d = 2.03$). In line with that, a significant decrease in students' quoting parts of the text is revealed at posttest

($t = 3.64$, $df = 58$, $p < .001$). The most remarkable shift is related to students demonstrating understanding by elaborating on the text. Whereas participants hardly make use of this strategy at pretest, it becomes a dominant monitoring strategy at posttest ($t = -11.22$, $df = 58$, $p < .001$, $d = 2.29$). Students make significantly more text interpretations ($t = -9.43$, $df = 58$, $p < .001$, $d = 1.86$) and there is more relating to different information-units ($t = -7.42$, $df = 58$, $p < .001$, $d = 1.51$). The results further indicate a decrease, albeit non-significant, in noting lack of comprehension ($t = 1.51$, $df = 58$, $p = .137$).

When regulating their performance, students significantly increase not only the monitoring of their comprehension, but also the monitoring of their progress ($t = -8.78$, $df = 58$, $p < .001$, $d = 1.64$). More specifically, students are significantly more involved in checking the adequateness of their problem-solving strategies during task execution ($t = -7.27$, $df = 58$, $p < .001$, $d = 1.18$). Table 2 further indicates a significant shift in controlling the correctness and effectiveness of task solutions in the course of problem solving ($t = -4.07$, $df = 58$, $p < .001$, $d = 0.71$). In addition, a significant increase in monitoring the quality of progress is revealed ($t = -7.13$, $df = 58$, $p < .001$, $d = 1.62$). By contrast, no changes are observed in students' controlling the available time while executing the task ($t = 0.01$, $df = 58$, $p = .999$).

Metacognitive evaluation

Compared to pretest, students not only evaluate learning outcomes significantly more at posttest ($t = -12.12$, $df = 58$, $p < .001$, $d = 2.46$), they also take the learning process itself significantly more into account ($t = -5.00$, $df = 58$, $p < .001$, $d = 0.92$).

The product evaluation of learning outcomes appears to become a prominent strategy at posttest. Students show significantly more control of the correctness of their solution ($t = -10.56$, $df = 58$, $p < .001$, $d = 2.00$), the completeness of their answers ($t = -4.07$, $df = 58$, $p < .001$, $d = 0.72$), and the effectiveness of their provided solution ($t = -11.16$, $df = 58$, $p < .001$, $d = 2.19$). Moreover, participants appear to start to recapitulate their problem-solving steps ($t = -4.49$, $df = 58$, $p < .001$, $d = 1.16$). Nevertheless, the latter metacognitive evaluation strategy is only applied in a limited manner.

Additionally, important differences in students' evaluation of the learning and problem-solving process can be distinguished. At posttest, students demonstrate a significant increase in reflection on their personal efficiency ($t = -4.85$, $df = 58$, $p < .001$, $d = 1.24$). Furthermore, they reflect more on the task difficulty ($t = -2.42$, $df = 58$, $p = .019$, $d = 0.45$). This effect is, however, only marginally significant. No significant changes occur in reflecting on self-efficacy ($t = 0.001$, $df = 58$, $p = .998$). It should be stressed that the average number of metacognitive strategies related to learning process evaluation remains low.

Discussion

The present study aimed to explore the potential influence of RPT on higher education students' metacognitive knowledge and use of metacognitive regulation strategies. Students tutored each other in a face-to-face setting during nine successive weeks while working on authentic assignments in small peer groups. Their metacognition was assessed using a multi-method pretest–posttest design, combining self-reports with think-aloud protocol analysis. The following research questions were put forward: What is the evolution in higher education students' (1) metacognitive knowledge and (2) metacognitive regulation skills from pretest to posttest, at the end of an RPT intervention?

Metacognitive knowledge

With regard to the first research question, results reveal that students generally report relatively high levels of metacognitive knowledge. This finding fits in with recent research claiming that university students estimate their metacognitive knowledge to be rather high and extensive (e.g. Hara et al. 2000; You and Joe 2001). They appear to be well aware of their declarative and procedural metacognitive knowledge (Brown 1987; You and Joe 2001). Since the development of metacognitive knowledge is correlated with age-related improvements in human memory and cognition, established when learners reach adulthood, this finding is not surprising (Perfect and Schwartz 2002; Schneider 2008).

