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SOCIALLY SHARED METACOGNITIVE REGULATION DURING COLLABORATIVE LEARNING PROCESSES IN STUDENT DYADS AND SMALL GROUPS

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Abstract

Traditionally metacognition has been theorised, methodologically studied and empirically tested from the standpoint mainly of individuals and their learning contexts. In this dissertation the emergence of metacognition is analysed more broadly. The aim of the dissertation was to explore socially shared metacognitive regulation (SSMR) as part of collaborative learning processes taking place in student dyads and small learning groups. The specific aims were to extend the concept of individual metacognition to SSMR, to develop methods to capture and analyse SSMR and to validate the usefulness of the concept of SSMR in two different learning contexts; in face-to-face student dyads solving mathematical word problems and also in small groups taking part in inquiry-based science learning in an asynchronous computer-supported collaborative learning (CSCL) environment. This dissertation is comprised of four studies.

In *Study I*, the main aim was to explore if and how metacognition emerges during problem solving in student dyads and then to develop a method for analysing the social level of awareness, monitoring, and regulatory processes emerging during the problem solving. Two dyads comprised of 10-year-old students who were high-achieving especially in mathematical word problem solving and reading comprehension were involved in the study. An in-depth case analysis was conducted. Data consisted of over 16 (30–45 minutes) videotaped and transcribed face-to-face sessions. The dyads solved altogether 151 mathematical word problems of different difficulty levels in a game-format learning environment. The interaction flowchart was used in the analysis to uncover socially shared metacognition. Interviews (also stimulated recall interviews) were conducted in order to obtain further information about socially shared metacognition. The findings showed the emergence of metacognition in a collaborative learning context in a way that cannot solely be explained by individual conception. The concept of socially-shared metacognition (SSMR) was proposed. The results highlighted the emergence of socially shared metacognition specifically in problems where dyads encountered challenges. Small verbal and nonverbal signals between students also triggered the emergence of socially shared metacognition. Additionally, one dyad implemented a system whereby they shared metacognitive regulation based on their strengths in learning. Overall, the findings suggested that in order to discover patterns of socially shared metacognition, it is important to investigate metacognition over time. However, it was concluded that more research on socially shared metacognition, from larger data sets, is needed. These findings formed the basis of the second study.

In *Study II*, the specific aim was to investigate whether socially shared metacognition can be reliably identified from a large dataset of collaborative face-to-face mathematical word problem solving sessions by student dyads. We specifically examined different difficulty levels of tasks as well as the function and focus of socially shared metacognition. Furthermore, the presence of observable metacognitive experiences at the beginning of socially shared metacognition was explored. Four dyads participated in the study. Each dyad was comprised of high-achieving 10-year-old students, ranked in the top 11% of their fourth grade peers (n=393). Dyads were from the same data set as in Study I. The dyads worked face-to-face in a computer-supported, game-format learning environment. Problem-solving processes for 251 tasks at three difficulty levels taking place during 56 (30–45 minutes) lessons were video-taped and analysed. Baseline data for this study were 14 675 turns of transcribed verbal and nonverbal behaviours observed in four study dyads. The micro-level analysis illustrated how participants moved between different channels of communication (individual and interpersonal). The unit of analysis was a set of turns, referred to as an 'episode'. The results indicated that socially shared metacognition and its function and focus, as well as the appearance of metacognitive experiences can be defined in a reliable way from a larger data set by independent coders. A comparison of the different difficulty levels of the problems suggested that in order to trigger socially shared metacognition in small groups, the problems should be more difficult, as opposed to moderately difficult or easy. Although socially shared metacognition was found in collaborative face-to-face problem solving among high-achieving student dyads, more research is needed in different contexts. This consideration created the basis of the research on socially shared metacognition in Studies III and IV.

In *Study III*, the aim was to expand the research on SSMR from face-to-face mathematical problem solving in student dyads to inquiry-based science learning among small groups in an asynchronous computer-supported collaborative learning (CSCL) environment. The specific aims were to investigate SSMR's evolvement and functions in a CSCL environment and to explore how SSMR emerges at different phases of the inquiry process. Finally, individual student participation in SSMR during the process was studied. An in-depth explanatory case study of one small group of four girls aged 12 years was carried out. The girls attended a class that has an entrance examination and conducts a language-enriched curriculum. The small group solved complex science problems in an asynchronous CSCL environment, participating in research-like processes of inquiry during 22 lessons (á 45–minute). Students' network discussion were recorded in written notes (N=640) which were used as study data. A set of notes, referred to here as a 'thread', was used as the unit of analysis. The inter-coder agreement was regarded as substantial. The results indicated that SSMR emerges in a small group's asynchronous CSCL inquiry process in the science domain. Hence, the results of Study III were in line with the previous Study I and Study II and revealed that metacognition cannot be reduced to the individual level alone. The findings also confirm that SSMR should be examined as a process, since SSMR can evolve during different phases and that different SSMR threads overlapped and intertwined. Although the classification of SSMR's functions was applicable in the context of CSCL in a small group, the dominant function was different in the asynchronous CSCL inquiry in the small group in a science activity than in mathematical word problem solving among student dyads (Study II). Further, the use of different analytical methods provided complementary findings about students' participation in SSMR. The findings suggest that it is not enough to code just a single written note or simply to examine who has the largest number of notes in the SSMR thread but also to examine the connections between the notes. As the findings of the present study are based on an in-depth analysis of a single small group, further cases were examined in Study IV, as well as looking at the SSMR's focus, which was also studied in a face-to-face context.

In *Study IV*, the general aim was to investigate the emergence of SSMR with a larger data set from an asynchronous CSCL inquiry process in small student groups carrying out science activities. The specific aims were to study the emergence of SSMR in the different phases of the process, students' participation in SSMR, and the relation of SSMR's focus to the quality of outcomes, which was not explored in previous studies. The participants were 12-year-old students from the same class as in Study III. Five small groups consisting of four students and one of five students (N=25) were involved in the study. The small groups solved ill-defined science problems in an asynchronous CSCL environment, participating in research-like processes of inquiry over a total period of 22 hours. Written notes (N=4088) detailed the network discussions of the small groups and these constituted the study data. With these notes, SSMR threads were explored. As in Study III, the thread was used as the unit of analysis. In total, 332 notes were classified as forming 41 SSMR threads. Inter-coder agreement was assessed by three coders in the different phases of the analysis and found to be reliable. Multiple methods of analysis were used. Results showed that SSMR emerged in all the asynchronous CSCL inquiry processes in the small groups. However, the findings did not reveal any significantly changing trend in the emergence of SSMR during the process. As a main trend, the number of notes included in SSMR threads differed significantly in different phases of the process and small groups differed from each other. Although student participation was seen as highly dispersed between the students, there were differences between students and small groups. Furthermore, the findings indicated that the amount of SSMR during the process or participation structure did not explain the differences in the quality of outcomes for the groups. Rather, when SSMRs were focused on understanding and procedural matters, it was associated with achieving high quality learning outcomes. In turn, when SSMRs were focused on incidental and procedural matters, it was associated with low level learning outcomes. Hence, the findings imply that the focus of any emerging SSMR is crucial to the quality of the learning outcomes. Moreover, the findings encourage the use of multiple research methods for studying SSMR.

In total, the four studies convincingly indicate that a phenomenon of socially shared metacognitive regulation also exists. This means that it was possible to define the concept of SSMR theoretically, to investigate it methodologically and to validate it empirically in two different learning contexts across dyads and small groups. In-depth micro-level case analysis in Studies I and III showed the possibility to capture and analyse in detail SSMR during the collaborative process, while in Studies II and IV, the analysis validated the emergence of SSMR in larger data sets. Hence, validation was tested both between two environments and within the same environments with further cases. As a part of this dissertation, SSMR's detailed functions and foci were revealed. Moreover, the findings showed the important role of observable metacognitive experiences as the starting point of SSMRs. It was apparent that problems dealt with by the groups should be rather difficult if SSMR is to be made clearly visible. Further, individual students' participation was found to differ between students and groups. The multiple research methods employed revealed supplementary findings regarding SSMR. Finally, when SSMR was focused on understanding and procedural matters, this was seen to lead to higher quality learning outcomes. Socially shared metacognition regulation should therefore be taken into consideration in students' collaborative learning at school similarly to how an individual's metacognition is taken into account in individual learning.

Keywords: socially shared metacognitive regulation, collaborative learning, inquiry learning, computer-supported learning, mathematical problem solving, science learning, high-achievers

Tiivistelmä

Metakognitiota on perinteisesti tarkasteltu teoreettisesti, tutkittu metodologisesti ja testattu empiirisesti yksilön oppimisessa. Tässä väitöskirjassa metakognitiota analysoidaan laajemmasta näkökulmasta. Väitöskirjan tavoitteena oli tutkia sosiaalisesti jaettua metakognitiivista säätelyä oppilasparien ja –pienryhmien yhteisöllisissä oppimisprosesseissa. Tavoitteena oli erityisesti laajentaa yksilön metakognition käsitettä sosiaalisesti jaettuun metakognitiiviseen säätelyyn, kehittää menetelmiä sosiaalisesti jaetun metakognitiivisen säätelyn analysoimiseksi ja validoida käsite kahdessa erilaisessa oppimisympäristössä; oppilasparien matematiikan sanallisessa ongelmanratkaisussa kasvokkain ja pienryhmien luonnontieteen ongelmanratkaisussa tietokoneavusteisessa yhteisöllisessä tutkivassa oppimisessa. Väitöskirja koostuu neljästä tutkimuksesta.

Tutkimuksen I tavoitteena oli tarkastella, ilmeneekö metakognitio oppilasparien ongelmanratkaisussa ja jos ilmenee, miten sekä kehittää menetelmä metakognitiivisen tietoisuuden, valvonnan ja säätelyn analysoimiseksi ongelmanratkaisuprosessissa sosiaalisella tasolla. Tutkimukseen osallistui kaksi oppilasparia. Oppilaat olivat 10-vuotiaita ja taitavia erityisesti matematiikan sanallisessa ongelmanratkaisussa ja luetun ymmärtämisessä. Tutkimus oli yksityiskohtainen tapaustutkimus. Aineisto koostui 16 (30–45 minuutin) oppitunnin ajalta parien videonauhoitetusta ja litteroidusta työskentelystä kasvokkain sekä haastatteluista (myös vihjeistetty haastattelu, 'stimulated recall'). Parit ratkaisivat tietokonepeliympäristössä yhteensä 151 sanallista matemaattista ongelmaa eri vaikeustasoilta. Analyysissä käytettiin vuorovaikutuksen etenemisen kaaviota. Tulokset osoittivat metakognition ilmenevän yhteisöllisessä oppimisessa tavalla, jota ei voida selittää vain yksilön metakognition käsitteellä. Tutkimuksessa ehdotettiin käytettäväksi 'sosiaalisesti jaetun metakognition' käsitettä. Tulosten mukaan sosiaalisesti jaettu metakognitio ilmenee erityisesti haastavissa ongelmissa. Myös parien väliset pienet sanalliset ja sanattomat viestit olivat tärkeitä sosiaalisesti jaetun metakognition prosessissa. Lisäksi toiselle oppilasparille muodostui systeemi, jossa he jakoivat metakognitiivista säätelyä omien oppimisen vahvuuksiensa pohjalta. Tulosten perusteella ehdotettiin, että metakognitiota on tärkeää tutkia prosessin ajan ja laajemmassa aineistossa. Tämän tutkimuksen tulokset loivat pohjan väitöskirjan toiselle tutkimukselle.

Tutkimuksen II tavoitteena oli tarkastella, voidaanko sosiaalisesti jaettua metakognitiota tunnistaa systemaattisesti eri vaikeustason tehtävissä oppilasparien matematiikan sanallisissa ongelmanratkaisuissa sekä tutkia metakognition tehtäviä (funktio) ja kohdetta (fokus). Lisäksi tarkasteltiin metakognitiivisen kokemuksen ilmenemistä sosiaalisesti jaetun metakognition prosessien alussa. Parit muodostuivat kahdeksasta taitavasta oppilaasta, jotka sijoittuivat parhaimman 11%:n joukkoon (n=393). Parit olivat samasta tutkimusjoukosta kuin tutkimuksessa 1. Parit työskentelivät tietokonepelillisessä ympäristössä ja ratkaisivat yhteensä 56 (30–45 minuutin) oppitunnin aikana 251 tehtävää kolmelta vaikeustasolta. Ongelmanratkaisuprosessit videonauhoitettiin ja litteroitiin. Aineistona oli parien sanallisen ja sanattoman käyttäytyminen pohjalta 14 675 puhtaaksikirjoitettua puheenvuoroa. Mikrotason analyysi havainnollisti oppilaiden kommunikoinnin liikkumisen eri tasojen välillä (yksilöllinen ja yksilöiden välinen). Analyysiyksikkönä oli puheenvuorojen muodostama kokonaisuus, episodi. Rinnakkaiskoodaus osoitti, että sosiaalisesti jaettu metakognitio, sen tehtävät, kohteet ja metakognitiiviset kokemukset voidaan analysoida luotettavasti myös isommassa aineistossa. Tulokset vahvistivat, että ongelmien tulisi olla mieluummin vaikeita kuin keskitasoisia tai helppoja. Tarkastelu oli rajattu taitavien oppilasparien kasvokkain tapahtuvaan yhteisölliseen ongelmanratkaisuprosessiin. Siksi tutkimusta tarvitaan myös eri kontekstissa, mikä loi pohjan tutkimuksille III ja IV.

Tutkimuksen III tavoitteena oli laajentaa sosiaalisesti jaetun metakognition tarkastelua parien matemaattisesta ongelmanratkaisusta kasvokkain pienryhmien tietokoneavusteiseen tutkivaan yhteisölliseen luonnontieteen oppimiseen. Tavoitteena oli tutkia sosiaalisesti jaetun metakognitiivisen säätelyn esiintymistä ja tehtäviä tietokoneavusteisessa yhteisöllisessä oppimisessa ja sen eri vaiheissa. Lisäksi tutkittiin pienryhmän oppilaiden osallistumista säätelyyn. Yksityiskohtainen tapaustutkimus kohdistui neljän 12-vuotiaan tytön muodostamaan pienryhmään. Oppilaat opiskelivat kielipainotteisella luokalla, jonne oli sisäänpääsykoe. Pienryhmä ratkaisi monimutkaisia luonnontieteellisiä ongelmia asynkronisessa tietokoneavusteisessa yhteisöllisen ja tutkivan oppimisen ympäristössä 22 (á 45 minuuttia) oppitunnin ajan. Aineisto muodostui oppilaiden verkkokeskusteluun kirjoittamista viesteistä (N=640). Analyysiyksikkönä oli viestiketju. Rinnakkaiskoodauksessa eri arvioitsijoiden yksimielisyys oli huomattava. Tulokset osoittivat sosiaalisesti jaetun metakognitiivisen säätelyn ilmenevän myös pienryhmien asynkronisessa tietokoneavusteisessa yhteisöllisessä luonnontieteen oppimisessa. Näin tutkimuksen III tulokset olivat yhdenmukaisia tutkimusten I ja II tulosten kanssa osoittaen, ettei metakognitiota voida redusoida vain yksilön tasolle. Tulokset vahvistivat myös, että sosiaalisesti jaettua metakognitiivista säätelyä tulisi tarkastella prosessin ajan, sillä säätely vaihteli prosessin aikana ja säätelyn ketjut olivat osittain päällekkäisiä. Vaikka säätelyn tehtävät olivat sovellettavissa pienryhmien asynkroniseen tietokoneavusteiseen yhteisölliseen oppimiseen, vallitseva tehtävä oli erilainen kuin parien matematiikan sanallisten tehtävien ratkaisemisessa (tutkimus II). Eri analyysimenetelmät täydensivät toisiaan. Tulosten pohjalta esitetään, ettei ole riittävää koodata yksittäisiä viestejä tai tarkastella, kenellä oppilaista on eniten viestejä säätelyn ketjuissa vaan on tärkeää tarkastella myös viestien välisiä yhteyksiä. Tutkimuksen tulokset pohjautuivat analyysiin yhdestä pienryhmästä. Sen vuoksi tutkimuksessa IV tarkastellaan useampia pienryhmiä sekä säätelyn kohdetta, mitä tutkittiin myös oppilaiden työskennellessä kasvokkain.

Tutkimuksen IV tavoitteena oli tutkia sosiaalisesti jaetun metakognitiivisen säätelyn ilmenemistä useammassa pienryhmässä asynkronisessa tietokoneavusteisessa yhteisöllisessä tutkivan oppimisen prosessissa luonnontieteen kontekstissa. Tavoitteena oli tutkia erityisesti säätelyn ilmenemistä prosessin eri vaiheissa, oppilaiden osallistumista säätelyyn ja säätelyn kohteen yhteyttä prosessin tuloksen laatuun, jota ei ollut aikaisemmin tutkittu. Osallistujina olivat 12-vuotiaat oppilaat samasta koululuokasta kuin tutkimuksessa III. Viisi pienryhmää koostui neljästä ja yksi pienryhmä viidestä oppilaasta (N=25). Pienryhmät ratkaisivat avoimia luonnontieteen ongelmia asynkronisessa tietokoneavusteisessa oppimisympäristössä osallistuen tutkivan oppimisen työskentelyyn 22 tunnin ajan. Aineistona olivat pienryhmien verkkokeskustelut, jotka muodostuivat oppilaiden kirjoittamista viesteistä (N=4088). Analyysiyksikkönä oli viestiketju samoin kuin tutkimuksessa III. Yhteensä 332 viestiä luokiteltiin osaksi 41 sosiaalisesti jaetun metakognitiivisen säätelyn ketjua. Rinnakkaiskoodauksessa verrattiin kolmen arvioijan sosiaalisesti jaetun metakognitiivisen säätelyn luokituksia analyysiprosessin eri vaiheissa. Yksimielisyys oli vähintään hyvä. Tulosten analysoinnissa käytettiin useita analyysimenetelmiä. Tulokset osoittivat sosiaalisesti jaetun metakognitiivisen säätelyn ilmenevän kaikkien pienryhmien oppimisprosesseissa. Tulokset eivät kuitenkaan osoittaneet säätelyn kehityssuunnan muuttumista prosessin aikana. Säätelyn ketjuun sisältyvien viestien lukumäärät erosivat merkitsevästi toisistaan sekä prosessin eri vaiheissa että pienryhmien välillä. Oppilaiden osallistumisessa ja ryhmien välillä oli eroja. Tulokset myös osoittivat, että säätelyn lukumäärä prosessin aikana tai osallistumisen rakenne eivät selittäneet ryhmien lopputulosten laadun eroja. Sen sijaan säätelyn kohdistuminen ymmärtämiseen ja etenemiseen tuki korkean tason lopputuloksen saavuttamista kun taas kohdistuminen yksittäisiin asioihin ja etenemiseen johti heikkoon tulokseen. Tulosten pohjalta säätelyn kohteen esitetään olevan olennainen tekijä lopputulosten laadussa. Lisäksi ehdotetaan monien analyysimenetelmien käyttöä.

Yhteenvetona neljä tutkimusta osoittaa luotettavasti metakognition ilmenevän myös sosiaalisesti jaettuna metakognitiivisena säätelynä. Sosiaalisesti jaetun metakognitiivisen säätelyn käsite oli

mahdollista määritellä teoreettisesti, tutkia metodologisesti ja validoida empiirisesti kahdessa erilaisessa oppimisympäristössä oppilasparien ja -pienryhmien työskentelyssä. Mikrotason analyysi tutkimuksissa I ja III osoitti, että metakognitiivinen säätely voidaan määritellä yhteisöllisen oppimisen aikana yksityiskohtaisesti ja tutkimukset II ja IV validoivat käsitteen suuremmassa aineistossa. Siten validointia testattiin sekä kahdessa ympäristössä että samassa ympäristössä suuremmassa määrässä tapauksia. Osana tätä väitöskirjaa määriteltiin myös säätelyn tehtävät ja kohteet sekä osoitettiin metakognitiivisen kokemuksen tärkeys säätelyprosessin alussa. Tulosten perusteella ehdotetaan, että säätelyn näkyväksi tekemiseksi tehtävien tulisi olla melko haastavia. Oppilaiden osallistumisen havaittiin eroavan oppilaiden ja ryhmien välillä ja monien menetelmien käytön täydentävän toistensa tuloksia. Lopuksi säätelyn kohdistumisen ymmärtämiseen ja etenemiseen todettiin olevan yhteydessä pienryhmän hyvään oppimistulokseen. Lopputuloksena esitetään, että sosiaalisesti jaettu metakognitiivinen säätely pitäisi huomioida oppilaiden yhteisöllisessä oppimisessa samalla tavalla kuin yksilön metakognitio huomioidaan yksilön oppimisessa.

Asiasanat: sosiaalisesti jaettu metakognitiivinen säätely, yhteisöllinen oppiminen, tutkiva oppiminen, tietokoneavusteinen oppiminen, matematiikan ongelmanratkaisuprosessi, luonnontieteen oppiminen, taitavat oppilaat

Contents

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In Turku, August 2015

Tuike Iiskala

List of empirical studies

This doctoral thesis is based on the following four studies reported in four original articles. The studies are referred to in the text by their Roman numerals:

Study I Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology, 1*, 147–178.

Study II Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction, 21*, 379–393.

Study III Iiskala, T., Volet, S., Lehtinen, E., & Vauras, M. (2015). Socially shared metacognitive regulation in asynchronous CSCL in science: Functions, evolution and participation. *Frontline Learning Research, 3*, 77–110.

Study IV Iiskala, T., Lehtinen, E., Vauras, M., & Volet, S. (2015). *Socially shared metacognitive regulation, students' participation, and quality of computer-supported collaborative inquiry learning*. Manuscript submitted for publication.

1. Introduction

Applying Granott's (1998) metaphor, the properties of a water molecule differ from its constituent atoms, that is, from the properties of oxygen and hydrogen. This means that water forms its own unique entity. Similarly, in football or in other team sports, the team is more than the sum of its players and a single player cannot form a team separately from the other players. Likewise, in a music group, a single musician does not form an orchestra or a band, and neither does a single actor form a theatre group. Similarly, in collaborative learning at school, a single student does not form a dyad or a small group alone. The idea of a dyad or a small group in learning has commonalities with a football team, a music or theatre group or even the property of water.

For example, the idea of the football team is that each player is connected with the other players and together, they form a team, whose aim is – as a team – to proceed towards a common goal. A player passes a ball to another player who passes it further. A player's moves are dependent on and connected with the moves of the ball and other players. Each player within a team adapts his or her own play to the conditions of the moment. Hence, referring to Kirsh (2005), the team orchestrates its process moment-by-moment so that each player is coordinated with the team. This means that as a part of the team, it is not enough that the player is focusing just on his or her own activity. Instead, the team has to regulate the ongoing situation as a whole. Thus, the team regulates its process according to the current and changing situation. The winner or the loser is the team. Further, a music group forms an entity when musicians aim to play coherently with each other (see Kirsh, 2005). As Granott (1998, p. 43) aptly puts it 'in a musical ensemble, participants […] weave together individual activities into interdependent, common processes. The activity and knowledge of each gains meaning only in relation to the activity and knowledge of others in the ensemble'. In a similar vein, Sawyer and DeZutter (2009) have indicated that in an improvisation within a theatre group, a collective product cannot merely be divided into the contributions of single actors. Instead, the complete meaning of an individual's contribution is determined in the flow of the process in relation to the contributions of other actors (Sawyer & DeZutter, 2009). In line with the above described examples, in students' collaborative learning within a dyad or small group, each move made by a student is dependent on the current understanding and response by the other student/s and the interdependent students determine together the direction of the learning process (King, 1998, 1999). This means that the group interdependence of cognitions and behaviours become *shared* (Salomon & Globerson, 1989).

Further, it has been suggested that good academic learning is an active and productive process involving *metacognitively* guided processing (Griffin, McGaw, & Care, 2012; Salomon & Globerson, 1989; Salomon & Perkins, 1998; Sawyer, 2006). This constitutes, for example, a learner's knowledge of cognitive processes and orchestration of them towards some goal (see Flavell, 1976), in which case metacognition is 'defined as any knowledge or cognitive activity that takes as its cognitive object, or that regulates, any aspect of any cognitive activity' (Flavell, 2000; see also Flavell, Miller, & Miller, 1993). For instance, a learner is keeping track of what she or he is doing during the learning process and how well things are going during that process (see Schoenfeld, 1987). The role of metacognition has been highlighted because metacognition has been seen as a basic characteristic of efficient thinking in various learning situations (Brown, 1978, 1980; Flavell, 1979; Flavell et al., 1993; van der Stel & Veenman, 2008; Veenman, 2008) and as a sign of high-level thinking (Meichenbaum & Biemiller, 1998). The significant role of metacognition is supported by research (e.g. meta-review from Wang, Haertel, & Walberg, 1990), which has shown that metacognition is one of the most powerful determinants in successful academic learning. Hence, it has been argued that school settings should serve as a base for the regulation of learning where the aim is towards intentional and conceptually oriented learning (Bransford, Brown, & Cocking, 2000; Griffin et al., 2012; Lehtinen, 2010; Salomon & Perkins, 1998; Sawyer, 2006). However, this has not always been the case. Although metacognition can be seen as a prerequisite, a *sine-qua-non* constituent of regulation in social interaction, such as in collaborative learning (Efklides, 2008), there is a concern, for example, about collective entities' lack of awareness of their learning from a metacognition point of view (see e.g. Goos, Galbraith, & Renshaw, 2002; Hogan, 2001; Salomon & Perkins, 1998; Volet, Vauras, & Salonen, 2009b). Hence, if we were still talking in terms of the metaphor of football and music, the main focus of learning research has been on the individual sport, such as on sportsmen and sportswomen, or on artists side-by-side, rather than on the sports team or the orchestra or a band in the sense of how these entities metacognitively regulate their own process.

Combining these two aspects of learning, namely, students' shared processes within a group on the one hand and the metacognitively guided process on the other, the aim of this dissertation is to explore *socially shared metacognitive regulation (SSMR)* in collaborative learning processes within student dyads and small groups. SSMR is used to refer to *the participants' goal-directed consensual, egalitarian and complementary regulation of joint cognitive processes in the collaborative learning context.* Hence, the focus is on the regulation aspects of metacognition (for regulation of cognition, see Brown, 1987; for metacognitive skills, see Brown & DeLoache, 1983). This means that the role of metacognition is to regulate the ongoing learning process towards a goal (see Wertsch, 1977) by having 'a bird's-eye view' of the process. Consequently, from the SSMR point of view, the learning partners interdependently and jointly regulate the ongoing cognitive learning process towards a common goal. In this dissertation, a metacognitive perspective is adopted. Hence, the concept of socially shared *metacognitive* regulation focuses specifically on the metacognitive viewpoint, which means that the regulation of other things, such as motivation and emotion, are not under scrutiny.

1.1 From individual metacognition to socially shared metacognitive regulation

1.1.1 Individual metacognition

The concept of metacognition has traditionally referred to knowledge of cognition and regulation of one's own cognitive processes (see Flavell, 1976, 2000; Flavell et al., 1993; Brown, 1978, 1987). Hence, research on metacognition has typically focused on an *individual*'s learning. This can be seen as a part of a wider trend of research on cognition and learning where the individual's perspective has been highlighted (see Levine, Resnick, & Higgins, 1993; Salomon & Perkins, 1998; Sfard, 1998). Also, research on metacognition has been seen to have its origins in the field of metamemory research (a person's knowledge and awareness of memory, e.g. Flavell, 1971; Flavell & Wellman, 1975; Kreutzer, Leonard, & Flavell, 1975), where interest has been on an individual's mind (Dinsmore, Alexander, & Loughlin, 2008). This has also channelled research on metacognition into studying an individual's thinking. As a consequence, there is an extensive range of empirical studies showing the importance of metacognition in individual learning. The importance of metacognition in academic performance has been indicated, for example, in mathematics (De Corte, Verschaffel, & Op't Eynde, 2000; Desoete & Veenman, 2006), reading (Annevirta, Laakkonen, Kinnunen, & Vauras, 2007; Garner, 1987; Kinnunen & Vauras, 1995; Paris & Jacobs, 1984) and science (Akyol, Sungur, & Tekkaya, 2010; Peters & Kitsantas, 2010; Zohar & Dori, 2012). Further, one has learnt from previous research on individual metacognition that the learning processes of high- and low-achieving students differ from each other such that high-achieving students display metacognition during the entire process unlike low-achieving students (Meichenbaum & Biemiller, 1998). Similarly, experts (e.g. mathematician) and novices (e.g. students) have been documented as differing from each other such that the expert had an efficient use of regulation during the learning process (see Schoenfeld, 1987). Metacognitive skilfulness appears alongside the learning process, for instance, as reflections on task assignments and expectations ('What am I supposed to know?'), keeping track of the process and mindfully changing the plan if needed, comprehension monitoring, criticizing one's own actions, and as elaboration, for example, on the content of the task ('That's not clear….') (see Veenman & Beishuizen, 2004). In sum, on the basis of previous metacognition research, it can be argued that metacognition research has, both conceptually and empirically, mainly been understood as an individualistic construct. However, from an SSMR point of view, research on individual metacognition is of critical importance since it has brought out the meaning of metacognition in learning and highlighted the issues that are connecting to metacognition, evidenced at the individualistic level. Hence, research on individuals can be seen as a trailblazer in the field of metacognition.

However, although the focus of metacognition research has been on the individual, already the first studies on metacognition also referred to the social aspects, such as role-taking (Brown, 1978), social learning theory (Flavell, 1979, 1981), social cognition and the role of metacognition in communication (Brown, 1978; Flavell, 1979, 1981). For example, Flavell (1976) presented as an example of metacognition how other people can be used in checking one's own understanding ('I think to ask someone about E to see if I have it right.', p. 232) and how one can also seek to store and retrieve information in other people's minds. Further, metacognition has been seen to play an important role in communication (e.g. Flavell, 1979, 1981). As an educational implication, it has been suggested that children be taught to be aware of the goal of communication and to monitor the progress in communication, and to detect problems in understanding speakers and in getting listeners to understand them (Flavell, 1981). There were also built-in social aspects in Flavell's (1979, 1981) conceptions of things that metacognitive thinking includes, for instance, a person's knowledge about other people as cognitive processors (e.g. a person's knowledge of inter-individual differences between people as a part of metacognition). Moreover, the meaning of sociohistorical context has been recognised as affecting the development and change of cognitive activity displayed by an individual (e.g. Brown, 1978). Also, in some cases, the topic has been social (e.g. knowledge that information can sometimes be insufficient in knowing what kind of person another person is) (Flavell, 1979). However, in the above-mentioned cases, the social point of view in metacognition is primarily seen to be harnessed for the sake of the individual and to serve individual learning, not for common sake or from the viewpoint of collaborative learning. In fact, this individual view is supported by Flavell (2000; Flavell & Miller, 1998) and colleagues who have pointed out that in metacognition research the interest has primarily been in a person's own rather than another person's mind and therefore, serving basically non-social rather than social goals.

1.1.2 Other- and co-regulation

Previous research has also highlighted the role of interaction in metacognition, pointing out that regulation of cognition must concern how regulation is manifested both in social ('inter-psychological') and individual ('intra-psychological') functioning (e.g. Wertsch, 1977). However, the aim of interaction is seen to enhance an individual's learning process. This kind of interaction can be described as asymmetric between the partners and therefore, is referred as *other-regulation* (Whitebread, Bingham, Grau, Pino Pasternak, & Sangster, 2007; Whitebread et al., 2009). The idea of other-regulation is that the learning is fostered by the activity of the supportive other (see Brown, Bransford, Ferrara, & Campione, 1983). The supportive other can be, for example more capable adults (e.g. teacher, parent) (e.g. Wertsch, 1977), peers (e.g. other student/s within a group) (e.g. King, 1998, 1999; Rogat & Adams-Wiggins, 2014) or other sources/artefacts (e.g. technology) (e.g. Nesbit et al., 2006) as well as a mix of these (e.g. Azevedo, Winters, & Moos, 2004). By means of interaction, the individual/s are thought to internalise skills within the zone of proximal development (ZPD, Vygotsky, 1978) by the way of scaffolding (see Wood, Bruner, & Ross, 1976), being later capable of carrying out the learnt skills independently. Hence, the goal is to proceed towards individual regulation (King, 1997, 1998).

Interestingly, other-regulation can also occur in a student dyad and in small group learning. For example, in reciprocal teaching (Brown & Campione, 1996; Brown & Palincsar, 1989; Brown et al., 1983; Palincsar & Brown, 1984), students' comprehension monitoring is supported and the regulatory role is internalised during the group's learning process. The idea is to give intentional social support to individuals within each student's own ZPD when a group of students with the help of a teacher externalise thinking and are jointly responsible for understanding and evaluation of the learning material and construct a joint meaning in regard to it. In the process, novices carry greater responsibility for more expert roles, each student leads the discussion in turn, and students can participate at the extension where they are able and obtain advantage from the other students in the group. Rather similarly, King's (1998, 1999) research highlights reciprocity between the learners based on the idea that tutoring partners mediate each other's learning, with the aim of promoting higher level complex learning. In her model, students are engaged in an interchange of tutor and tutee roles, where they metacognitively scaffold each other's thinking and learning progressively to higher levels. In both models, mutual appropriation (Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, 1993; Brown & Campione, 1994; King, 1998) is important so that students share thinking in a bi-directional manner. As Brown and colleagues (1993) argued, mutual appropriation is manifested within a ZPD. In these cases, the issue can be seen as one of the social mediation of individual learning (see Salomon & Perkins, 1998). From the SSMR viewpoint, research on other-regulation in dyadic and small group settings pays important attention to the interdependence of interacting learners and how they challenge each other's thinking. Further, thoughts in interaction have been understood, in a manner of speaking, to operate as if they were external objects (i.e. objectivisation, see Salomon & Perkins, 1998). In sum, the need to belabour both a group's ongoing learning process and transactionality during the process has been highlighted.

Further, recent investigations (Rogat & Adams-Wiggins, 2014; Rogat & Linnenbrink-Garcia, 2011; Volet et al., 2009b; Whitebread et al., 2007) have extended the concept of other-regulation to cover also small groups without a limitation to an expert–novice interaction and where peers do not have any predetermined roles. In this sense, there would be a possibility for symmetric collaboration. However, it has been found that in small student groups, one student can regulate the group by guiding others' conceptual understanding but also by controlling and managing others, for example determining what should be done next in the task (Rogat & Adams-Wiggins, 2014). Hence, the whole group does not necessarily have a shared goal (Schoor, Narciss, & Körndle, 2015). Also, previous research (Rogat & Adams-Wiggins, 2014; Rogat & Linnenbrink-Garcia, 2011; Whitebread et al., 2007) has shown that other-regulation can occur temporarily. This means that different types of regulation can vary, that is, individual regulation, other-regulation and SSMR can alternate during the process or these forms of regulation can be overlapping. For example, Whitebread and colleagues (2007) have empirically differentiated these types of regulation during the process, showing the emergence of all of them. However, it is important to remember that individual metacognitive regulation within a group is not the same as individual metacognitive regulation in a solo learning situation (Volet, Summers, & Thurman, 2009a); rather, it represents how individuals regulate their own learning activities within the group (Grau & Whitebread, 2012; Whitebread et al., 2007, 2009). Also, Rogat and Adams-Wiggins (2014) have indicated how other-regulation can, in some cases, facilitate the process towards co-equal regulation and sustain a shared focus on the task. However, in other cases, other-regulation can also be used only to ensure one's own position in the group's processes (Rogat & Adams-Wiggins, 2014). In all, other-regulation can be seen as important from the SSMR viewpoint in the sense that it can lead towards SSMR during the learning process and keep the group members focused on the task. However, although other-regulation in small-group learning can attempt to proceed towards a group's good, there is still asymmetry in the interaction, since the load of metacognitive regulation is not equally shared between the students, but instead, is resting on a single student's shoulders.

The concept of *co-regulation* has also been used in research on students' interactions in learning. Although the prefix 'co' refers to regulating together, the focus is still associated with self-regulation. For example, Hadwin and Oshige (2011) have brought out that co-regulation is a transitional process towards a person's self-regulation. This means that during co-regulation, students share a common learning plane and regulation is shared between a person and other person/s, yet the emphasis is on the appropriation of self-regulation in response to a social and cultural context and orientation towards it (Hadwin & Oshige, 2011). Further, co-regulation is thought to occur within the ZPD (Hadwin & Oshige, 2011). According to this line of thought, the concepts of co-regulation and other-regulation can be seen as coming close to each other. For example, appropriation of self-regulation within the ZPD is at the core of both. However, Rogat and Adams-Wiggins (2014, p. 880) suggest also the idea of directive other-regulators (controlling and managing others), to be included in the concept of other-regulation, in addition to guiding, which are the foci, for example, in the co-regulation as envisaged by Hadwin and Oshige (2011) (see Rogat & Adams-Wiggins, 2014). Further, one view is that in co-regulation (Hadwin, Järvelä, & Miller (2011) use the concept of 'co-regulated learning'), peers do not regulate the collective process towards a joint goal; rather, they are seen to regulate each other's metacognitive and cognitive actions (Hadwin et al., 2011). Therefore, at its core, it is still essentially seen as a mediation process aiming at individual regulation. However, like other-regulation, co-regulation is important from the SSMR standpoint, for example, because the results of research have suggested that co-regulation can lead to a common ground in the event that multiple partners are engaged in dialogue where a high-level of content knowledge is dealt with (Lajoie & Lu, 2012).