The results indicate that students' metacognitive knowledge did not change significantly from pretest to posttest. This can be explained by theorists stating that—after an initial phase where metacognitive knowledge can be promoted from the early age throughout adolescence—it becomes relatively stable in adult learners (Brown 1987; Perfect and Schwartz 2002). Although metacognitive knowledge may improve as students' age increases, the acquisition of this knowledge is not part of natural development (Boekaerts 1997). This insight encourages researchers to explore initiatives promoting metacognitive knowledge development. In this respect, it is argued that the development of metacognitive knowledge can be fostered by frequent and intensive metacognitive experiences, even with adult learners (McCrindle and Christensen 1995; White 1999; White and Frederiksen 2005). More specifically, collaborative learning environments are assumed to be potentially rich with metacognitive experiences, since students make their thinking visible to peers, often resulting in deeper insights in and adaptation of their own metacognition, including their metacognitive knowledge (Hara et al. 2000; Hurme et al. 2006).

Metacognitive regulation

The second research question addressed the potential influence of RPT on students' metacognitive regulation skills. The results show a clear difference in students' actual use of metacognitive regulation skills at posttest, compared to pretest.

Students' awareness of metacognitive regulation

The results of the self-reports indicate that students judge their metacognitive strategy use to be rather high before, during, and upon completion of task-execution, both at pretest and at posttest. However, we should be careful with this finding, for these high estimations may be invoked by the instrument and method used. Off-line assessment and self-report questionnaires do not always provide a reliable or accurate measure of learners' metacognitive skillfulness (Meijer et al. 2006; Moos and Azevedo 2009). It can invoke an overestimation of one's metacognitive regulation (Veenman 2005). Some research clearly shows discrepancies between these off-line measures and actual metacognitive behaviour as observed during task performance (Artelt et al. 2003; Meeks et al. 2007). In fact, our comparison of the prospective questionnaire and the data resulting from the think-aloud protocols, confirms this tendency to overestimate metacognitive regulation. In particular, students claim to metacognitively regulate their performance throughout all problem-solving phases but concurrent assessment of their regulation reflects very limited use of orientation, planning, and evaluation skills, especially at pretest. Different reasons for this overestimation of self-reported metacognitive regulation are put forward in literature. First, self-reports can easily elicit social desirable answers (Meeks et al. 2007; Veenman 2005). Adult learners are well aware of the ideal sequence of problem-solving activities (Artelt et al. 2003). Consequently, the risk of getting social desirable answers increases. Second, students' biased perceptions might be caused by memory failure (Ericsson and Simon 1993; Veenman 2005). Since the prospective measurement in this study was aimed at assessing students' metacognitive strategy use in general (i.e. without explicit reference to a specific task) students were expected to reconstruct their regular metacognitive behaviours. Previous research illustrated, however, the constraints of human memory when trying to retrieve information, resulting in inaccurate recollection (Meeks et al. 2007; Son and Metcalfe 2000).

The discrepancy between students' self-reported and their actual metacognitive behaviours has important implications. It hazards students' engagement in productive self-regulated learning (Winne 2004), for students monitor their learning in relation to their personal perceptions of their learning approach and its outcomes (Winne and Jamieson-Noel 2002). Consequently, misinterpretations (i.e. overestimation) of metacognitive regulation will result in persistent use of inadequate or mediocre regulation strategies, since the need for more productive forms of self-regulation will not be experienced (Pintrich 2002; Zabrucky 2010). Whereas some researchers claim the mismatch between students' perceived and actual metacognitive behaviour implies a negative impact on their academic achievement (e.g. Schraw and Nietfeld 1998), others have failed to confirm this result (e.g. Lin and Zabrucky 1998; Winne and Jamieson-Noel 2002). It is clear, however, that inadequate self-perceptions impair students' ability to learn significantly (Lin and Zabrucky 1998; Winne 2004). From this perspective, the observed discrepancy between students' perceived and actual regulation in the present study confirms the need to promote metacognitive awareness among higher education students (Maclellan and Soden 2006).