1.1.3 Socially shared metacognitive regulation (SSMR)

In keeping with the general trend in learning research, the emphasis in metacognition research on the learning of an individual has increasingly been viewed as inadequate (e.g. Efklides, 2008; Goos et al., 2002; Hacker & Bol, 2004; Hadwin & Oshige, 2011; Hadwin et al., 2011; Hogan, 2001; Hurme, Merenluoto, & Järvelä, 2009; Jermann, 2004; Jermann & Dillenbourg, 2008; Khosa & Volet, 2014; Molenaar, Chiu, Sleegers, & van Boxtel, 2011; Molenaar, Roda, van Boxtel, & Sleegers, 2012; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003; Whitebread et al., 2007; Winne, Hadwin, & Perry, 2013). For example, from the perspective of socially shared cognition, human thinking and social functioning are seen as essential aspects of one another and social and cognitive aspects as merged (see Resnick, 1991). In line with this view, the need to reconceptualise metacognition as social practice has been highlighted (Goos et al., 2002). This means that to understand the group's learning process, it is crucial to investigate specifically how metacognition operates at a group level (Goos et al., 2002; Hogan, 2001). As emphasised earlier in this theoretical introduction, a group cannot be viewed merely as a collection of individuals; rather, it should be viewed as a whole organism that regulates its learning process (Hogan, 2001). The importance of metacognitive regulation in a successful group's learning process has been supported by previous research showing that successful – unlike unsuccessful – problem-solving and knowledge building processes in dyads and small groups consist of students' metacognitive contributions (Artzt & Armour-Thomas, 1992; Eizenberg & Zaslavsky, 2003), such as joint monitoring (Barron, 2000; Hmelo-Silver, Chernobilsky, & Jordan, 2008). This means, for example, that learners monitor the group's progress in regard to what else the group has to do (e.g. revisions) or whether it should move on (Hmelo-Silver et al., 2008). This previous research on the importance of metacognition in groups also seems to support the evidence obtained from research on an individual metacognition. However, collaborative learning processes in student dyads and small groups have long been an unexplored area from the point of view of metacognition. Therefore, the focus of this dissertation is to explore specifically metacognition during collaborative learning process in student dyads and small groups.

In this research, the concept of *socially shared metacognitive regulation* (SSMR) is adopted. In SSMR, the focus is on the cognitive collaborative learning process in dyads and small groups, in which students of the dyad/small group jointly regulate the process – focusing on the task and the joint activities leading to a common goal; the students' regulatory activities are conceptualised as being reciprocal, that is, dependent on each other and shared. Moreover, the learning process is theorised to proceed through students' regulatory involvement so that together they affect the course of the process. Hence, metacognition is not considered merely through single individual actions; rather, a dyad/small group is seen as a core where individual actions are viewed together, so that metacognition is manifested as socially shared. In seeing it like this, the focus of metacognition moves away from individual cognitive processes towards the dyad's/small group's ongoing collaborative cognitive learning process, putting the focus on the dyad/small group (see Iiskala, Vauras, & Lehtinen, 2004; Iiskala, Vauras, Lehtinen, & Salonen, 2011; Iiskala, Volet, Lehtinen, & Vauras, 2015; Iiskala, Lehtinen, Vauras, & Volet, 2015; see also Vauras et al., 2003).

In SSMR, the focus is on the regulation aspects of metacognition (i.e. for regulation of cognition, see Brown, 1987) which is also referred to as metacognitive skills (see Brown & DeLoache, 1983). In the present research, the concept of regulation of cognitive processes is used instead of the concept metacognitive skills, since the concept of regulation itself highlights that the issue is about regulation. However, the meaning is consistent with Efklides (2006) and Veenman (2011b), who define metacognitive regulation as a procedural component of metacognition and which they refer to as metacognitive skills. Metacognitive regulation concerns actual metacognitive activity (Veenman, 2005), that is, executive function for regulating cognitive activities (see Brown et al., 1983; Flavell & Miller, 1998). Hence, metacognitive regulation refers to activities that are used to oversee learning (Brown, 1987; Brown, et al., 1983; see also Schoenfeld, 1987). These kinds of activities are, for example, planning, monitoring of task requirements/demands, checking and regulating of cognitive processing, and evaluating of the outcome (Efklides, 2006). This means that metacognition interprets and supervises the cognitive system, acting as a kind of intelligent evaluator of its own activity (see Brown et al., 1983). It is what is done to control cognition (Efklides, 2006) throughout the whole process (Wertsch, 1977). For instance, the quality of the ongoing process is monitored: whether the process is progressing towards a desired goal (e.g. reviewing progress on task and checking detection of errors) and controlled as a result of monitoring (e.g. changing strategies as a result of previous monitoring) (Whitebread et al., 2009). Therefore, monitoring of the ongoing learning process is seen as a part of the metacognitive regulation.

Regulation from an individual metacognition viewpoint can consist of checking the results of one's actions ('did it work?'), monitoring one's ongoing activity ('how am I doing?'), reality testing ('does this make sense?') and a variety of other activities by a person who is coordinating and controlling deliberate attempts at learning and solving a problem (Brown & DeLoache, 1983). In SSMR, these activities are shared between learners, in which case the learners together regulate their collaborative cognitive learning process, such as asking 'did it work?', 'how are we doing?', 'does this make sense for us?' and so on. This means that the viewpoint of regulation is 'we' (Järvelä & Hadwin, 2013; Volet et al. 2009b, Whitebread et al., 2007; Winne et al., 2013). However, it is not enough that one learner regulates 'how are we doing?' Hence, the word 'we' does not alone automatically make the regulation a form of SSMR. Indeed, a single group member's regulation regarding the group can be seen as other-regulation (Rogat & Adams-Wiggins, 2014). Instead, in SSMR, metacognitive regulation has to be carried out interdependently, resting on the shoulders of at least two learners (Khosa & Volet, 2014; Rogat & Adams-Wiggins, 2014). This means that multiple participants jointly regulate their collective activity (Hadwin & Oshige, 2011). In this process, the action of one student does not become a part of the group's common activity until another/other group member/s react to it; proceeding in the group's process results from interactions among participants and must be analysed as an ongoing social process; in that sense, the group's process cannot be reduced to a participant's activity alone (Sawyer & DeZutter, 2009). If no-one reacts to one's attempt to metacognitively regulate the group's common process, this regulation is excluded from SSMR and is seen as 'ignored metacognitive activity' (Molenaar, 2011). Therefore, 'uptake' is important, in the sense that a student takes up another student's contribution and continues it (Suthers, 2006). This means that members of a community are critically dependent on each other and meaning is negotiated in the process of members sharing their expertise (see Brown et al., 1993). In SSMR, metacognitive regulation is by definition shared.

In the regulation of cognitive activity, the identification of goals is a determining factor, since something is or is not relevant for some (sub)goal and thus, goal-directed regulation is at the centre of the analyses of metacognition (see Wertsch, 1977). From an SSMR point of view, the common goal is assumed to be shared between the collaborative learners. Hence, goals and standards are co-constructed (see Hadwin & Oshige, 2011). It has been suggested that co-construction of meaning is included in collaboration (Littleton & Häkkinen, 1999). Further, mutuality and equality have been suggested as characterising peer collaboration (Damon & Phelps, 1989; Goos et al., 2002) and mutuality has been defined as a reciprocal process where students explore each other's thinking in order to construct a shared understanding (Goos et al., 2002). 'Collaborative ZPD' (Goos et al., 2002) is created when students are engaged in each other's thinking and the challenge entails the students moving towards new thinking. Hence, equal peers interact in order to co-construct a shared understanding of the task and progress in that task within the collaborative ZPD. Correspondingly, if students fail to engage with each other's thinking, they are unable to create a collaborative ZPD (Goos et al., 2002). This view is supported by findings (see Kumpulainen & Kaartinen, 2003) that have shown that equal participation in social interaction, consisting of joint negotiation and active conceptualisation/visualisation, characterises collaborative reasoning and mediates learning opportunities in peer interactive dyads. Hence, a collaborative context without an expert–novice imbalance can be seen as favourable, such that SSMR can emerge. In this respect, regulation from an SSMR viewpoint can be seen as symmetrical.

To sum up, in the concept of SSMR i) the 'social' element acknowledges that the context of learning is social, ii) 'shared metacognition' indicates that the metacognition process is shared between the participants, iii) the term 'metacognitive' highlights that the focus is on metacognition and not, for example, on motivation or emotions, iv) 'metacognitive regulation' stresses the regulation aspects of metacognition, and v) 'socially shared metacognitive regulation' illuminates that it is a cognate of the concept of 'socially shared cognition', but from the viewpoint of metacognition.

The relationship between the concepts of individual metacognition, other-regulation/co-regulation and SSMR are sketched out in Figure 1. This figure illustrates how in individual metacognition, students' regulation is directed to their own cognitive processing; in other- and co-regulation, students' regulation is directed to others cognitive processes; and in SSMR, students regulation is directed towards joint cognitive process. Although not illustrated in the figure, it is important to note that in both SSMR and other-/co-regulation, students regulate their own cognition as a concurrent regulatory process. Further, although Figure 1 does not feature the context, the goal of the task or other features that are essential for learning, their role is nevertheless acknowledged. Therefore, in this sense, Figure 1 is only a sketch of different forms of regulation. Although individual metacognition, other-/co-regulation, and SSMR are illustrated separately, it is important to remember that they are not conceptualised in isolation from each other, but can interact and be intertwined. Finally, all forms of regulation are seen as important in successful learning and hence do not compete with each other.

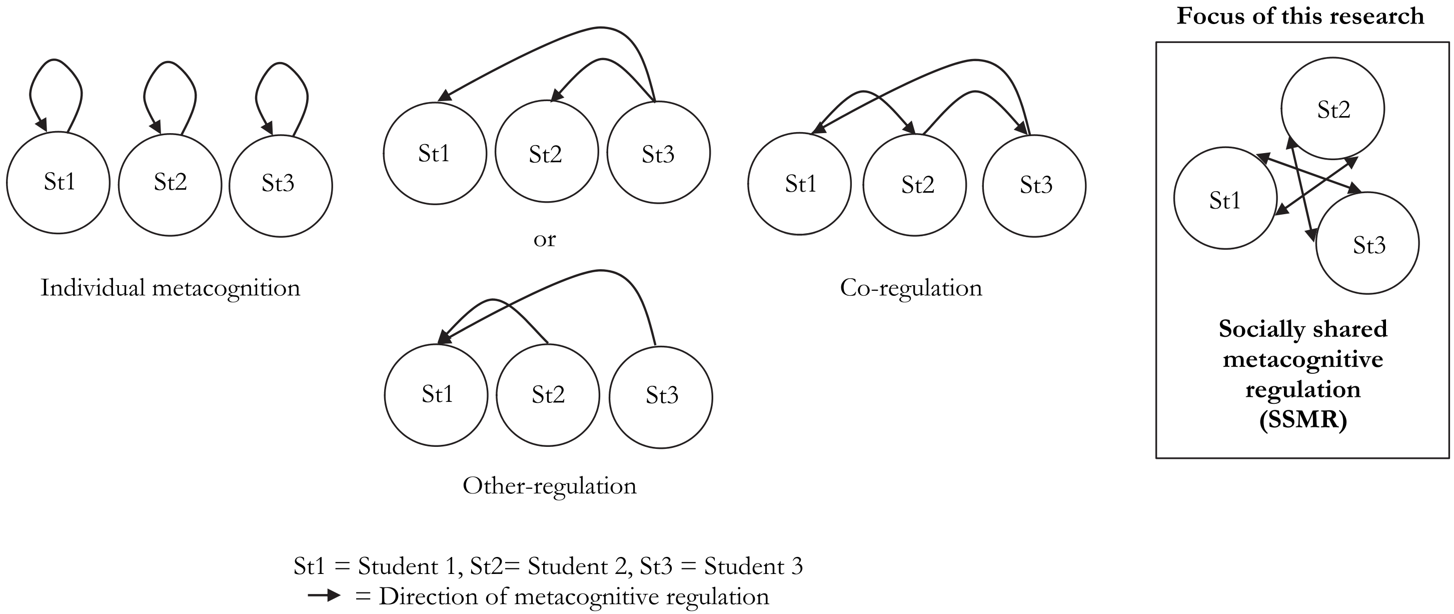

Figure 1. The simplified differentiation between individual metacognition, other- and co-regulation and socially shared metacognitive regulation (SSMR) according to 'what is regulated'.

1.1.4 Challenges in research on SSMR

Research on SSMR encounters challenges from both sides; from a metacognition viewpoint as well as from a social viewpoint. For example, it is widely agreed that the definition of metacognition itself is problematic (Brown, 1987; Brown et al., 1983; Flavell, 1981, Flavell et al., 1993; Veenman, Van Hout-Wolters, & Afflerbach, 2006) in least two ways: firstly, how to distinguish 'meta' from 'cognition' and secondly, how to approach the different historical roots of metacognition (see Brown et al., 1983). Similarly, research on social aspects, such as collaboration in learning (see e.g. Dillenbourg, 1999), is regarded as eclectic. Further, being related to socially shared cognition, SSMR has similar problems to socially shared cognition. For instance, Cole (1991) has argued that the concept of socially shared cognition has been used differently by different researchers and from different theoretical viewpoints. This same concern has been highlighted in research on SSMR (Schoor et al., 2015; Volet et al., 2009b). Hence, the concepts can also differ from each other according to how widely they take the social aspects into account. Therefore, the doubled issues (metacognition and social) also seem to cause dual challenges in the research on SSMR.

First, determining the relationship between cognition and metacognition is difficult (Wertsch, 1977). The prefix 'meta' suggests that metacognition is cognition about cognition (see Flavell et al., 1993). Hence, metacognition is suggested to be cognitive processes that monitor (Flavell, 1979, 1987) and control (Wertsch, 1977) other cognitive processes. This means, for example, that if the role of cognitive strategy is to carry out cognitive process and to reach a cognitive goal, the role of metacognitive strategy is to monitor the cognitive progress and to make sure that the goal is reached (see Flavell, 1987). In line with this, cognitive activities represent the executive function of task-related processes on the object-level, whereas metacognitive activity regulates cognitive activity as the executive function on the meta-level (Veenman, 2011b). Hence, summing up according to Nelson and Narens (1990, 1994), cognitive action (object-level) is separated from metacognitive action (meta-level) so that metacognitive action is seen as using information from cognitive action in monitoring or to regulate cognitive action by modifying it. However, it has been criticised that the 'level' can give an impression that metacognition is higher in relation to other cognition; however, they can be seen as being at the same level, though there is a difference in the topics around which learners operate (Winne et al., 2013). Furthermore, in some cases, for example, the same strategy can serve either a cognitive or metacognitive function (Flavell, 1979) or both (King, 1991). Also, the difference between these two levels is seen as relative (Nelson, 1999; Nelson & Narens, 1990). Hence, the difficulties in demarcation between cognition and metacognition creates a danger where the same action can be classified – according to a situation and/or a researcher – as cognitive, metacognitive or both. However, alternatively, differences in how the relationship between metacognition and cognition is defined can reveal different sides of metacognitive regulation (see Volet, Vauras, Khosa, & Iiskala, 2013).

Secondly, metacognition consists of two distinct areas with different roots, namely research on knowledge about cognition (i.e. metacognitive knowledge) and regulation of cognition (i.e. metacognitive skills) (Brown, 1987). They are seen as being partly distinct in nature. For example, metacognitive knowledge refers to a person's acquired knowledge regarding cognitive matters (Flavell, 1987; Flavell et al., 1993), which is stored in long-term memory (Flavell et al., 1993), and therefore, is relative stable (Brown et al., 1983). Further, it does not necessarily lead to actual learning behaviour (Veenman, 2005). However, although the concept of metacognition itself can refer to different things and its meaning can be rather broadly and loosely defined (Flavell, 1981; Flavell et al., 1993), separating the components of metacognition (metacognitive knowledge and skills) can lead to oversimplification, since they can be seen as recursively feeding each other

(Brown, 1987). For example, metacognitive information about the learning process (e.g. of the failure) may produce new metacognitive knowledge, which in turn may modify metacognitive regulation actions (see Veenman, 2011b). In this way, metacognitive knowledge can be seen to affect metacognitive regulation and vice versa. This same danger of vagueness or oversimplification exists in research on SSMR because it arises from metacognition tradition and uses the same views (metacognitive knowledge and skills). Hence, effective collaboration from an SSMR point of view can be seen as requiring representations of mental states of others and reality (task/situation/context), which implies that SSMR would also be nuanced by metacognitive knowledge (see Efklides, 2008, 2009). This suggests that SSMR would make use of metacognitive knowledge in collaborative learning (see Efklides, 2008).

Further, the analysis of the concepts of metacognition, self-regulation and self-regulated learning has shown them to be partly nested, although they have different roots and there appear to be differences between the concepts (Dinsmore et al., 2008). Similarly, research on SSMR presents similar challenges. For example, Järvelä and Hadwin (2013, p. 26) specify that their approach is grounded in early conceptions of self-regulated learning, which extends, unlike metacognition, beyond cognitive processes like motivation and emotion. In the same vein, the analysis of Dinsmore and colleagues (2008) suggest that in self-regulation and self-regulated learning, for example, behaviour, cognition and motivation are controlled and monitored, which is in contrast to metacognition research, where monitoring and controlling of cognition are specifically highlighted. Hence, in line with the difference between self-regulated learning and metacognition, in the concept of 'socially shared regulation of learning' (e.g. Hadwin et al., 2011), other activities such as behaviour and motivation are also considered, whereas SSMR focuses specifically on the metacognition aspect. Nevertheless, SSMR and socially shared regulation of learning can be difficult to differentiate empirically because it is not always empirically clear how, for example, emotions or motivation are regulated or shared in the socially shared regulation of learning. Hence, in the analyses of socially shared regulation of learning, the focus also seems to be on the cognitive aspect of the self-regulation or self-regulated learning.