Findings further reveal that participation in the RPT programme could not establish significant differences in students' perception of their metacognitive behaviours. Shapiro and Niederhauser (2004) found similar results when concluding that explicit metacognitive prompts during learning have a positive influence on students' actual application of various cognitive and metacognitive strategies, but could not improve students' awareness of their metacognitive skillfulness. An explanation might be found both in the relatively short-term nature of the RPT intervention and in its rather implicit focus on metacognition. Hartman and Sternberg (1993) and Kuhn (2000) argue that successful enhancement of students' metacognitive awareness requires long and intensive teaching and modelling of metacognitive skills. Moreover, they stress the necessity to make explicit the modelled metacognitive behaviours. It can be assumed that the present RPT intervention was too short, and did not make the metacognitive strategies sufficiently explicit.

Students' actual use of metacognitive regulation: occurrence of metacognitive activities

With regard to students' actual use of metacognitive skills, results point in the direction of an increased application and more differentiated use of types of metacognitive regulation strategies. At pretest, students almost exclusively pay attention to monitoring their problem solving and their strategy use. They hardly engage in orientation, planning, or evaluation activities. However, at posttest, students increasingly apply orientation and evaluation strategies, although their activities remain dominantly characterised by metacognitive monitoring. It should be noted, however, that dominance of monitoring is inherent to every learning process, since it refers to the continuous quality control of performance (Moos and Azevedo 2009). Given that orientation and evaluation strategies can only be applied before commencing and upon completion of task execution, metacognitive monitoring will always dominate (Meijer et al. 2006; Perfect and Schwartz 2002).

The significant increase in metacognitive orientation and evaluation is worth noting. A possible explanation might be related to the RPT programme, in particular the design of the RPT learning materials. The assignments and the tutor curriculum script explicitly referred to learning objectives. These not only encouraged students to get acquainted with task requirements and expectations concerning the content of the discussions, but also served as an evaluative reflection tool (Falchikov 2001). Our findings suggest that students might have internalised these systematically trained orientation and evaluation behaviours.

Further analyses reveal multiple significant changes in students' metacognitive regulation. A significant difference in the metacognitive planning behaviour of participants could not be distinguished, however. This might be due to the structure of the think-aloud task, considering literature stating that the task can partially influence the outcomes of a think-aloud protocol analysis (van Someren et al. 1994). Since students were instructed to provide answers on two thought-provoking questions concerning a given text, the opportunities for planning the process of problem solving were scarce.

In contrast to metacognitive planning, students revealed a significantly increased use of metacognitive orientation, monitoring, and evaluation at posttest. Despite the medium to large effect sizes (Hattie 2009), the average occurrence of certain metacognitive strategies remained rather low (see Table 2). Nonetheless, the large effect sizes are in line with previous research about the impact of peer tutoring and peer discussions on students' higher-order thinking and learning (e.g. Ellis et al. 2006; Ireson 2004; Rosé and Torrey 2005). Effects above 0.40 are desired because they indicate an added value and have a greater impact on students' achievement (Hattie 2009). Taking this into account, RPT might be considered a promising instructional approach to promote metacognitive regulation in higher education.

With regard to metacognitive orientation, major changes can be distinguished on task analysis and content orientation. These are important findings, given the shortage of empirical studies underpinning this regulation strategy.

Our findings also reveal a significant increase in students' metacognitive monitoring of both their comprehension and their progress. The increase in comprehension monitoring might be explained by the theoretical perspective of metacognition as a socio-cognitive construct (Volet et al. 2009). When collaborating with peers, students are confronted by differing interpretations, resulting in negotiations about the meaning of learning content (Puntambekar 2006). These discussions can be further fostered and optimized by the tutor's thought-provoking questions (King 1997; Roscoe and Chi 2008). Consequently, students critically (re)consider their own interpretations and presumably become aware of the need to permanently monitor their comprehension. The key features of tutoring are furthermore assumed to have a direct influence on students' awareness of the necessity to control the efficiency and effectiveness of problem solving (Falchikov 2001). In particular, the provision of continuous feedback and the modelling of evaluative reflections—two responsibilities that were explicitly outlined in the tutor curriculum script—are essential when fostering students' monitoring of progress (Kuhn 2000). Contrary to our expectations, no significant change in monitoring of strategy use was observed. This is a rather remarkable result, since research states that tutoring can make learners more attentive towards their problem-solving strategies as it encourages students to implement more profound and strategic learning approaches (Falchikov 2001; Topping 2005). However, the design and structure of the think-aloud task might be responsible for the present limited metacognitive monitoring of strategy use (van Someren et al. 1994).

Findings further reveal a significant increase in metacognitive evaluation strategies. Students engage significantly more in evaluating their learning outcomes, and make more evaluative comments concerning their personal efficiency. Nevertheless, product evaluation dominates the reflections about the problem-solving process. The social-cognitive approach towards metacognition can help to explain the increased application of metacognitive evaluation at posttest. The key elements of peer collaboration (i.e. scaffolding, asking thought-provoking questions, reflective modelling, providing feedback, etc.) are hypothesised to foster students' self-reflection and evaluation (Chi et al. 2001; Falchikov 2001).

Students' actual use of metacognitive regulation: types of metacognitive activities

Within the four types of metacognitive regulation, our results also point at an increase in more profound and higher-quality strategies at posttest. This is especially obvious in relation to the orientation, monitoring, and evaluation strategies.

During orientation, students go beyond the exploration of task requirements by reading task instructions, when they quote and even paraphrase instructions to ensure awareness of task demands. Furthermore, students pay considerably more attention to the title and subtitles in the given text, resulting in a higher activation of prior knowledge. In short, students seem better prepared since they engage in more strategic and profound orientation activities.

In relation to metacognitive monitoring, students develop more structure by making notes instead of merely underlining parts of the text. This suggests that students became more sensitive to the deeper processing of information. It should be noted, however, that this was not a common practice for all participants. In contrast, a clear majority of students engage in high-quality comprehension monitoring at posttest. In this respect, they claim understanding by asking themselves critical, thought-provoking questions about the content of the task and by answering related questions afterwards. Instead of merely quoting parts of the text, students also show a clear tendency to paraphrase information, demonstrating their comprehension. Furthermore, results reveal a significant increase in students' elaborative comments on the text content. A possible explanation can be drawn from the tutoring literature (e.g. Falchikov 2001; King 1997; Roscoe and Chi 2008; Topping 2005). Tutors are expected to ask critical questions and to provide cognitive scaffolds to tutees, making them discuss meaning, explore connections, and gain deeper insights into complex theoretical frameworks. It might be assumed that observing this modelled behaviour of cognitively challenging peers eventually becomes internalised.

As to the changes in evaluation strategies, students are more involved in evaluative reflections about the efficacy and efficiency of their problem-solving strategies, both during and upon completion of task execution. Moreover, students make clear judgments about the perceived quality of their activities. When evaluating their learning outcomes they go beyond merely controlling the completeness of their answers, by also summarising and recapitulating the problem-solving process. In some students, this results in an outline of critical aspects to consider in future problem-solving tasks. In sum, it appears that, at posttest, students have the tendency to step back and consider both the task and their performance, with the aim of guaranteeing both comprehension and, in turn, effective problem solving.

Since the present study was conducted in an authentic setting, an experimental design could not be realised for ethical reasons. Consequently, caution is needed when interpreting the significant changes in students' metacognitive strategy use, for they cannot exclusively be explained by the students' tutoring experience, or the tutoring literature. Alternative explanations for participants' increased and higher-level use of metacognitive activities at posttest can be found in students' (domain-specific) cognitive gains due to the regular curriculum; their experienced need for self-regulation when getting acquainted with the demands of higher education; and in the provided interim support during the RPT intervention, aimed at self-reflection.