Furthermore, the concept of co-regulation has created some confusion, which also reflects on the concept of SSMR. In fact, the use of co-regulation has been seen as the most varying in research on regulation in a social context (Schoor et al., 2015). On the one hand, co-regulation can be seen as close to the concept of other-regulation and in some cases, other- and co-regulation have also been used interchangeably (see Whitebread et al., 2007, 2009; Grau & Whitebread, 2012). Also, it might be that the concept of other-regulation is mainly used in the metacognition tradition and the concept of co-regulation interlocks more with self-regulation tradition that covers elements such as motivation and emotion. On the other hand, research on co-regulation (e.g. Lajoie & Lu, 2012; Volet et al., 2009a) can be seen to be close to SSMR and, sometimes, as Schoor and colleagues (2015) have analysed, co-regulation can be seen as an umbrella term (e.g. DiDonato, 2013). Hence, generally, there are variations in how to use the concepts 'co-' and 'shared-' in the field. As an example, Molenaar (2011) uses the concepts of shared metacognitive activities and co-constructed metacognitive activities. In her definition, shared metacognitive activities refer to interactions where students share metacognitive activity but do not engage in discussion, elaboration or revision of the metacognitive activities of each other. This means that shared metacognitive activity is only transactive at the medium level. Instead, in co-constructed metacognitive activity, students build their metacognitive contribution on each other's metacognitive contribution in order to regulate the groups' cognitive activity together. In this case, metacognition is highly transactive, which means that the students are related to and engaged in other students' metacognitive contributions within the group (Molenaar, 2011). Hence, Molenaar's (2011) concept of co-constructed metacognitive activity – not the concept of shared metacognitive activities – is somewhat similar to the concept of

SSMR. Hence, it is important to note that different concepts can be used when considering rather similar phenomena.

Definitions can vary among the same researcher/s. For example, in the same year 2011, Hadwin placed the SSMR studies of Vauras and colleagues (2003) and Iiskala and colleagues (2004) into different categories; in Hadwin and Oshige's (2011) article, they were categorised as examples of shared regulation and in the article of Hadwin and colleagues (2011), they were categorised as examples of co-regulated learning. In line with the assumption of Schoor and colleagues (2015), these kinds of inconsistencies can be seen as a sign of evolving concepts, whose use is not yet fully established. Instead, the field is still emerging and hence, messy and in a state of flux (Volet et al., 2009b). Further, there exist many different concepts [e.g. collective metacognition (Hogan, 2001), socially mediated metacognition (Goos et al., 2002), shared-regulation (Vauras et al., 2003), socially-shared metacognition (Iiskala et al., 2004; Hurme et al., 2009), socially shared regulation of learning (Hadwin et al., 2011), shared regulation of learning (Järvelä & Hadwin, 2013), and team regulation (Duffy et al., 2014)], which shows that the learning research on metacognition in social contexts is diverse, although the concepts also have genuine differences. One reason for the variety of concepts may be that different research traditions have studied rather similar phenomena in parallel (Panadero & Järvelä, in press).

On the whole, the same challenges that are associated with metacognition research generally and specifically to the ambiguity of the concept (e.g. Brown, 1987; Brown et al., 1983; Flavell, 1981; Flavell et al., 1993) are also evident in research on SSMR. These differences also have consequences as to what and how to code and what is the unit of analysis (e.g. an individual or a whole group). Therefore, the danger of reductionism can be seen as twofold: as a reduction to the individual-level or to the social level (Volet et al., 2009b). Further, the differences in the field can complicate the comparisons of different studies. Hence, not only is 'what is shared' problematic (see Cole, 1991; Järvelä & Hadwin, 2013; Winne et al., 2013), but also 'how much is shared'. As an example, there are differences in how many members of the group have to share regulation so that it is defined as shared. For example, some studies seem to presume that all members share the regulation (e.g. Hadwin et al., 2011, p. 70: '… [the] focus is on regulated learning processes and constructs that are shared, common to all members, …'), while others presume that at least two group members co-equally regulate (e.g. Rogat & Adams-Wiggins, 2014, p. 887: '2 or more group members co-equally regulating…'). These differences make it difficult to compare results, for example, such as differences in the frequency of shared regulation. It is therefore essential to be alert to all the differences that create challenges in SSMR research. For clarity's sake, the concept of socially shared metacognition/socially shared metacognitive regulation (SSMR) is used throughout this dissertation, and its meaning is defined also in relation with other concepts. The previous research used in this dissertation is considered specifically from the SSMR perspective.

1.2 Assessing SSMR in collaborative learning processes

As cognitive theories have focused on the individual, the analyses also have stressed the importance of assessing individual thinking (Lehtinen, 2003). In line with this, individual's metacognition has been assessed in various ways (Veenman, 2005; Veenman et al., 2006). However, research on interpersonal regulation remains – also from a methodological viewpoint – an under-examined field of research (Vauras & Volet, 2013). In SSMR research, the core is collective interactions rather than individual cognition; this means, on the one hand, that new forms of assessment methods are needed, where individuals are seen as a part of social entities (see Hadwin & Oshige, 2011). However, on the other hand, the methods of assessment used in research on individual metacognition can also be seen to form a basis for research on SSMR. This is because research on metacognition has its own features that have to be taken into account. For example, research on the assessment of an individual's metacognition has shown that different methods reveal different results (see Veenman, 2005) demonstrating both pros and cons (Veenman et al., 2006). Therefore, it is important to consider carefully what methods of assessment of metacognition can be applied for which purposes (Veenman et al., 2006; Winne & Perry, 2000).

1.2.1 On-line and off-line methods

On-line methods are conducted concurrently during the learning process, unlike off-line methods that are used prospectively and retrospectively, that is, before or after the actual task has been performed (see Azevedo, Moos, Johnson, & Chauncey, 2010; Veenman, 2011a; Veenman et al., 2006). Both on-line and off-line methods have traditionally been used in metacognition research (see Veenman, 2005, 2011a), although it has been suggested that off-line methods have been used more (Dinsmore et al., 2008). Off-line methods are based on self-reports from a learner her-/himself (Veenman, 2011b) and one reason for their wide use may be the historical connection with metamemory research, which has relied on children's own reports of their knowing (see Brown et al., 1983). In SSMR research, both on-line and off-line methods have been used.

On-line methods such as observations, think-aloud protocols or computer log-file registrations (see Veenman, 2011b; Veenman et al., 2006) have been used to access perceptions of an actual activity (Jacobse & Harskamp, 2012) as well as temporally occurring metacognitive processes (Azevedo et al., 2010). This can be seen as important because metacognitive regulation refers, specifically, to the regulation of ongoing cognitive process (see Brown et al., 1983; Flavell & Miller, 1998; Veenman, 2005). Additionally, the actual process is focused according to external criterion, which means that learners' subjective perceptions are not seen to cause an error variance (Veenman, 2011b).

As an example of on-line methods, observation has mostly been used in SSMR research (see review by Panadero & Järvelä, in press). One benefit of systematic observation is that it does not depend on what learners report or recall (Azevedo, 2009; Whitebread et al., 2009; Winne & Perry, 2000). For instance, Whitebread and colleagues (2009) videotaped young children (aged 3–5 years) collaboratively working in a natural setting and found that over a third of metacognitive behaviour was evidenced through nonverbal behaviour. This finding suggests that although nonverbal behaviour is underutilised in research on metacognition, nonverbal indicators as well as social processes can be accessed within the observed context (Whitebread & Pino-Pasternak, 2013). Nonverbal behaviour (e.g. nodding, body language, gestures, or eye contact) has also been used as additional information among older students in an elementary school (Rogat & Adams-Wiggins, 2014), upper secondary school (Lehtinen & Repo, 1996) and at university (e.g. Khosa & Volet, 2014; Volet et al., 2009a). For example, in the study of mathematical concepts in upper secondary school, students' joint reflection on thinking processes appeared also to be nonverbally mediated by a computer, which was helpful in the construction of complex mathematical knowledge (Lehtinen & Repo, 1996). However, observation reveals only visible behaviour (Veenman, 2011a, 2011b; Whitebread et al., 2009). This means that mental behaviour that has not been made overt remains hidden (Veenman, 2011b). Further, observation can be used only in certain circumstances. For instance, when learner collaboration is only audiotaped (e.g. Molenaar et al., 2011), observation (e.g. nonverbal indicators) as such cannot be used in studying SSMR.

Another example of on-line methods is think-aloud protocols, in which learners are asked to verbalise their thoughts during the process (Veenman, 2005). However, learners do not need to necessarily reconstruct or reflect on their thoughts (Veenman, 2005; Veenman, 2011b). Hence, memory distortions are seen to interfere less in the findings (Jacobse & Harskamp, 2012), although reactivity, that is, environmental influences such as the researcher intervention, stress, or task demands, may affect cognitive processing (Goos & Galbraith, 1996). Think-aloud can be viewed as particularly beneficial when verbalisation is needed for the action (see Brown, 1987; Brown et al., 1983), such as in collaborative learning in research on SSMR. However, a think-aloud protocol may be incomplete when a learner's verbalising is sketchy, does not consider the processes of interest (Goos & Galbraith, 1996), is not able to verbalise all ongoing thoughts (Goos & Galbraith, 1996; Veenman, 2011a), and highly automated, extremely difficult, or effortful processes (Veenman, 2011b). For example, think-aloud may slow the ongoing regulatory process or be distorted if the available working memory is too burdened (Veenman, 2005), or verbalisation may stop when difficulty is encountered and start again when cognitive load decreases (Brown et al., 1983). These arguments have been supported by research findings (see Prins, Veenman, & Elshout, 2006), which have indicated that metacognitive regulation, as assessed by means of think-aloud protocols, appears to be essential to learning, particularly when students work at the boundary of their knowledge. However, in the study by Jacobse and Harskamp (2012), think-aloud measures in total explained 33% of the variance in mathematical performance in primary school students problem solving.

In collaboration contexts, small-group protocols have been explored instead of a single-student or a think-aloud protocol (see Artzt & Armour-Thomas, 1992). Hence, the think-aloud protocol has been applied so that verbalisation has been presumed to occur or verbalisation is specifically asked from participants (see Ericsson & Simon, 1993). In some studies (e.g. Vauras et al., 2003), students are asked to verbalise their thoughts during the interaction, while the environment is arranged to facilitate verbalisation. For example, Goos and Galbraith (1996) studied a student pair's metacognition in mathematical problem solving processes by means of think-aloud protocols. Their study was able to combine the pair's progress (and failure) during the process and show that collaborative students possessed different roles from a metacognitive viewpoint. Similarly to Goos and Galbraith (1996), Hurme and colleagues (2009) studied collaborative students' mathematical problem solving but used students' written messages in a computer-supported collaborative learning (CSCL) context. Their study revealed the appearance of socially shared metacognition during a small group process. Hence, in CSCL, protocols are based on written verbalisations instead of oral verbalisations. However, when collaboration in CSCL has been studied, self-report questionnaires are mostly used (33%) and collaboration is mostly measured retrospectively (51%) (see review by Gress, Fior, Hadwin, & Winne, 2010). Therefore, it can be argued that on-line methods in the research on regulation, such as SSMR, can also reveal new insights into the CSCL context.

Further, discourse and dynamic exchange as well as the evolution of regulatory activities have been argued as characterising research on socially shared regulation (e.g. Hadwin & Oshige, 2011). As shown by Salonen and colleagues (2005), in the context of student pair's mathematical problem solving process, scrutinising the ongoing interaction enables us to look at recurrent interbehavioral patterns and coordination moment-by-moment. This means that microgenetic analysis, which addresses dynamic and relational invariance, can reveal metacommunicative messages and patterns (Salonen, Vauras, & Efklides, 2005). Further, Sfard and Kieran's (2001a, 2001b) study revealed how participants of an interaction move between different channels of communication (individual, interpersonal) and different levels (cognitive, metacognitive). The case study of two students working as a pair also made visible how thinking itself was as an act of communication (Sfard & Kieran, 2001a, 2001b). Hence, these kinds of microgenetic analyses provide estimates on learning as it emerges over time (see Brown et al., 1993). Micro-level analysis which is contextualised by macro-level regulatory episodes is also seen to characterise shared regulation research (Hadwin et al., 2011). Hence, in-depth analyses, which are based on on-line data, seem to be detailed enough and flexible enough to reveal both fine-grained processes among collaborative students at the micro level as well as revealing more macro-level episodes at the meta-level. Social network analysis (SNA, see Scott, 1991; Wasserman & Faust, 1994) and the State Space Grid (SSG, see Hollenstein, 2013) are also tools that make it possible to reveal and summarise participation structures created during the process.

However, learners may share only some thoughts by means of verbal and nonverbal behaviour. Thus, it has been argued that metacognition can also be inferred from cognitive activities; for example, a sign of metacognitive planning can be that a learner proceeds to do things step-by-step (Veenman et al., 2006). Trace methods are one way to capture concrete indicators of metacognitive activity (Winne & Perry, 2000) in which case, for example, planning can be evidenced also from a written outline (Perry & Winne, 2013). Thus, besides recorded conversations and observations, software can also be used for capturing traces (Perry & Winne, 2013). For instance, in a study by Molenaar and colleagues (2012), on-line registration was collected in an e-learning environment that allowed the researchers to follow students' progression through the task. However, when metacognition is inferred from cognitive activities, the difficulty is to differentiate which activities are indicative of metacognition or of cognitive activity (Schoor & Bannert, 2012; Veenman et al., 2006). Hence, although, for example, trace data provides evidence of actual processes during learning, it has been suggested that they are combined with other data; for example, if current trace data is lacking, it is possible to investigate what a learner is doing at that time through other data (Azevedo et al., 2010).

In contrast, in the case of *off-line methods*, such as interviews and questionnaires, a learner is asked questions about his or her strategy use or skill application (Veenman, 2011a). However, it has been argued that learners show a lack of accuracy in reporting their metacognitive behaviour, since they need to retrieve this information from memory processes that occurred earlier (Jacobse & Harskamp, 2012; Veenman, 2011a). Memory failure is also assumed to increase with greater intervals between the performance and the reporting (Veenman, 2011a). These may be a reason that research has shown little or no correspondence between off-line methods and concurrent behaviour (e.g. Veenman, 2005). Also, this kind of finding may suggest that off-line methods would be the most suitable for assessing metacognitive knowledge rather than cognitive regulation (Veenman, 2011b) such as SSMR.

Stimulated recall interview is an example of an off-line method that has been used in metacognition research. In a stimulated recall interview, participants describe their behaviour after completing a specific task, and a videotape, for example, can be used in the reviewing (Winne & Perry, 2000). De Grave, Boshuizen and Schmidt (1996) found that the verbal interaction during a small group's problem solving process was only 'the tip of the iceberg' of the metacognitive processes on which it is based on. Some metacognitive processes, such as meta-reasoning (e.g. reflections on the learning process) were more tacit in the group's process and became visible in the interview. Similarly, Artzt and Armour-Thomas (1992) found stimulated recall interview as complementary to the small-group protocol, such that interviews provided metacognitive information especially about moments where students were silent during the process.

Questionnaires, in turn, have not been seen as having a relationship with the actual learning performance (see Veenman, 2005). In the study by De Backer, Van Keer and Valcke (2012) students claimed to regulate their performance more in the self-report questionnaire than they did according to concurrent measures. Hence, what a respondent says they did and what they actually did can differ (e.g. Brown, 1987; Brown et al., 1983; Veenman, 2005). Further, questionnaires have not been found to predict performance, as shown in a study of mathematical problem solving in the fifth grade (Jacobse & Harskamp, 2012). These findings suggest that questionnaires have limitations in investigating the regulation of actual learning processes. Instead, self-report questionnaires are seen to elicit respondents' generalised action across situations rather than action related to specific learning events (Winne & Perry, 2000). However, the usefulness of questionnaires may also be dependent on the task. For instance, in a writing task, self-report questionnaires appear to have predictive value for on-line task execution (Tillema, van den Bergh, Rijlaarsdam, & Sanders, 2011). Also, questionnaire data have revealed students' perceptions of how they were engaged in the learning process as a member of a group (Garrison & Akyol, 2013).

As a sum, although on-line methods are preferred as the most appropriate in research on metacognitive regulation (e.g. Veenman, 2005, 2011b), previous research (e.g. Artzt & Armour-Thomas, 1992; De Grave et al., 1996) has also provided evidence, for example, that stimulated recall interviews add complementary information about learners' metacognitive regulation. Azevedo and colleagues (2010) claimed that any single method cannot capture all metacognitive processes in all different situations.

1.2.2 The unit of analysis

The choice of the unit of analysis is important since it reflects the theoretical position of the study (see Clarà & Mauri, 2010) and has essential implications regarding the findings (Granott, 1998). Following the framework of Whitebread and Grau Cárdenas (2012) based on Rogoff's (1997) conceptualisation, the analysis of regulation can be considered according to three planes; personal, interpersonal and community. This framework suggests a need to broaden the unit of analysis from the individual level to the group and community levels.

In SSMR research, the unit of analysis concerns at least two issues; what is selected for the unit of analysis during the process (e.g. an individual's turn or a wider unit such as a set of turns, that is, an episode, or a combination of the two), and for the product (e.g. a product of each individual's or a group's common product, or both). During the *process*, for example, in Molenaar and her colleagues' studies (e.g. Molenaar et al., 2011; Molenaar & Chiu, 2014), each conversation turn was coded either as metacognition (and divided into subcodes such as planning, monitoring and evaluation) or something else (cognitive, relational, procedural etc.) so that categories were mutually exclusive and exhaustive. As shown in their study, the turn-level analysis made it possible to apply a variety of statistics in the analyses, such as a multivariate, multilevel analysis of the conversation turns (Molenaar et al., 2011) and statistical discourse analysis (Molenaar & Chiu, 2014), given the large amount of coded turns. Molenaar and Chiu (2014) indicated in their study of primary school students working in triads that students metacognitively regulated their progress towards the goal, which made students focus on the task and cognitive processing. Reading and processing (e.g. writing of text) turns were often followed by metacognitive planning turns, and further by meaning construction turns.