Various researchers state that metacognitive skillfulness is strongly related to intellectual ability (e.g. Veenman and Beishuizen 2004) and correlates with students' cognition (e.g. Prins et al. 2006; Sternberg 1998) and learning performance (e.g. Coutinho et al. 2005; Van der Stel and Veenman 2010). Average to high intellectual learners with appropriate (general and domain-specific) knowledge are expected to demonstrate higher metacognitive skill use, often resulting in higher academic achievement. Additionally, Schneider and Pressley (1997) argue that, in the course of cognitive development, the influence of constraints of the information processing system gradually reduces, resulting in more recourses becoming available for metacognitive processes. Moreover, higher levels of both knowledge and experience are assumed to increasingly influence the quality of learners' metacognitive activities (Schneider and Pressley 1997). Taking this into account, it could be expected that our participants' cognitive gains, related to their semester-long learning experiences within different courses of their regular curriculum, might have resulted in an increased use of (higher-quality) metacognitive skills and strategies at posttest. Moreover, the course 'Instructional Sciences' in particular might have had a beneficiary impact on participants' awareness and use of metacognition, for it introduced different theories on learning and instruction, their differentiated benefits and pitfalls, specific learning strategies and characteristics of deep-level learning and problem solving, including metacognition and self-regulation. It seems plausible to assume that students in the present study might have benefitted metacognitively from gaining these insights. An increased awareness of their personal learning and general problem-solving approach might have resulted in the adoption of a desirable, theoretically driven, execution of the think-aloud task.

Another external factor that might have contributed to the reported metacognitive gains at posttest concerns the experienced need of students to manage and self-regulate their learning in higher education. When engaged in academic tasks and learning processes during their first semester at university, students were presumably faced with the requirement for independent self-regulated learning, self-control, and elaborative thinking (Gynnild et al. 2008). It can be assumed that students practiced dealing with these new demands, developing the required metacognitive skills during the course of the semester and demonstrating them at posttest.

Lastly, the potential influence of the interim support, inherent to the RPT intervention, should also be acknowledged. The formal supervision session on the one hand, the spontaneous—informal—peer discussions on experiences with the innovative tutoring programme on the other hand, might have yielded students' awareness of learning and problem-solving strategies (Falchikov 2001). Students' engagement in self-reflection could in its turn not only have optimized students' tutoring behaviours but also their metacognitive development (Veenman et al. 2006).

Limitations and recommendations for future research

Although the present study suggests a potentially positive influence of RPT on higher education students' actual metacognitive regulation, further research is needed to verify and explore these results. In this respect, it is advisable to adapt the current design and opt for an experimental pretest posttest design, involving a control group. The absence of the latter is an important methodological constraint of the present study (Mason 2002). Without a control group, one does not have an objective baseline on which the (differential) outcomes for several groups or an experimental group can be compared, making it hard to claim or even explore the potential beneficiary impact or the specific added value of an instructional approach such as RPT. Additional analyses of videotaped tutoring interactions, resulting in process data on RPT, could also (partially) compensate for the present non-experimental design (Barron 2003; Mason 2002). Direct observation of tutoring behaviours and peer interactions could shed light on the occurrence of metacognitive regulation within the RPT groups and corresponding evolutions in time during the course of the RPT intervention. As such, process data might yield explanations for the statistically generated effects, or at least clarify whether or not the significant increase in students' metacognitive strategy use can be related to their participation in the RPT-programme. Furthermore, the present study has been conducted in a particular setting with a medium-size group of students, studying a specific course in one university setting. Future research should try to replicate the current findings by involving other student populations and alternative instructional settings or knowledge domains.

Limitations have already been suggested in the instruments used. The off-line questionnaire in particular might not have been sensitive enough to accurately measure changes in students' metacognitive knowledge or their awareness of metacognitive strategy use. First, due to reasons of internal consistency, only outcomes on students' general metacognitive knowledge and regulation could be reported. It was, however, not possible to provide accurate differentiated information regarding the theoretical subcomponents within these scales. Second, since the MAI is a self-report instrument, outcomes depend on students' recall of task-performance. When recollecting learning episodes, human memory appears to be rather inaccurate, however (Perfect and Schwartz 2002; Son and Metcalfe 2000). Consequently, student responses might represent a biased perception of what metacognitive knowledge and skills they deploy (Artelt et al. 2003). The current study reiterates the validity discussion about off-line metacognitive measures.