A number of researchers (e.g. Beers, Boshuizen, Kirschner, & Gijselaers, 2007; Hmelo-Silver et al., 2008; Volet & Summers, 2013) have argued that a turn is too fine-grained a level to investigate negotiation processes within groups. Instead, episodes that include turns from different participants are considered a more appropriate unit of analysis (Beers et al., 2007). Also, single turns can happen in succession so that they do not form an episode but just represent many consecutive individual regulations (Grau & Whitebread, 2012). This means that successive regulation turns themselves do not necessarily form SSMR. Hence, SSMR has also been analysed by means of a wider analytical unit than the turn. This is shown, for instance, in Khosa and Volet's (2014) study, where at least two students had jointly regulated the flow of cognitive processes, which constituted SSMR. However, if only episodes as an entity are analysed, an individual's contribution to the SSMR is neglected. Therefore, it has been suggested that in SSMR research, both the group and individuals' part within the group should be considered (Grau & Whitebread, 2012). Hence, both Khosa and Volet (2014) and Grau and Whitebread (2012) have studied group-level and individual-level contributions to SSMR. Also, although Molenaar and colleagues (2011) and Molenaar and Chiu (2014) have used a turn as the unit of analysis, they have also investigated sequences of turns in discourse, that is, how turns follow each other. Hence, they have also adopted a broader perspective, that is, the flow of turns.

An example of research on the relationship between an individual and a group is Grau and Whitebread's (2012) study of third graders' collaborative learning in science. Their study revealed that when two groups were compared, one group had more individual-level contributions to shared regulation episodes and hence, more symmetric collaboration than another group (Grau & Whitebread, 2012). Also, there is evidence from undergraduates' collaborative problem solving that the balance of participation in planning is more symmetric in successful than in unsuccessful pairs problem-solving (Jermann & Dillenbourg, 2008). Further, Molenaar's research (2011) has shown that metacognitive activity embedded in more transactive interactions is more likely to facilitate the group process than in less transactive interactions in elementary education. However, Rogat and Linnenbrink-Garcia's (2011) study of regulation among small groups of sixth graders has also shown that the frequency of regulation in the interaction process varies substantially between different small groups; students' non-collaborative regulation in some groups did not support the group to focus on the understanding content and common effort. Hence, findings from previous research imply that when individual-level contributions (e.g. individuals' turns) to collective regulation are symmetric between students, it is positive for the group's common enterprise. This means that analysis of both a turn (e.g. an individual's turn as a contribution) and an episode during the process are important and useful. However, the unit of analysis represents how discussion is divided into items for coding (De Wever, Schellens, Valcke, & Van Keer, 2006). This means that a turn (or e.g. a student's message in CSCL context) and the individual-level analyses do not necessarily mean the same thing. For example, individual participation can be examined in many ways (e.g. regarding online learner participation, see Hrastinski, 2009), not only counting the frequencies of turns or messages by students.

Metacognition research has also been expanded to the community level. For example, Hacker and Bol (2004) have proposed including cultural factors in metacognition measures and have suggested paying attention to their investigation. Hogan's (2001) view is that metacognition should cover the collective norms and practices of a discipline when collaborative learning in schools is provided. In her view, metacognition serves as a nexus for the integration of the interplay between personal, interpersonal and cultural levels in the group's collaborative working. Hogan's (2001) analyses of 12 target-group discussions during collaboration of middle school students in science showed that cultural norms as a part of meta-knowledge play a role in metacognitive regulation in the groups' knowledge construction. In her study, the cultural norms of science were analysed through students' metacognitive statements directed at the social plane. Although the unit of analysis was a student's statement, the community level was focused on through the categorised statements. This may imply that the community level has been studied such that the unit of analysis has been an individual or a turn. Moreover, as Hacker and Bol (2004) show in their literature review, the community level in metacognition research has also been acknowledged when social influences on individuals have been considered.

Similar to process, the *product*, as a unit of analysis, has varied in SSMR research. This means that the individuals' or groups' outcome has been analysed or both. An example of measuring individuals' outcomes is Molenaar and colleagues' study (2011), where they analysed the impact of scaffolding the metacognitive activity of small groups of elementary school students in their individual learning achievements. They found that students who received problematising metacognitive scaffolding (i.e. metacognitive activities and explanations elicited with the help of a computer, e.g. 'How are you going to make…?' and groups had to react to the question) engaged in more metacognitive activities than the control group who did not receive any scaffold and outperformed in terms of individual domain-knowledge which was mediated by individual metacognitive knowledge. Contrary to the study of Molenaar and colleagues (2011), Khosa and Volet (2014) measured group outcomes in veterinary science learning. They compared two groups in a collaborative learning context whose conceptual understanding differed from each other. Their findings revealed that the group with better outcomes not only engaged more in high-level co-construction of knowledge than the group whose outcomes were not as good, but from an SSMR viewpoint, the more successful group displayed more metacognitive regulation of high-level cognitive processes, in particular monitoring (Khosa & Volet, 2014). Learning outcomes have also been measured both on an individual and a group level. For instance, scaffolding of socially shared regulation in a computer-based learning environment in a middle school context has been found to have a positive effect on dyad performance but not on individual students' domain knowledge (Molenaar et al., 2012). Hence, the results of previous studies suggest that the findings are also connected to whose product is measured (individual or group).

Overall, the unit of analysis in SSMR research varies regarding both the process and the product. Furthermore, different theoretical views are interested in the role of the individual and the social (e.g. group, community) to different extents (see Schoor et al., 2015; Volet et al., 2009b). However, as Clarà and Mauri (2010) proposed from a CSCL point of view, in research on SSMR, the individual level can also be used when group learning is interpreted, or learning can be viewed as both an individual and a group process, which means that the relationship has to be considered at both levels (Clarà & Mauri, 2010). Hence, by citing Granott's (1998, p. 51) metaphor '…Although one could analyse the tune played by each musician, it makes sense to do so in relation to the tunes that other musicians in the ensemble play and to the whole musical piece.' Similarly, when considering the unit of analysis in SSMR research, it makes sense to undertake individual-level analysis in relation to the group-level analysis.

1.2.3 Considering validity

In regulation research, an assessment of validity has not always been properly conducted, even though validity is extremely important, particularly for new methods of assessment (see Veenman, 2007), such as SSMR. Hence, new assessment methods should be considered carefully regarding what they measure exactly and how successfully (Veenman, 2011a). For Veenman (2007), multiple ways of assessing a *construct* are crucial: internal consistency, construct validity and external or predictive validity.

Internal consistency can be measured from assessment material using inter-raters (Veenman, 2007, 2011a). However, there is no general consensus about what indices should be used in inter-coding and therefore, it is suggested to use many coefficients in order to provide more information to readers (e.g. percentage agreement and Krippendorff's alpha, which takes into consideration also agreement by chance, unlike with percentage agreement) (De Wever et al., 2006). In SSMR research, both inter-coder percentages (e.g. 86% of agreement in categorisation of regulation according to whether it focused at classroom context on self, other or shared, Whitebread et al., 2009) and coefficients (e.g. Cohen's kappa 0.94 in categorisation metacognitive activity turns during collaborative learning, Molenaar & Chiu, 2014) have been reported. However, also in SSMR research, as Beers and colleagues (2007) suggest from the CSCL point of view, the challenge is to construct coding rules that lead to reliable results but do not lose the original meaning of the construct.

Further, inter-coder agreement can be assessed in SSMR research at different levels as in Whitebread and colleagues' observational study (2009), where the 'unitising' level, that is, agreement of what units should be coded (66.0%) and the level of absolute agreement, that is, agreement about what codes should be given to the agreed units (96.1%) were assessed. The differences in agreement percentages (66.0% and 96.1%) show that on the one hand, the 'unitising' level is difficult to code in observational data but on the other hand, high agreement can be maintained between different codes given. The same trend, although to a lesser extent, is visible in Grau and Whitebread's study (2012), where the agreement percentages were 71 and 85, respectively. In some cases, such as in Khosa and Volet's (2014) study, inter-coding has been used but reported qualitatively without exact numbers (p. 296 '...coding was undertaken separately by the two co-authors. All metacognitive possibilities were discussed at great length and included only if both coders were in complete agreement...'). Additionally, when inter-rater reliability is reported, it has been suggested in online discussion groups that it is important to also report information about the sample, the training of coders and the coding process (De Wever et al., 2006). The coding sample would therefore differ between studies. For instance, in Grau and Whitebread's (2012) study, 10% of the data was inter-coded, whereas in Khosa and Volet's (2014) study, both coders had to accept all SSMR activities identified from the data.

Although internal consistency is important for statistical interpretation, it does not tell what is being measured (Veenman, 2011a). *Construct validity* refers to the content validity, in that assessment instruments are meaningfully designed, and to convergent validity, in that a new assessment instrument assesses the same construct as in other assessments (Veenman, 2011a). Hence, construct validity can be supported by convergent validity, in which case different methods of analysis (multi-method design) give similar kinds of results (Veenman, 2007). Actually, the use of a multi-method design has been recommended in studying metacognitive regulation in general (e.g. Veenman, 2005, 2007), as well as in the SSMR literature (e.g. Hadwin & Oshige, 2011) in order to understand different assessment methods (Veenman et al., 2006) and the complex nature of the regulation of learning (Hadwin & Oshige, 2011). Further, regarding convergent validity, it is important to note that it makes sense only if a new assessment method and an existing method where the new method is reflected represent the same construct. If they assess different constructs, their use from the construct validity viewpoint is not functional (Veenman, 2011a). Dinsmore and colleagues' (2008) systematic review of the literature revealed that only 71% of the reviewed studies on metacognition showed evidence of full alignment between the definition and measure. Due to the lack of multi-method designs in SSMR, more research is badly needed.

According to *external or predictive validity*, a new assessment instrument should act in line with established theory, for example, how it is related to other variables and how it predicts learning (Veenman, 2007). As an example, Whitebread and colleagues' (2009) instrument (CHILD 3-5) has been tested regarding its external validity, in which unrelated research projects have indicated that the instrument behaves in line with previous theory. For example, correlations with an established instrument and other variables (e.g. memory) have been found to meet with what would be expected. However, there is limited research on the relationship between SSMR and outcomes of learning and the findings are partly inconsistent. For example, Schoor and Bannert (2012) compared higher and lower performance dyads but did not find differences between performance groups in the frequency of regulatory activities during CSCL processes. In contrast, Zhao and Chan (2014) found the opposite findings, namely that more regulatory activities during small group's learning process were related to better performance. Janssen, Erkens, Kirschner and Kanselaar (2012), in turn, indicated that in CSCL, regulating task-related activities (e.g. planning the task, monitoring task progress) themselves had no effect on group performance but regulating social activities (e.g. planning the collaboration, monitoring the group process) had a significant positive effect on the group performance. Additionally, Khosa and Volet (2014) found that the number of regulation episodes did not differ between different performance groups, but quality differed so that a better performance group, unlike a lower performance group, focused more on regulation of knowledge co-construction than on only co-production of the task. Hence, in sum, different findings from previous research have revealed that more research on SSMR is required from an external or predictive validity perspective.

Research on metacognitive regulation also needs to address *ecological validity,* which means that metacognitive regulation should have counterparts in the 'real world', for example in problem solving (Brown 1978, 1980). This has been taken into consideration in some SSMR studies. For example, Grau and Whitebread's (2012) naturalistic study unveiled different SSMR findings at different time points. Furthermore, metacognitive skills are seen as important to use in many situations, such as at school and in everyday life situations (Brown, 1978). Therefore, it is reasonable to measure metacognition in different contexts. This also refers to external validity in the sense of generalizability, so that findings can be generalised across multiple contexts (De Wever et al., 2006). However, similar to what was found in CSCL research (see Beers et al., 2007), it is a challenge for SSMR research to develop measures that are reliable and valid enough to be used in different contexts.

1.3 SSMR across contexts: in face-to-face learning and in computer-supported collaborative learning (CSCL)

Generalizability of SSMR is important since it makes it possible to compare SSMR in different contexts, such as with different age groups, tasks and activities (Khosa & Volet, 2014). Molenaar and colleagues (2012) also posited the importance of validating the research findings of SSMR in different settings. Overall, findings from different studies have showed that SSMR appears across contexts (see also the qualitative review by Panadero & Järvelä, in press), for example in face-to-face learning and also in CSCL. However, findings between contexts also seem to reveal both differences and similarities.

SSMR has been found in *face-to-face* learning in various educational contexts. For example, among children aged 3–5 years in a naturalistic educational setting (Whitebread et al. 2007, 2009; Whitebread & Pino-Pasternak, 2013), SSMR occurred both in unsupervised and in small groups supervised by adults, although more in unsupervised groups (Whitebread et al., 2007). This result show that SSMR appears also naturally in peer learning settings among children, and that student-led collaboration can give adequate space for SSMR to occur. Further, a case study collaboration among 5-year-old children in an intervention context, although aimed at developing individuals' metacognition, also showed that children could already develop a collective awareness of metacognition, for example, an awareness of planning and evaluation (Larkin, 2006). Additionally, a study of 8-year-old children in a mathematic solving process indicated that children are not only capable of collaborating but also of steering the collaborative solving process by regulating it together (Dekker, Elshout-Mohr, & Wood, 2006). Hence, as a foundation, previous research has shown that children are capable of metacognitively regulating their learning process together in a face-to-face context.

The objects of SSMR have also been studied. A study of small group work among primary school children in a natural context of biology learning revealed that SSMR can be directed towards different aspects, such as fundamental knowledge and the superficial aspects of the task (Grau & Whitebread, 2012; Whitebread & Grau Cárdenas, 2012). Although the focus of SSMR was found to be more on the superficial than the fundamental aspects, the finding implies that SSMR can support the group to deal with the essentials of the task (Grau & Whitebread, 2012). However, to date there is no evidence beyond this initial study of the relationship between the focus of SSMR (e.g. essential or superficial aspects) and the outcomes of collaboration among primary school students. Further evidence from a study looking at undergraduate students' collaborative learning at university in veterinary medicine showed that a higher performing group metacognitively regulated more co-construction of knowledge than a lower performing group during a collaborative learning activity (Khosa & Volet, 2014). Therefore, based on these findings obtained from face-to-face learning contexts, it seems insufficient to study whether SSMR simply occurs or not during the process, but it is also essential to consider what is the focus of SSMR.

It has been suggested that the timing of regulation activities can indicate adaptation to changing contextual conditions (Azevedo, 2005). Hence, some researchers have mentioned the need to explore sequences from a shared regulation viewpoint (e.g. Molenaar & Järvelä, 2014). However, that line of research is still under-examined (see Molenaar & Järvelä, 2014) and so far only a few studies have addressed this issue. Researchers have reported what kind of cognitive activities follow metacognitive regulation when primary school students (Molenaar & Chiu, 2014) and middle school students (Hogan, 2001) are working in triads. For example, fourth, fifth and sixth graders monitoring their progress and evaluation of the learning process enacted controlling actions (e.g. planning) to direct cognitive activity towards the goal (Molenaar & Chiu, 2014). Similarly, Hogan (2001) reported evidence of eighth graders' cognitive and metacognitive behaviour during science learning that were intertwined; for example, metacognitive statements, such as those directing action, suggesting strategies, taking stock of the progress, and evaluating the task, supported steering and deepened the subsequent conceptual interchange. Additionally, Rogat & Linnenbrink-Garcia (2011, 2013) found a synergy between metacognitive regulatory processes, among four-student groups in upper-elementary school (sixth grade). Group differences in metacognitive planning, monitoring and behavioural engagement were found to differentiate the quality of the groups' mathematics learning process. Taken together, these findings show patterns in the subsequent events (Hogan, 2001; Molenaar & Chiu, 2014), where SSMR (or the lack of it) (Rogat & Linnenbrink-Garcia, 2011, 2013) has implications regarding what happens in the evolving process. Hence, the function of SSMR is a crucial yet largely unexplored topic.

Compared to face-to-face learning, *CSCL* offers a different context. Asynchronous online discussion refers to a text-based computer-mediated communication environment that makes it possible for students to interact at any time and place (Hew, Cheung, & Ng, 2010). Students also have the possibility to see previous communication on the screen and return to it when needed (Hew et al., 2010; Lehtinen, 2003). Further, students have more time to think about their contributions to the common enterprise in CSCL than face-to-face (Volet et al., 2013). A previous study (Pugalee, 2004) revealed that high school students who wrote descriptions of their thinking succeeded better in their algebra problem solving tasks than students who only verbalised their thinking. This finding implies that writing can support metacognitive behaviour (Pugalee, 2004). However, from an SSMR viewpoint, in CSCL, students have to apply regulatory activities during the process without non-verbal signs or gestures (Saab, 2012). Nevertheless according to Cheung and Hew (2004), text-based asynchronous environments appear to assist with allowing the expression of thoughts to flow more freely and descriptively when participants do not see each other. However, although the body of literature on CSCL is extensive (Järvelä & Hadwin, 2013), research on regulation in that context is still lacking (Järvelä & Hadwin, 2013; Saab, 2012). To gain the full benefits of CSCL environments, higher-order thinking skills, such as metacognitive regulation, are essential (Pifarre & Cobos, 2010). Hence, metacognitive regulation is seen as crucial in CSCL environments (Järvelä & Hadwin, 2013; Pifarre & Cobos, 2010; Saab, 2012).

A number of studies have revealed how SSMR emerges in CSCL (e.g. see Hurme et al., 2009; Janssen et al., 2012; Lee, 2014). For example, Lee's (2014) study of shared regulation in 13 undergraduate pre-service student groups revealed a similar kind of regulation of cognitive processes at collective level as was traditionally found at individual level. Hence, their log file data of small groups' cognitive processes in synchronous CSCL showed regulation activities such as planning and goal setting, scheduling, task and content monitoring, and evaluation. In the small group context, and according to Lee (2014), these processes reflected students' shared plans, goals and monitoring.

In turn, a study by Hurme and colleagues (2009) of pre-service primary teachers in a university mathematic course using asynchronous CSCL revealed how metacognitive regulation was important in constructing a joint solution. Their case study of two small groups of three students showed that shared metacognitive regulation was essential in their successful problem solving. Importantly, according to the authors, social and cognitive interaction was not sufficient for successful problem solving when socially shared metacognitive regulation was absent. Similarly, Janssen and colleagues (2012) found that regulation of task-related activities in secondary education was not a sufficient condition for successful performance in a historical inquiry task. In contrast, their study showed how regulation of social activities (e.g. monitoring the group process) in 101 small groups affected positively the group's performance. Contrary to Hurme and colleagues (2009) and Janssen and colleagues (2012), Schoor and Bannert (2012) did not find differences between lower and higher performance dyads at university when the frequencies of regulatory activities were compared in CSCL. However, these studies in CSCL contexts did not scrutinise the focus of SSMR, which has been shown to be important in a face-to-face learning context (see e.g. Grau & Whitebread, 2012; Khosa & Volet, 2014).