While the think-aloud methodology is generally recognised as a useful source of data that can provide insight in the covert (meta)cognitive structures and processes underlying problem solving (Veenman 2005; Yang 2003), its limitations should also be recognised. A first risk inherent to thinking out loud concerns the problem of reactivity (Branch 2000; Stratman and Hamp-Lyons 1994). Subjects required to verbalise their thoughts while problem solving hear their own voices, which can increase their critical attention to the cognitive activities taking place. As a result, verbal protocols might report on a biased representation of (meta)cognitive processes (Branch 2000). Second, the subject's level of cognitive development can influence the content of verbal protocols: subjects with lower cognitive abilities more easily encounter cognitive load when engaging in academic task execution, needing their full attention to complete the task (Meichenbaum and Biemiller 1992). Consequently, little or no capacity is left for verbalising their thoughts during task execution (Stratman and Hamp-Lyons 1994). Third, verbal reports cover conscious activities from the short-term memory (Yang 2003), implying that automated cognitive processes will not get verbalised by participants (Branch 2000). Despite these limitations, concurrent think aloud protocols still provide more accurate data on subjects' actual use of (meta)cognitive strategies and skills, compared to off-line measurements (Veenman 2005). As already suggested by Meijer et al. (2006) and Veenman (2005), our results provide clear indications for the need to apply multi-method designs in future research, preferably combining multiple concurrent instruments in order to get a full and accurate portrayal of students' metacognition (Moos and Azevedo 2009).

Conclusions

Although metacognition is critical to successfully achieve learning goals, adult learners' metacognitive self-regulation often appears to be insufficient (Maclellan and Soden 2006).

The present study presented a contribution to both the related theory and practice by exploring the potential of a tutoring initiative enhancing higher education students' metacognition. Results show that RPT appears to be a promising instructional approach fostering metacognitive regulation in particular. Comparison of pretest and posttest data more specifically revealed a significantly increased and more varied use of metacognitive orientation, monitoring, and evaluation skills and strategies. Results of the present study raise the question to what degree ongoing interaction processes between peers and particular tutor and/or tutee behaviours are crucial to ensure and optimize the assumed metacognitive benefits of RPT, and therefore offer interesting directions to gain new insights in peers' regulation of their own and each others' cognition. From this perspective, the present study might serve as a starting point for future research in the emerging field of socially shared metacognition (Iiskala et al. 2011) or social regulation (Volet et al. 2009).

Appendix A: Example of an assignment to be solved during a RPT-session

The epistemologic controversy and instructional behaviourism

Learning objectives

- Explaining the epistemologic controversy within instructional science.
- Clarifying the objectivist viewpoint within epistemology.
- Clarifying the constructivist viewpoint within epistemology.
- Situating the behaviouristic vision on learning and instruction within the epistemologic discussion.
- Explaining the basic principles of instructional behaviourism.
- Designing behaviouristic instruction activities and/or learning materials.

Introduction

In instructional science, an epistemologic discussion is going on about the meaning and the nature of knowledge. On the one hand, adherents of objectivism claim the absolute nature of knowledge. On the other hand, adherents of constructivism state that knowledge reflects personal experiences of the learner and stress the importance of individual knowledge construction based on these experiences. Both epistemologic viewpoints result in different visions on learning and instruction.

Part I: Familiarising with the terminology

Which of the following statements is correct? Explain and motivate your group's point of view.

(1) Instructional behaviourism is mainly based on the epistemology of constructivism.
(2) Instructional behaviourism is mainly based on the epistemology of objectivism.

Part II: Applying the terminology

An educational publisher is planning to bring a new biology handbook on the market, inspired by behaviouristic instructional principles. The target group for this handbook consists of first grade secondary school students. The publisher asks the help of your tutoring group to develop one chapter of this new handbook, in which one of the following themes can be presented: (1) the human body; (2) health care; (3) environmental care. The publisher expects your tutoring group to develop some behaviouristic learning materials and learning and instruction activities for this chapter. Consider potential behaviouristic teaching strategies, learning materials for the student, exercise materials, assignments for the students and the teachers. Attached you can find an excerpt from the national biology standards, that can give insight in the specific learning contents within each of the aforementioned themes.

Appendix B: Schematic overview of a stepwise problem solving approach

Tutor card

- Let the tutees brainstorm (broadly).
- Keep the available time in mind.

- In advance
  - Let the group develop an action plan for task execution.
  - Ask questions which suggest a purposeful approach for task execution.
  - Let the tutees decide for themselves how to execute the task.
- In between
  - Check the available time and the progress made.
  - Delegate the task to check the time frequently regularly to a tutee.

- Check whether all tutees are participating actively.
- Check whether the proposed solution is in line with the task demands.
- Check tutees' comprehension by giving feedback and by asking differentiated questions.