Similarly to face-to-face discussions, the importance of sequences has been highlighted in CSCL. For example, correct evaluations and questions in a recent message has been found to increase the likelihood of a correct, new idea in the present message in an asynchronous online mathematics discussion among high school students (Chen, Chiu, & Wang, 2012). Further, a double loop of monitoring, working at the task, and coordination with working at the task has been revealed. For instance, coordination and monitoring has been shown to be followed by discussion at the content level, which in turn is followed by monitoring or coordination (see Schoor & Bannert, 2012). These studies clearly imply that it is possible to also specify the functions of metacognitive regulation during CSCL.

To sum up, research on face-to-face contexts has covered a wide age range (from young children to university students), whereas CSCL research has focused more on older students, such as those in secondary education and university students. Hence, there is a need to explore SSMR in CSCL among primary school students. Further, SSMR has been found among dyads as well as small groups in both contexts, which suggests that different sized groups can engage in shared metacognitive regulation (see also Panadero & Järvelä, in press). Additionally, in both contexts, various tasks have been used. Moreover, mathematical problems, historical inquiry, science tasks, problem solving and inquiry learning all appear to be favourable contexts to reveal SSMR. Further, and based on previous research, there is a need to study the emergence of SSMR in greater detail; for instance, its function and focus are both seen as important. Coding schemes have varied in previous research on SSMR. In research on regulation in collaborative learning generally (Volet & Summers, 2013) and particularly in CSCL (see Beers et al., 2007), it has been challenging to apply analytical methods, such as coding schemes, from one context to another. Similar phenomena have been reported in both contexts (e.g. Chen et al., 2012; Panadero & Järvelä, in press) although with partly different findings. Hence, this dissertation set out to validate the analysis of SSMR in a face-to-face context and then in a CSCL context.

2. Aims and the structure of the study

This dissertation has three general aims; theoretical, methodological and empirical. As has been shown, the focus on metacognition research has been – theoretically, methodologically and empirically – on individual metacognition. This means that individual metacognitive regulation has been theoretically defined, methodologically studied in a range of ways and empirically validated across various learning contexts. On the contrary, research on metacognitive regulation in a collaborative learning context as a shared phenomenon is – theoretically, methodologically and empirically – lacking. Hence, the aims of this dissertation are as follows:

- *Theoretical aim* is to extend the concept of individual metacognition to socially shared metacognitive regulation (SSMR), since there is lack of research on metacognition in collaborative learning where the focus is on the dyad/small group and not on the individual students themselves.
- *Methodological aim* is to develop methods to capture and analyse SSMR, since metacognition research has mainly been conducted at the individual level and thus, there is lack of methods for analysing collaborative processes.
- *Empirical aim* is to validate the usefulness of the concept of SSMR in two different learning environments by collecting empirical data.

The specific aims of each of the four studies are described in Figure 2. The concept of SSMR is explored in two different learning environments; in face-to-face word problem solving in mathematics in student dyads (Study I and Study II) and in inquiry CSCL in science in small groups (Study III and Study IV). As a main principle, the first study (Studies I and III) in both environments is an in-depth micro-level case analysis, which makes it possible to capture and analyse in detail SSMR during the collaborative process. Similarly, in both environments, the second study (Studies II and IV) uses more cases from the same learning environment, whereupon it is possible to validate SSMR within the same environment but in different cases. Hence, validation is tested both between environments and within the same environments with more cases. Furthermore, the four studies are intertwined so that each study forms always a base for the next study, which further enlightens about SSMR. In short, Study I is an original study exploring socially shared metacognition in collaboration and revealing the emergence of SSMR. Study II aims to scrutinise in detail the functions and foci of SSMR, with a consideration of different difficulty levels of tasks as well as investigating how SSMR emerges. Study III aims to apply the coding of SSMR to another environment addressing functions and students' participation in SSMR in different phases of the process. Further, the aim of study IV is to apply SSMR's focus to another environment and to analyse students' participation as well as to investigate the focus of SSMR during different phases of the inquiry process, and how the focus of SSMR is related to the outcomes of the collaboration.

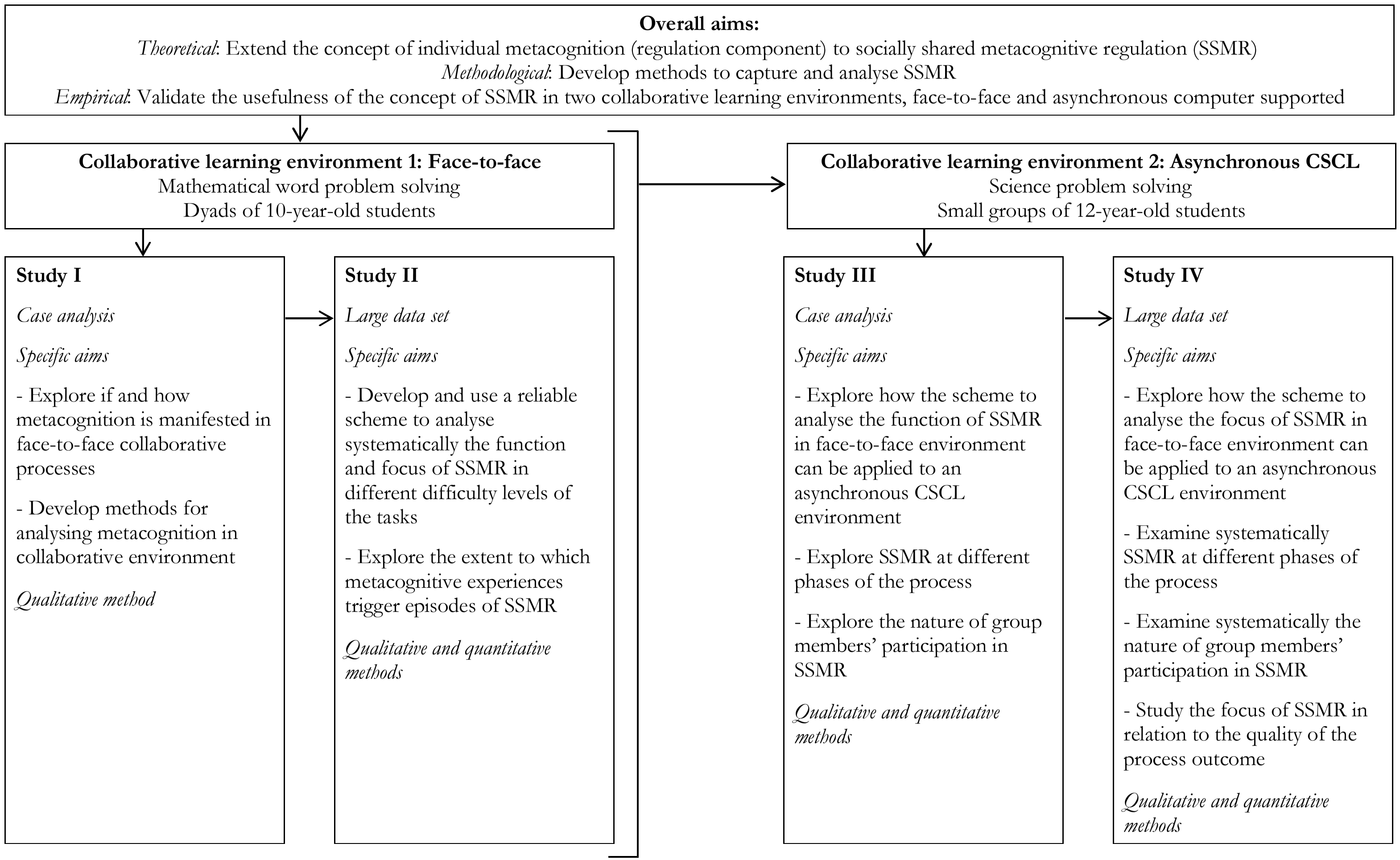

Figure 2. Overview of the empirical studies.

3. Methods

3.1 Participants

Participants in the studies reported in this dissertation were exclusively above-average ability students. This decision was made because metacognition is typically seen as high-order thinking, which high-achieving students have been found to employ in the learning process (e.g. Meichenbaum & Biemiller, 1998).

In collaborative learning situations, high-achieving peers have been shown to use a metacognitive framework to guide their inquiry and to verbalise their thinking at primary school level (Jones & Carter, 1994; Meichenbaum & Biemiller, 1992). For instance, above average peers have been found to use prior experiences, organize learning issues, maintain focus on the learning task, and spend time on the task until it has been completed more than low achievers (Jones & Carter, 1994; see also Meichenbaum & Biemiller, 1992, 1998). Further, high-achievers are seen to direct their task-directive language to peers and have more elaborated verbalisations (Meichenbaum & Biemiller, 1992). Moreover, findings of primary-school-aged children (e.g. Fuchs, Fuchs, Hamlett, & Karns, 1998) have shown that dyads comprising high achieving peers operate more collaboratively, generate greater cognitive conflict and resolution, as well as produce better quality work than dyads comprising high and low achieving students. Hence, high achieving students have been seen to be able to work metacognitively with other high achieving students of primary school age (Fuchs et al., 1998; Jones & Carter, 1994). Based on these findings, above average students at primary school level were selected for studies in this dissertation to set an optimal environment for SSMR to emerge.

Studies I and II

Participants for Studies I and II were high-achieving ten-year-old students selected from among 393 fourth graders who attended the research project 'Quest for Meaning'.[1] Students worked in dyads of the same gender, and succeeded approximately at the same level in the screening measures, which were used as selection criteria. Students of approximately the same level were selected so that students would have the possibility to engage in symmetric collaboration (see e.g. Damon & Phelps, 1989; Goos et al., 2002; Granott, 1993), an element viewed as important for the emergence SSMR. The screening measures used for selection were mathematical word problem solving, reading comprehension, metacognitive knowledge, co-operation skills and a nonverbal intelligence test. These measures were administered in a classroom situation.

Participants in Study I comprised two dyads. One of the dyads consisted of two girls and the other of two boys. On all measures, the girls ranked in the top 1–22% of the mainstream students. The boys ranked in the top 7–22% in mathematical word problem solving, reading comprehension and metacognitive knowledge measures. In co-operation skills and the nonverbal intelligence test, one boy was an exception to this rank. All the selected students were confirmed by the class teacher as being suitable for the study.

Participants in Study II comprised four dyads. Two of the dyads consisted of girls and the other two of boys. All the selected students ranked among the upper 11% of the mainstream students in mathematical word problems and reading comprehension.

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[1] The project was funded by Grant Nos. 47369, 201 782 and 114 048 from the Council of Cultural and Social Science Research, the Academy of Finland awarded to Professor Marja Vauras.

The screening measures to select participants were as follows:

Mathematical word problem solving was assessed by 15 (Study I) and 23 (Study II) one- and multi-step problems that demanded consideration of the reality of the situation described; thus these were not solvable by using straightforward arithmetic operations (Kajamies, Vauras, Kinnunen, & Iiskala, 2003). The total number of correct solution steps (Study I) and solutions (Study II) was used as an indicator of mathematical word problem solving skills.

Reading comprehension was assessed in Studies I and II with the Finnish Standardised Reading Test (Lindeman, 1998). The students were given 24 multiple-choice questions about two texts that they read. The total number of correct choices was used as an indicator of reading comprehension skills.

Metacognitive knowledge about learning in Study I was assessed in written form using three pictorially presented tasks that presented different alternatives in order to learn a particular cognitive task (modified from Annevirta & Vauras, 2001). First, the student had to select one picture that s/he thought to be the best choice. Second, the student had to choose the best explanation among 8–10 given choices for her/his first selection. The explanations were used as an indication of the student's metacognitive knowledge.

Co-operation skills were assessed by MASCS (Junttila, Kaukiainen, Voeten, & Vauras, 2006). Classmates evaluated how skilfully the student usually works together with classmates. Five items using a scale 1–4 were used. In Study I, the mean of the classmates' evaluations was used as an indication of the student's co-operation skills.

Nonverbal intelligence was assessed by Standard Progressive Matrices (Raven, Raven, & Court, 2000). In Study I, the total number of correct choices was used as an indication of the student's nonverbal intelligence.

Studies III and IV

Participants for Studies III and IV were small groups of 12-year-old students.[2] This class was selected from among other volunteering classes since it was considered as more above average than the others. The class was involved in a language-enriched curriculum and had an entrance examination (cognitive skills) to select students for admission to the class. Given the high criteria for admission, students could be described as above average regarding their cognitive skills. However, these students did not have extensive experience of CSCL or inquiry learning. The small groups were formed at the beginning of the inquiry learning activity and were based on students' similar interests in the domain of 'the universe'.

One small group of four girls was selected for Study III. The group was selected as suitable for the in-depth case analysis because there was preliminary evidence of SSMR in their collaborative process. All six small groups were involved in Study IV. Two of the small groups consisted of girls, one of boys and three comprised girls and boys.

[2] The studies were funded by Grant Nos. 131 490 and 274 163 from the Council of Cultural and Social Science Research, the Academy of Finland funding awarded to Professor Erno Lehtinen, and Grant No. 274 117 awarded to Professor Marja Vauras.

3.2 Collaboration environments

Two collaboration environments were used for the empirical work. For Studies I and II, the collaboration environment was face-to-face learning in the domain of mathematical word problem solving. It involved a mathematical adventurous game 'Quest of the Silver Owl' developed by Vauras and Kinnunen (2003) to support primary school students' mathematical problem solving skills in a technology-based environment. In the game, each dyad had a common goal which was possible to reach when students within the dyad together solved mathematical word problems. For Studies III and IV, the environment was inquiry CSCL in the domain of science. It focused on research-like social processes of inquiry, where the aim is to process and deepen explanatory knowledge instead of merely factual knowledge (see Brown & Campione, 1994; Hakkarainen, 2003; Scardamalia & Bereiter, 1994). Each small group had a common goal. The group set up a common research question, constructed a hypothesis, developed a work plan, searched for and processed knowledge, and finally, summarised findings and concluding.

Both environments involved some similar main principles. The *environments required collaboration* between the students, and collaboration was also highlighted to the students. The researcher/teacher was involved in the process only if students asked for help when they had reached a dead-end and could not continue by themselves. This was done because teacher–student interaction can sometimes dominate and control the interaction (see Kumpulainen & Wray, 2002). In the present research it was essential to maximise opportunities for students' interactions with each other.

Since one reason for failure in collaboration can be that it has been taken granted and students have been left to themselves (see Kreijns, Kirschner, & Jochems, 2003), the environments were arranged so that students had to collaborate at a cognitive level and regulate the common process metacognitively. For example, in mathematical word-problem solving game, the dyad was required to write together some steps on the screen (expression/s, solution, unit), and in inquiry learning, the small groups were required to write down sub-conclusions after each phase (Setting up the research question, Constructing a hypothesis, Developing a work plan, Searching for and processing knowledge, Summarising findings and concluding). Hence, the *environments required students' regulation* but also gave freedom to the dyads and small groups to establish their own ways to collaborate.

The environments were structured so that the tasks were not solvable mechanically. It has been shown that metacognition is not necessarily visible when working is too easy (see Prins et al., 2006) or when the learning tasks are highly automated (see Carr & Jessup, 1995). Since the aim of the present research was to explore SSMR, the *environments needed to be sufficiently demanding* in order to induce metacognitive regulation and make it visible. Also, the environments were made flexible so that different dyads and small groups were able to operate at the boundaries of their ability, where metacognition has been shown to be activated (see Prins et al., 2006). For example, the game environments offered students opportunities to control the task difficulty according their ability (Study I and Study II). Inquiry learning (Study III and Study IV) made it possible for small groups to go beyond surface-level phenomena and towards a higher-level understanding (see Hakkarainen, 2003; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007).

In both environments, the students were given opportunities to select some aspects of the task. In the mathematical game environment (Studies I and II), the dyads could choose the difficulty level of the task and in the inquiry learning environment (Studies III and IV), the small groups could generate the research question that they wanted to solve. These *arrangements had a* *motivational aspect* as well. This was seen as important because the relationship between metacognition and motivation has been highlighted in previous research (e.g. Pintrich, 1999). Furthermore, as motivational incentives, mathematical word problems were solved in adventure game-format environments with an attractive graphical environment where the dyad had a common goal. In inquiry learning, after deliberation with the teacher, the domain of 'the universe', which is part of the national curriculum, was chosen, since it was perceived as of interest to many students. Each small group also had a common goal when solving the research question it had set up. In sum, both environments were designed in such a way that the emergence and visibility of SSMR would be possible.

3.3 Assessment of SSMR

In this dissertation, *the concept of SSMR* was developed and assessed. In assessing SSMR, the unit of analysis was a sequence of interconnected spoken turns (Studies I and II) or written notes (Studies III and IV). A sequence of interconnected turns/written notes was classified as an SSMR if students, through their turns/written notes, demonstrated evidence that they were metacognitively jointly regulating the progress of their thinking processes towards their common goal. A minimum of two students had to be involved in the process, and the students' reciprocal turns/written notes were interdependent, together affecting the course of the ongoing cognitive process. Furthermore, although SSMR had to involve a minimum of two turns/written notes, no upper limit was set for the number of turns/written notes included. The meaning of each turn/written note, whether it was a part of an SSMR or not, was thus dependent on the flow of other preceding or subsequent turns/notes, which means these turns/notes were interconnected. Each turn/note included in an SSMR had to be a reaction to some previous turn(s)/note(s) or had to be followed by a turn(s)/note(s) reacting to it. The turns/notes in the SSMR did not necessarily follow each other immediately, but other turns/notes could appear in between or in parallel. If a student's cognitive turn/note (e.g. a proposal) triggered an SSMR, the first regulatory turn/note reacting to it was analysed as the starting point of the SSMR. The end was signalled by the turn/note that ended the regulation process, and the SSMR displayed its executive function and focus of the group's thinking process. An example of SSMR is as follows: Student 1: 'We want to address the task's goal but we don't know enough of this issue because…', Student 2 (reacting to Student 1): 'Hmm, let's think about this issue in more detail. So far, we know that … but we still don't have knowledge about…', Student 3 (reacting to Student 1 and/or Student 2): 'So, let's try to fill in these gaps before concluding. First, we have to find out … Next, we have to…' and the interaction continues further.

As a part of this dissertation, the functions and foci of SSMR were detailed and developed and their usefulness tested. Hence, each SSMR thread was analysed in terms of its regulatory *function* during the learning process. The function of SSMR was analysed because metacognition regulates the fluency of cognitive processing and whether an error has appeared (see Efklides, 2008), while it also initiates, continues or terminates actions (Nelson & Narens, 1990). Thus, depending on the dyad's or group's perceived appropriateness of the direction of its cognitive process, the SSMR's function was either to Continue (originally referred to as Facilitate in Study II, but changed to Continue in Study III and thereafter) or Inhibit the dyad's or group's evolving cognitive process. Both functions, Continue and Inhibit, sought to achieve a better performance. The Continue function had two sub categories – Activate and Confirm. A *Continue* SSMR captured situations when the dyad or group, by way of metacognitive regulation, *activated* further cognitive processes in the ongoing direction or decided to seek to *confirm* that the direction of its current thinking was appropriate. In contrast, Inhibit had three sub categories – Slow down, Change and Stop. Hence, an *Inhibit* SSMR captured situations when the dyad or group perceived the current direction of its cognitive processes as inappropriate and decided to re-think their approach. For example, the dyad or group might question previous thinking but despite *slowing down*, would continue doubtfully in the same direction. In *changing*, the dyad or group interrupted its current train of thought and re-oriented their thinking in a new direction. The dyad or group could also *stop* the direction of its thinking, have concluded it was inappropriate, but did not develop, based on that conclusion, a new way of thinking. As an example of the categories is students' ability to change their thinking. For instance: Student 1: (states the students' common answer reached) (glances at Student 2), Student 2: 'Yes, it has to be this', Student 1: 'Let's think on it' (looks at Student 2), Student 2: 'What else could it be, could that be a reasonable answer?' (glance at each other), Student 1: 'Just a moment…' (glances at Student 2), Student 2: 'It can't be the answer (glances at Student 2), hey look, how can it be…' (look at each other), Student 1: (thinks of the core of the task) '…that we should get' (looks at Student 2), Student 2: 'So, let's continue so', Student 1: 'Let's think of this', Student 2: (starts to calculate) (look at each other), Student 1: (calculates, students get a new answer) 'But it can't be, but, yes, it doesn't…' (look at each other), Student 2: 'So, yes' (look at each other), Student 1: (gives a reason for a new answer) 'Because it has to…' (looks at student 2), Student 2: 'Yep'.

SSMR also was analysed according to its *focus*. This means that metacognitive regulation can be directed to different things during the process. The focus categories were the Situation model, Operation and Incidental matters in the mathematical word problem solving (Study II) and in inquiry learning, it was Understanding, Procedural, and Incidental matters (Study IV). Focus categories were developed based on ideas from the previous research literature (see van Dijk & Kintsch, 1983; see also Cummins, Kintsch, Reusser, & Weimer, 1988). Originally, van Dijk and Kintsch (1983) proposed that text comprehension goes beyond the analysis of propositions presented in the text (textbase) and requires the construction of a situation model, which integrates the existing world knowledge with information derived from the text. Cummins and colleagues (1988) in turn did show that in complex mathematical word problems, the straightforward formulation of mathematical operations on the basis of a problem text is not enough; first a situation model has to be constructed. In line with these ideas, SSMR's focus was distinguished according to whether it referred to the formation of the situation model/understanding, operations/procedural matters or more incidental matters. In *situation model/understanding*, the attempt is to regulate cognitive representation and the focus is on the understanding of the phenomenon. In an *operation/procedural matter*, the attempt is to regulate more strategies, procedural issues or a local matter (e.g., of that moment) without considering the whole problem. Finally, *incidental matters* refer to the regulating of things that have no crucial meaning in the process. As an example of the categories is students' focus on the situational model as illustrated: The students are thinking at the beginning of the problem solving process how they understand the issue described as 'from one point to another and back' (which is a crucial issue to understanding the problem). Student 1: 'Is this 2 or 3? (looks at Student 2)', Student 2: 'Hmm (thoughtfully) …, does that from one point to another and back mean that …?' (glances at Student 1), Student 1: 'Let's draw' (students start to draw), Student 2: 'So, how can you run back if you leave from here?' (glances at Student 1), Student 1: 'Look, here is the starting point, it runs here, then it runs…', Student 2: 'But it doesn't come back then' (glances at Student 1), Student 1: 'Yes, it doesn't come back to the starting point then' (glances at Student 2), Student 2: 'Hmm, so it's 2 times, okay'.

Additionally, *metacognitive experiences* were analysed in Study II concerning whether they started SSMR or not. According to Efklides (2001, 2006), metacognitive experiences monitor and inform a person about a feature of cognitive processing in relation to the task at hand. They can be seen as important in regulation also in collaborative learning because they provide information to the partner about the quality of cognitive processing and progress towards the shared goals (see Efklides, 2006, 2008) and may trigger metacognitive regulation processes

(Efklides, 2001, 2006, 2008; Flavell, 1979). In contrast, there is evidence (see Salonen et al., 2005) that misperception of the interacting partners' metacognitive experiences may lead to failure in collaboration. Therefore, the presence of observable expressions of metacognitive experiences was examined at the starting point of the SSMR, in which case the first turn of the SSMR was analysed. Following Efklides (2006), the first turn was classified as a metacognitive experience if it referred (a) to feelings such as familiarity, difficulty, knowing, confidence or satisfaction; (b) to judgments/estimates such as judgments of learning, source memory information, an estimate of effort or time; or (c) to online task-specific knowledge such as task features or procedures employed. For example, turns such as 'I'm not sure if this is correct' or 'This may be time-consuming to solve' were classified as metacognitive experiences.

In study IV, the focus of SSMR was investigated in relation to the group's *outcome*. Study II as well as other previous SSMR studies (Grau & Whitebread, 2012; Khosa & Volet, 2014; Whitebread & Grau Cárdenas, 2012) have shown that SSMR can be directed to different aspects of the process in face-to-face learning. However, its role in group's outcome has not been scrutinised. Hence, in Study IV, the relationship with the focus of SSMR and the group outcome was analysed at different phases of the process. This means that the group's research questions, hypotheses and final outcomes (reports) were assessed by experts (a natural scientist and educational psychologist as principal coders). In the research questions, two categories were used according to whether the research questions were factual or explanation-seeking. This was based on the previous research literature (Hakkarainen, 2003) which has suggested that if research questions are more explanation-seeking, there are more possibilities to go deeper into the processing of understanding. Instead, a factual research question can lead to a more superficial discussion. Applied the coding scheme from Hakkarainen (2003), the group's hypothesis and reports were assessed according to whether they included 1) superficial information/separated pieces of facts without explanation, 2) partly facts and partly explanation or 3) explanation.

As SSMR has been conceptualised as symmetrical interaction between students, and symmetric interactions have also been shown to be beneficial to common enterprise (see e.g. Grau & Whitebread, 2012; Molenaar, 2011), *each students participation* in SSMR was also analysed in Studies III and IV. Hence, each written note by a student that contributed in SSMR was counted in different phases of the process and according to its function (Study III). In Study IV, different small groups were compared.

3.4 Analyses

In all studies, on-line methods were mainly used because they are considered a validated way to assess an ongoing cognitive process (e.g. Veenman, 2005) and SSMR is primarily focused on the actual process. Data for the analyses of the face-to-face interactions were gathered using both videotaped and transcribed solving processes and interviews. Data for the analyses of the asynchronous CSCL consisted of written notes.

Both qualitative and quantitative analyses were used in order to examine different aspects of SSMR in the two environments. As has been argued, multi-method design reveals different aspects of metacognition (e.g. Veenman, 2005, 2007) and shared metacognitive regulation (Hadwin & Oshige, 2011). The analytical methods used were as follows: in-depth case analyses; interviews; non-parametric tests; cross-tabulations; goodness-of-fit tests; linear regression analyses; social network analyses; and state space grids. In addition, inter-coder agreement was also assessed.

In-depth case analysis. This analysis provided an opportunity to go deep into a dyad's or group's collaboration processes and to reveal the metacognitive regulation. It involved qualitative, micro-level interaction analysis of single cases and captured the whole context. Furthermore, it also revealed macro level patterns. Case analysis was used at the initial stage of exploring SSMR in the two environments (Study I and Study II for the face-to-face environment, and Study III and Study IV for the asynchronous CSCL environment). The protocols for the dyadic and small-groups were analysed (see Artzt & Armour-Thomas, 1992). An *interaction flowchart* (applied from Sfard & Kieran, 2001a, 2001b) was used to analyse and visualise SSMR at the inter-individual level. This approach deals with how participants of an interaction move between different channels of communication (individual, interpersonal) and different levels (cognitive, metacognitive).

Interviews. Interviews were used to complement the observed interactions at the exploratory stage of the mathematical word problem solving sessions in the face-to-face learning environment (Study I). Interviews were conducted at two stages in the problem-solving activity: first, prior to students getting feedback on their performance, and second, immediately at the end of their session (stimulated recall). In the prior-to-feedback interviews, the researcher elicited group reflections on problem-solving processes from the SSMR point of view. The prior-to-feedback interviews were conducted because the previous research literature suggests that student analyses tend to vary according the phase of the process (see Efklides, Samara, & Petropoulou, 1999) and according to the feedback given (see Butler & Winne, 1995; Labuhn, Zimmerman, & Hasselhorn, 2010), although outcome feedback gives only minimal guidance on how to regulate (Butler & Winne, 1995). However, that kind of interview may also interrupt the process and have an effect on the ongoing and subsequent processes and thus, it can act as an intervention, where the questions of the researcher may prompt the respondents' answers. The second interview, using stimulated recall, was carried out immediately after each game session. In this interview, the dyad watched at least one of its problem solving processes after each session and also analysed it from the SSMR point of view.

Non-parametric tests. Non-parametric tests were used to analyse the extent to which the level of difficulty of the tasks had an impact on the amount and length of SSMR in Study II. The number and length of episodes of SSMR at different difficulty levels of the problems were compared by means of the Kruskal–Wallis test, using exact distributions. Also, a Mann–Whitney *U*-test applying the Bonferroni correction was used as post hoc comparisons when different difficulty levels of the problems were compared.

Cross-tabulations. Cross-tabulations and associated tests (Chi-square, Fisher's exact test and the Monte Carlo method) were used in Studies II, III and IV to analyse a range of relationships concerning SSMR. Pearson's chi-square test and Cramér's V correlation coefficient were used to test associations (see Siegel & Castellan, 1988) when studying metacognitive experiences at the beginning of SSMR episodes in Study II and students contribution to SSMR and non-SSMR activity and the Continue and Inhibit functions in Study III. Fisher's exact test was used due to the small expected values in some of the cells when functions and foci of SSMR were studied between different difficulty levels in Study II and the students' contribution in the different phases of the process in Study III. The Monte Carlo method was used because of the computational demands when the relationship between foci and functions of SSMR were investigated in Study II. In addition, adjusted standardised residuals were used to indicate the differences between the observed and expected values in both Studies II and III. Moreover, regarding students' participation in Study III, comparisons of column proportions (z-test) were used to indicate whether proportions of students' notes differed significantly from each other in SSMR and non-SSMR threads and in SSMR's Continue and Inhibit functions.

Goodness-of-fit tests. A series of Chi-square goodness-of-fit tests were used to compare the distribution of notes in SSMR threads at the different phases of the process, while pairwise comparisons were used to investigate whether the number of written notes included in SSMRs differed between phases and groups in Study IV.

Linear regression. This method of analysis was performed in Study IV in order to test whether there were changes in the amount of written notes in SSMR during the learning processes.

S*ocial network analysis and the State Space Grid method.* Different analyses were conducted in order to study the nature of participation between the group members in Studies III and IV. In addition to Pearson's chi-square test, Cramér's V correlation and z-tests with Bonferroni correction, *social network analysis (SNA)* in Studies III and IV and an application of the *State Space Grid method (SSG)* in Study IV were applied. Regarding the SNA, density (how much pupils have connections with one another, represents the total of all values divided by the number of possible connections), centrality (indicates who is at the centre of a number of connections) and centralisation (a group-level quantity that means how tightly connections are organized within the small group (see Scott, 1991; Wassermann & Faust, 1994) were calculated. Regarding SSG (see Hollenstein, 2013), dispersion was calculated, that is, how participation was dispersed between the students (see GridWare Manual, p. 40). Different analytical methods were used in order to compare their results and to get a more extensive picture of the nature of the participation.

Inter-coding agreement. Inter-coding agreement was assessed in all studies in order to provide measures of the reliability of the coding. In Study I, it was done qualitatively using three coders because of the explorative nature of the study. Since SSMR research was at an exploratory stage and was still an emerging field of study, three coders were used in order to confirm the feasibility of the SSMR. In Studies II, III and IV, inter-coder agreement was calculated using percentage agreement and Cohen's kappa. In addition to these, Krippendorff's alpha was computed in Study IV. Given the criticisms that percentage agreement does not account for chance agreement, and that kappa includes a dependence on prevalence that can result in statistical artefacts, Krippendorff's alpha has been proposed as a preferred method of measuring inter-coder agreement (see De Wever et al. 2006; Strijbos & Stahl, 2007). Since alpha has not typically been used in CSCL research to date (see Strijbos & Stahl, 2007), all the named methods were used in Study IV to calculate inter-coder agreement.

Similar to Study I, three coders were used in Study IV, when SSMR was applied to the CSCL context. Overall, inter-coder agreement was assessed at different phases of the coding processes and from different points of view. In Study II, for example, the trained inter-coder had to locate episodes of SSMR from the dyads' problem-solving processes (episodic level) and turns that were included or excluded from the episodes were inter-coded, as well as foci, functions and metacognitive experiences. Metacognition research has been exposed to criticisms because of limitations in assessing validity, especially in new methods (see Veenman, 2007). This limitation was addressed by carefully taking inter-coding issues into consideration in all the studies conducted as part of this dissertation. In all cases, inter-coder agreement was seen at least as good (see Landis & Koch, 1977).

4. Overview of the empirical studies

This dissertation includes four studies that extended the concept of metacognition to the collaborative learning environment. The first study was exploratory in nature and led to the conceptualisation of SSMR. The three subsequent studies elaborated on this concept and extended the empirical work from face-to-face learning in dyads to learning in an asynchronous CSCL environment in small groups.

Study I

Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology, 1*, 147–178.

The main aim of this exploratory study was to examine if and how metacognition is manifested in social interaction during a collaborative learning process. A second aim was to develop a method for analysing the social level awareness, monitoring, and regulatory processes during dyads' problem solving.

Data for this study were from a larger data set of 10-year-old mainstream students (n=393) engaged in mathematical word problem solving and reading comprehension. To address the aims of this explorative study a comprehensive case analysis was conducted. The participants were two high-achieving student dyads. One dyad consisted of two girls and the other of two boys. These above–average ability students (e.g. in mathematical word problem solving and in reading comprehension), who succeeded approximately at the same level, were selected from the data set. Data were collected over 16 (30–45 minutes) face-to-face sessions. Over time the dyad of boys solved 76 and the dyad of girls 75 mathematical word problems presented in a game-format learning environment. These ranged in levels of difficulty. All sessions were videotaped. Verbal occurrences were transcribed and nonverbal behaviour was documented. Evidence of metacognition in students' collaboration within the dyads was qualitatively explored by three coders and agreement finalised through discussion. The flow of students' comments was analysed by interaction analysis. An adaptation of Sfard and Kieran's (2001b) interaction flowchart was used to represent the data and highlight the occurrences of socially shared metacognition at the inter-individual level. In addition to the video data of the ongoing process of the students' problem solving sessions, stimulated recall interviews were conducted with the students in order to obtain further information about socially shared metacognition.

The results revealed that metacognition was manifested throughout the face-to-face collaborative mathematical problem solving processes in high-achieving student dyads. When the dyads did not encounter difficulties with the problem, there was no evidence of socially shared metacognition between the students. In contrast, socially shared metacognition was frequent in the more difficult problems, as the students encountered and confronted the challenges. In these case studies, socially shared metacognition became evident when students halted the process, gave small verbal and nonverbal (e.g. gazes) signals to each other and started to share metacognitive thinking in order to further the solving process. The dyad of girls also appeared to have a system whereby they shared metacognitive regulation. The findings suggest that in order to discover patterns of socially shared metacognition, it is important to investigate metacognition over time. The study also showed that singular comments did not necessarily need to be metacognitive in nature; however with other comments as a part of the flow of speech, they could contribute to metacognition meaning. This finding suggests that it is not sufficient to analyse single comments alone in order to reveal occurrences of socially shared metacognition. The connection between comments needs to be part of the analysis in order to capture socially shared metacognition. The interaction flowchart proved useful to represent the flow of socially shared metacognition occurrences. Nonverbal behaviour and stimulated recall interviews further validated the interpretations of the video data, although caution is needed when relying on them.

In conclusion, this study revealed that metacognition can be manifested in a collaborative context, and cannot always be reduced to individual conceptions. Given that metacognition was previously conceptualised as an individual association, the concept of socially-shared metacognition was proposed in order to highlight the manifestation of metacognition in collaborative contexts at the inter-individual level. However, it was concluded that more research on socially-shared metacognition from larger data sets was needed. The results of this study also stressed the importance of taking into account the level of task difficulty. Finally, the study also revealed how small verbal and nonverbal signals between students, triggered episodes of socially shared metacognition. These considerations and findings formed the basis of the second study (Study II).

Study II

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction, 21*, 379–393.

The specific aim of this study was to investigate whether socially shared metacognition can reliably be identified in collaborative face-to-face mathematical word problem solving processes in high-achieving student dyads. A second aim addressed the extent to which task difficulty has an impact on the emergence of socially shared metacognition. As the third aim, the functions and foci of socially shared metacognition were examined. Finally, the extent to which metacognitive experiences were present at the beginning of socially shared metacognition was explored.

As in Study I, data were from a larger data set of 10-year-old mainstream students (n=393) engaged in mathematical word problem solving and reading comprehension. Baseline data for this study constituted 14 675 turns of transcribed verbal and nonverbal behaviours in four dyads. These dyads were comprised of eight high-achieving 10-year-old students, ranking in the top 11% of fourth grade peers. The students worked face-to-face in a computer-supported, game-format learning environment. Working sessions were videotaped. Processes from 251 problems solved by dyads at three levels of difficulty during 56 (30–45 min) lessons were analysed. The micro-level analysis was based on an adaptation of Sfard and Kieran's (2001a) interaction flowchart, which illustrates how participants of an interaction move between different channels of communication (individual, interpersonal). The unit of analysis was a set of turns, referred to as an episode. Both video-recordings and transcriptions of the sessions were used in the analyses. A classification of functions (activate, confirm, slow, change, stop) and foci (situation model, operational, incidental matter) of socially shared metacognition was created. Inter-coder agreement was assessed in different phases of the study, commencing with identification of the episodes of socially shared metacognition. In all phases, inter-coder agreement was seen as being at least substantial (see Landis & Koch, 1977).