Examples of questions:

. What does… mean?
. Summarise the characteristics of… .
. Can you give an example of…?
. In what is … different from/comparable to…?
. Why do you say that?
. Does everyone agree?
. Can you explain why…?
. Can someone elaborate on that?
. What are the strengths/weaknesses of…?
. What can you conclude about …?

- Check whether the final task solution corresponds with the task demands.
- Check to what degree the learning objectives are met by all tutees.
- Check whether tutees still have questions.
- Reflect on the peer collaboration.

Appendix C

See Table 3.

Table 3 Categories of the coding scheme for think-aloud protocols

Orientation	Task analysis	Exploring task subject and constitution	Reading general title (e.g. "I read the title and notice the task will be about forms of evaluation")
			Reading subtitles (e.g. "I see the text consists of a theoretical framework and a case. At least that is what the subtitles tell me")
			Global text screening (e.g. "I globally overlook the text page. I turn the page. But the text seems to be only on this side of the page")
		Detecting task demands	Reading task instructions (e.g. "I check what I have to do by reading the instructions")
			Rereading task instructions (e.g. "I want to reread the instructions to make sure I understand them very well")
			Quoting task instructions (e.g. "Okay, so which forms of evaluation can you find in the case?"
			Paraphrasing task instructions (e.g. "I read the task instructions. For the first question, I have to search in the text which forms or evaluation I can find and then I also have to give an example from the case for each of these forms")
		Becoming aware of one's task perceptions	Reflecting on task-difficulty (e.g. "I am not familiar with the theme so the task will probably be challenging")
			Reflecting on one's self-efficacy (e.g. "I will have to read very carefully because I am normally not good in finding the required information in a text")
			Considering other task perceptions (e.g. "It could be interesting. The theme sounds interesting")
	Content orientation	Generating hypotheses (e.g. The second part of the text will probably show a classroom example, whereas the first part will go into detail about theoretical concepts"	
		Activating prior knowledge (e.g. The theme is not new for me. I have learned about this in previous courses. I am thinking of product and process evaluation now")	
	Structuring task instructions	Underlining core concepts (e.g. I underline 'forms of evaluation' because I have to pay special attention to that")	
		Schematizing task instructions (e.g. I schematically write down what is expected from me")	
Planning	Planning in advance	Planning problem-solving approach	Developing reading plan (e.g. "I will first read the full text")
			Developing action plan (e.g. "I will first read the text and highlight interesting information. Afterwards I will try to solve the questions one by one")

Table 3 continued

			Considering various alternatives for problem-solving (e.g. "I can first read the full text and look at the questions afterwards. Or I can check the questions first and deduce which parts of the text I preferably read, so reading more purposefully")
		Making a time schedule (e.g. "I plan to spend maximum ten minutes on processing the text. Then I have twenty minutes left to solve the questions")	
	Interim planning	Planning problem-solving approach	Developing reading plan (e.g. "I have finished reading the theory. Now I will concentrate on reading the case")
			Developing action plan (e.g. "Before answering the first question I will reread the theoretical framework. Then I will answer both questions")
			Considering various alternatives for problem-solving (e.g. "Now that I solved the first question, I could evaluate my answer immediately by rereading part of the text. Or I could focus on the second question first and evaluate both answers at the end")
		Making a time schedule (e.g. "I notice that I have 15 minutes left. I will take my time to provide an answer for the second question, but make sure there is some time left for evaluation afterwards")	
Monitoring	Monitoring of strategy use	Text structuring	Highlighting important information (e.g. "I underline 'process evaluation' in blue and its purpose in green. I need that information for the first question")
			Making notes (e.g. "Peer evaluation is the sixth form I discover in this text. So I write '6' in the margin and add 'peers'")
			Schematizing (e.g. "I think it is important to keep the overview. It might help for me to make a scheme on the backside of the page. Summative and formative evaluation are the first parts of the scheme")
		Selective text navigation	Focusing on specific text components (e.g. "The second question asks about the functions of evaluation. This will be in the theory so I will only read that part")
			Scanning text (e.g. "I quickly screen the text and pay attention to the word 'function' because that is what I am looking for")
		(Re)reading	Reading aloud [Student rereads (part of) the text literally]
			Rereading important information (e.g. "I reread the part on self-evaluation because it is crucial for the first question")
			Rereading after confusion (e.g. I don't get what I just read. I read it again")
			Adapting reading pace [Student's reading pace is adapted: reading remarkably slower compared to previous sentences]
		Adapting strategy use (e.g. "It does not seem to be necessary to finish reading the full text. I stop and concentrate on solving the questions")	

Table 3 continued

	Comprehension monitoring	Noting lack of comprehension (e.g. "I am afraid I really don't understand this text part"	
		Claiming understanding	Concluding on text content (e.g. "Okay, I get the difference between self and peer evaluation")
			Questioning text content (e.g. "But I wonder if the teacher has no role at all in case of self-evaluation")
		Demonstrating comprehension by repeating	Quoting text contents (e.g. So I understand summative evaluation occurs at the end of a learning cycle, for example an examination")
			Paraphrasing text contents (e.g. "The difference between summative and formative evaluation is in the moment of evaluating")
		Demonstrating comprehension by elaborating	Interpreting text contents (e.g. "I guess peer evaluation helps students to gain more insight in their own comprehension because they are challenged to judge each others' work and probably become more aware of their own insight")
			Relating text contents (e.g. "In the case students can test their knowledge before taking a test. That is a form of self-evaluation")
	Monitoring of progress	Reflecting on strategy use (e.g. "It was a wise idea to structure the text because it is very easy to find the information now")	
		Reflecting on the proposed solution (e.g. "I made a mistake. I am explaining what formative information is but I should provide information on its purpose")	
		Reflecting on the available time and the time schedule (e.g. "I still have enough time for the last question")	
		Reflecting on the quality of the progress made (e.g. "Okay, the work done so far is quite good")	
Evaluation	Evaluating learning outcomes	Checking correctness of the solution (e.g. "I think I made the right interpretations in my first answer")	
		Checking completeness of the solution (e.g. "I gave five examples, that is enough")	
		Checking effectiveness of the solution (e.g. "I just reread my answer. It is quite okay I guess. At least it is an answer to the question")	
		Recapitulating answers (e.g. "For the first question, I read the text and underlined the different forms of evaluation. Then I read the case and searched for examples. That is how I distinguished product, formative, and teacher evaluation")	
	Evaluating learning process	Reflecting on personal efficiency (e.g. "I lost a lot of time with the first question. I didn't read it carefully and misinterpreted. I should have read it better")	
		Reflecting on task difficulty (e.g. "It was tougher than I expected")	
		Reflecting on self-efficacy (e.g. "It went quite well. I am surprised because I am normally not good at keeping my full concentration on a text")	
Off-task			

Appendix D

See Table 4.

Table 4 Examples of units of meaning within a verbal protocol excerpt

Units of meaning in the verbal protocol	Codes
I got two pages. I see it's about assessment and evaluation	Reading general title (orientation)
I first read the instructions to know what I have to do. And it will also make it easier to pay special attention to some text parts [student reads in silence]	Reading task instructions (orientation)
Okay, I have to search for different forms of evaluation in the case. And for the second question, I have to tell for which purposes assessment is used	Paraphrasing task instructions (orientation)
Now I'll read the full text	Developing a reading plan (planning)
[Student starts reading the text out loud] "Evaluation takes a central place in contemporary education. With regard to its functions a distinction is traditionally made between summative and formative evaluation. Summative evaluation takes place at the end of a learning cycle, and checks whether or not students reached one or more leaning objectives; for example, whether certain knowledge or skills are developed, whether a student passed an examination and can start the next class, etc. Formative evaluation, on the other hand, takes place earlier in the learning cycle because it is intended to provide interim feedback to students about ..." [student does not finish the sentence]	Non-metacognitive
Wait a moment (...) so there is summative and formative... but what is the difference?	Noting lack of comprehension (monitoring)
I reread this part [student rereads in silence]	Rereading after confusion (monitoring)
Okay, so summative is at the end, while formative takes place during learning	Paraphrasing text contents (monitoring)
I want ... I am going to underline 'formative' and 'summative' [student underlines in the text]. They are important for the questions	Highlighting important information (monitoring)

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