First, qualitative results described characteristic episodes of socially shared metacognition and were labelled according their function and focus. Second, statistical tests showed that there were significantly more and longer episodes of socially shared metacognition in the difficult than in the moderately difficult and easy level problems. There were no significant differences between the moderately difficult and the easy problems in the number or the length of episodes. Further, there was a significant relationship between the function and the focus of the episodes, that is, the dyads mostly confirmed operations. Regarding the function and the difficulty level of the problems, a significant relationship was found. In the episodes of socially shared metacognition, the dyads mostly confirmed and activated the process in the moderately difficult and difficult level problems, but mostly confirmed the process in the easy level problems. A significant relationship was also found in the relationship between the focus and the difficulty level of the problems, in which the dyads' socially shared metacognition focused more often on the situation model and less often on incidental matters in the difficult level problems and vice versa in the easy level problems. Metacognitive experiences were found at the beginning of episodes (54%), but there was no significant relationship between the difficulty level of the problem and the observable appearance of the metacognitive experience. Further, when metacognitive experiences were identified at the beginning of an episode, the function of that episode was more often changed or stopped, and the focus was on the situation model.

In conclusion, this study showed that it is possible to define the function and the focus of socially shared metacognition from a large data set. The study also indicated that socially shared metacognition and its functions and foci, as well as the appearance of metacognitive experiences can be defined in a reliable way by independent observers. As part of the study, classification of the functions and foci of socially shared metacognition was developed in order to expand the research on socially shared metacognition. Further, the importance of metacognitive experiences at the beginning of the problems was found. This means that even small signals that display metacognitive experiences and which the students make to each other during the process have important meaning in triggering socially shared metacognition. The comparison between different difficulty levels of the problems suggested that in order to support socially shared metacognition in small groups, the problems should be difficult rather than moderately difficult or easy level problems. Although socially shared metacognition was found in collaborative face-to-face processes in mathematical word problem solving in high-achieving student dyads, more research is still needed in different contexts. This consideration created the basis of our research on socially shared metacognition in Studies III and IV.

Study III

Iiskala, T., Volet, S., Lehtinen, E., & Vauras, M. (2015). Socially shared metacognitive regulation in asynchronous CSCL in science: Functions, evolution and participation. *Frontline Learning Research 3*(1), 77–110.

The overall aim of this study was to expand the research on SSMR the face-to-face environment in dyads to an asynchronous CSCL environment in small groups. The specific aim of this study was to investigate SSMR's manifestation and functions in a CSCL environment and to explore how SSMR emerges at different phases of the inquiry CSCL process, as there has been lack of research in this area. Finally, the study also aimed to determine how individual group members participate in SSMR during the process and how specific individuals' contributions influence the group's regulatory effort.

To address these aims, an in-depth explanatory case study was carried out. Data included the networked discussions, in the form of written notes (N=640) of one small group of four girls. The girls were all aged 12 years and were in the 6th grade. The school that they attended has an entrance examination and has a language-enriched curriculum. The small group solved complex science problems in an asynchronous CSCL environment, participating in research-like processes of inquiry during 22 lessons (approximately 45 minutes). The collaborative process was partly divided into different phases. A micro-level analysis (microgenetic) which also revealed macro-level threads of the students' interaction was used, and a set of written notes was also used as the unit of analysis. Inter-coder agreement was regarded as substantial (see Landis & Koch, 1977).

Results indicated that SSMR emerges in a small group's asynchronous CSCL process. Different functions of SSMR were discernible in an asynchronous CSCL environment. Thus, the classification of functions of SSMR observed in face-to-face contexts appeared to also be applicable in the asynchronous CSCL contexts. The results revealed that the small group was particularly able to slow down and stop its ineffective progression of the process but was not as able to activate or confirm the direction of the process by SSMR. Further, the findings revealed that the emergence of SSMR varied according to phases, which suggests that in order to get an accurate picture of the emergence of SSMR, different phases of the process need to be examined, as opposed to keeping the examination at a general level. SSMR threads were also found to continue over different phases of the process, and different SSMR threads overlapped and were intertwined. These findings supported the expectation that SSMR should be examined as a process and also over an extended period of time. Further, the use of different analytical methods was critical, as they provided complementary findings into students' participation in SSMR. No individual differences appeared in the number of written notes in SSMR when compared with non-SSMR notes. However, social network analysis revealed that one student's written notes were responded to the most by other students. Also, students played different roles in different SSMR threads and in different phases of the process. The findings suggest that it is not enough to code just a single note or only to examine who has the largest number of notes in the SSMR, but also to examine the connections between the written notes. The finding also suggests that it is useful to apply different analytical methods to arrive at a more inclusive understanding of participation SSMR.

To sum up, the results of the present study were in line with those of previous studies (Study I and II) and revealed that SSMR cannot be reduced to the individual level. However, SSMR appeared, at least in part, to operate differently in different contexts (e.g. in dyads' face-to-face mathematical word problem solving processes and in small groups' inquiry CSCL). The same functions could be observed in the different contexts but the dominant function may be different. However, the results did not deal with either SSMR's focus, which has been studied in the face-to-face context, or the role of SSMR in relation to quality of the learning process's outcome. As the findings of the present study were based on in-depth analysis of a single case, it was concluded that further cases would need to be examined, which was the focus of Study IV.

Study IV

Iiskala, T., Lehtinen, E., Vauras, M., & Volet, S. (2015). *Socially shared metacognitive regulation, students' participation, and quality of computer-supported collaborative inquiry learning*. Manuscript submitted for publication.

The main aim of this study was to investigate the emergence of socially shared metacognitive regulation (SSMR) with a larger data set in an asynchronous inquiry CSCL process in science in small student groups. Other specific aims were: to examine the emergence of SSMR at different phases of the process; to explore the distribution of students' participation and patterns of initiators' and respondents' roles in SSMR threads within and across groups; and to explore the relationship between the focus of SSMR and the quality of outcomes.

Six small groups of 12-year-old students (N=25) were involved in the study, five groups of four students and one group of five students. All groups came from the same class, which followed a language-enriched curriculum and had an entrance examination. Groups were asked to solve ill-defined science problems in an asynchronous CSCL environment. The problems encouraged the groups to engage in research-like processes of inquiry, which lasted over an extended period of time. The networked discussion of the six groups, which consisted of 4088 written notes, formed the baseline data for the exploration of SSMR. The unit of analysis was a thread, that is, a set of interconnected notes. In total, 332 notes were classified as a part of 41 SSMR threads. Inter-coder agreement between three independent judges was calculated for different phases of the analysis. Three indices (percentage agreement, Cohen's kappa, and Krippendorff's alpha) were obtained, and the inter-coder agreement was found to be reliable (see De Wever, Schellens, Valcke, & Van Keer, 2006; Landis & Koch, 1977; Strijbos & Stahl, 2007).

The results showed evidence of SSMR in all asynchronous CSCL inquiry processes in the small groups. However, there was no significant changing trend in the emergence of SSMR over time. The distribution of notes in SSMR threads differed significantly at different phases of the process, when all groups were tested together as well as when the groups were tested separately, with the exception of one group. Further, pairwise comparisons revealed that the notes included in the SSMR threads were distributed differently between phases and across groups, with the exception of two pairs of groups. The distribution of students' contributions to SSMR threads within groups was analysed using several complementary methods, including Social Network Analysis (SNA) and the State Space Grid (SSG). Overall, students' contributions varied widely within groups. In all groups, at least one student acted both as an initiator and a respondent less than other students in SSMR threads. Further, in some groups, students had fewer connections with each other than in other groups. Overall, participation was highly dispersed between the students. Finally, the analysis of the relationship between SSMR's focus and the quality of outcome showed a remarkable consistency. This was evident in two of the three groups with high quality outcomes involved in SSMR focused on understanding and procedural matters over the whole process; the group with an outcome of average quality displayed SSMR focused mainly on procedural matters; while the groups with low quality outcomes displayed an SSMR focus more on incidental and procedural matters.

To sum up, the findings highlighted that neither the quantity of SSMR during a CSCL inquiry process nor the groups' participation structure could explain differences in the groups' quality of outcomes. Rather, it was the focus of the SSMR activity that differentiated between the quality of groups' outcomes, with evidence that a focus on a combination of understanding and procedural matters supported high quality outcomes. Alternatively, a focus on a combination of incidental and procedural matters was found to be associated with low quality outcomes. Hence, the findings stress that the focus of SSMR is strongly related to the quality of the learning outcomes. This study also demonstrated the value of using multiple analytical methods for the study of SSMR because they revealed different manifestations of student participation (e.g. density, centrality, centralisation, and dispersion).

5. Main findings and discussion

5.1 Main findings of the studies

The main aim of this dissertation was to analyse how dyads and small groups regulate their cognitive processes in collaborative learning situations and to explore whether it is possible to recognise metacognitive regulation that is socially shared. The present work has its basis in the metacognition research tradition in which metacognition has traditionally been conceptualised as an individual-level phenomenon. Against this background the aim of the present work was, firstly, to widen the understanding of metacognition to include collaborative learning. It was theoretically assumed that metacognition can also be understood as being socially shared. A new concept, socially shared metacognitive regulation (SSMR), was introduced and defined as the participants' goal-directed consensual, egalitarian and complementary regulation of joint cognitive processes. Secondly, the aim was to develop methods that can be used to analyse SSMR in collaborative learning processes. The methods that have been used in analyses of metacognitive regulation have traditionally focused on the individual's metacognition. Thirdly, the aim was to empirically validate the concept of SSMR in collaborative learning contexts by analysing how it is related to learning and problem solving processes. Four studies were conducted in two different collaboration environments. The first two studies (Study I and Study II) were conducted in dyads where students participated in face-to-face collaborative mathematical word problem solving activities. The students were 10 year olds. Study III and Study IV were conducted in small groups and focused on inquiry-based science projects in an asynchronous, computer supported collaborative learning (CSCL) environment. In those studies, the students were 12 year olds.

The main findings of this dissertation support the assumption that metacognition also emerges as SSMR. This means that metacognitive regulation can be viewed as a wider concept beyond the domain of individual learning. In all four studies, SSMR was reliably identified. Study I showed that the theoretical idea of socially shared metacognition can be empirically identified in high-achieving student dyads' problem solving processes. In that study, qualitative in-depth and micro-level case analyses indicated that SSMR emerged throughout the entire process and that socially shared metacognition could not be reduced to the participants' individual metacognition. The study laid the foundation for the other three studies of this dissertation.

In the further studies, episodes of SSMR (sequence of turns following each other turn by turn) were identified in the student dyads' face-to-face problem solving (Study II) and SSMR emerged as threads (sequence of written notes having other notes between) in the small groups' asynchronous CSCL environment (Study III and Study IV). The CSCL notes included in the SSMR threads did not necessarily follow each other immediately; rather, there could be a time span between the notes. Hence, SSMR in the small groups' asynchronous CSCL looks different when compared to the student dyads' face-to-face problem solving. Moreover, in many cases, the SSMR threads overlapped and intertwined, especially in the CSCL environment.

The SSMR's functions (Study II and Study III) and foci (Study II and Study IV) were determined in the series of studies. SSMR was found to have different specific functions during the mathematical word problem solving activities (Study II). SSMR can facilitate the progression of the process or inhibit inappropriate progression. Hence, the students in the dyads either activated new cognitive processes by means of SSMR or they decided to check whether or not the ongoing direction was appropriate and confirmed the direction of the ongoing cognitive processes. In contrast, the students in the dyads also inhibited perceived inappropriate cognitive processes, in the event of which they slowed down, changed or stopped the direction of the process by means of SSMR. In the mathematical word problem solving activity, the student dyads mainly decided to check the appropriateness of the current lines of thought and confirmed their perceived correctness through SSMR. Similar SSMR functions, as documented in the dyads' face-to-face problem solving processes, were also identified in the small group's asynchronous CSCL processes (Study III). However, the dominant functions differed, such that in the CSCL context, the members of the small group mostly inhibited the ongoing perceived inappropriate line of thought.

It was found that SSMR focused on the situation model (understanding the situation described in the mathematical word problems), operations or incidental matters in the dyads' face-to-face problem solving activities (Study II). There was a significant relationship between the difficulty level of the problem and the focus of the SSMR. Hence, in easy problems, the SSMR focused mainly on incidental matters, whereas in difficult problems it focused on the situation model. The relationship between the SSMR's focus and the quality of the outcome was also studied (Study IV). The SSMR foci from the dyads' face-to-face problem solving process were applied to the small groups' asynchronous CSCL process in science where the SSMR focused on understanding concepts and on procedural or incidental matters. The groups with high quality outcomes focused on understanding and procedural matters in SSMR. In contrast, the average quality outcome group focused SSMR mainly on procedural matters, while the low quality outcome groups focused on incidental and procedural matters. Hence, these findings imply that, in SSMR, focusing on understanding in addition to procedural matters is beneficial to a high quality outcome.

The findings also revealed that observable metacognitive experiences are important triggers for the emergence of SSMR (Study II). In particular, when there were observable metacognitive experiences at the beginning of the SSMR episode, the SSMR's function was more regularly to change or stop the perceived inappropriate thought processes. In addition, SSMR focused more regularly on the situation model when the SSMR episode was triggered by metacognitive experiences. No relationship was found between the difficulty level of the problem and the presence of metacognitive experiences.

A clear relationship was found between the SSMR and the difficulty level of the problem (Study II). SSMR episodes were found to emerge more regularly and they were longer in difficult problems than in moderately difficult and easy problems. In difficult problems, the dyads' SSMR also focused on the situation model more than it did in the moderately difficult or easy problems. In light of this finding, surprisingly, the amount of SSMR (number of written notes in SSMR or number of student connections with each other in SSMR) did not explain variations in the small groups' quality of outcomes in the asynchronous CSCL in science (Study IV). Moreover the students' equal participation did not explain variations in the small groups' outcomes in the asynchronous CSCL. The use of multiple analytical methods revealed supplementary findings about individual students' participation in SSMR (Study III and Study IV), for example, the different manifestations of students participation (e.g. density, centrality, centralisation, and dispersion). Students contributed a different number of notes to the SSMR and typically one student had less of a connection with other students than other members within the groups. Students also had different roles. For example, one student contributed mostly to the SSMR that inhibited the perceived inappropriate line of thought (Study III). All of the students did not participate in all of the SSMR threads (Study III and Study IV). Additionally, there was evidence that the emergence of SSMR varies between phases and between small groups (Study IV).

To sum up, this dissertation produced evidence that shows that metacognition can be theoretically conceptualised as SSMR and that it is methodologically researchable in collaborative learning contexts. The empirical results provided support that SSMR can be found in different collaborative contexts, although it emerges differently according to the context. This study's findings validated the idea that similar kinds of SSMR functions and foci can be found in different contexts: Study III and Study IV validated the findings of Study I and Study II.

5.2 Theoretical, methodological and empirical considerations

The main theoretical, methodological and empirical contributions of this work are discussed in this chapter. First and foremost, the contribution of this dissertation is the expansion of the individualistic view of metacognition to include collaborative learning contexts where the core is not in regulating individual learning. As has been argued in this dissertation, the traditional concept of metacognition – both explicitly and implicitly – has been associated with individual-level phenomena. This view is supported by one of the pioneers of metacognition research (see Flavell, 2000) who has recognised that interest in metacognition primarily focuses on an individual's own mind. In the present work, the concept of socially shared metacognitive regulation, SSMR, is used in reference to the collaborators' interdependent and joint regulation of the ongoing cognitive learning process towards a common goal within student dyads and small groups. Study I (Iiskala, Vauras, & Lehtinen, 2004) in this dissertation was the first to establish the concept of socially shared metacognition in students' collaborative learning. In this sense, the nature of this dissertation is exploratory.

SSMR's functions and foci were specified in the current work. Hence, one of the main contributions of this work was to reveal that SSMR has different functions and foci during collaborative learning processes. This finding suggests that it is not sufficient to scrutinise SSMR only by itself, at a general level. Instead, the definition of functions increases our understanding of the emergence of SSMR in collaborative learning contexts. It was revealed that cognitive learning processes were jointly regulated to either facilitate progressing thoughts in line with the current direction or to inhibit the continuation of the current direction. For example, this study's findings revealed that students not only activated new constructs together, they also metacognitively regulated that activation process through SSMR or decided, after checking, to confirm the perceived appropriateness of the direction of the current cognitive process. Similarly, SSMR inhibited the direction of cognitive processes by slowing down, changing or stopping the perceived inappropriate direction of ongoing processes. In fact, these kinds of functions can be seen as being built into the metacognition concept because metacognition is seeking to monitor (see Flavell, 1979, 1987) and regulate (see Brown et al., 1983) cognitive action by modifying it (see Nelson & Narens, 1990, 1994). For example, if the ongoing process is not proceeding towards the goal, the strategies that are used can be changed (see Whitebread et al., 2009). Hence, the SSMR's functions are in line with the definition of metacognition, but they are specified in the collaborative context.

This dissertation found that SSMR focuses on the situation model, operations or incidental matters in the dyads' face-to-face mathematical word problem solving activities and, correspondingly, on understanding, procedural or incidental matters in the small groups' inquiry-based science activities in the asynchronous CSCL environment. These findings are supported by the studies of Grau and Whitebread (2012) and Khosa and Volet (2014), which also found that SSMR can be directed towards different aspects during collaboration. Furthermore, previous metacognition research has shown that the difficulty level of the task has an impact on an individual's learning (e.g. Prins et al., 2006). The role of the task's difficulty in the emergence of SSMR was also brought out in this dissertation. For instance, if the task is too easy for students, SSMR less frequently focuses on the situation model. It is assumed that, in an easy task, SSMR is not necessarily required in order to achieve the learning goals. This notion of difficulty level also connects SSMR to the concept of zone of proximal development (ZPD) (see Vygotsky, 1978) and collaborative ZPD (see Goos et al., 2002). Hence, this current work proposes that it is important to contemplate the difficulty level of the task when the emergence of SSMR is scrutinised. Furthermore, it is noteworthy that the difficulty level can vary between different groups. As shown in Study IV, the emergence of SSMR in different phases of the process differed between the groups. This finding is supported by research that has also found variations between groups (Grau & Whitebread, 2012; Rogat & Linnenbrink-Garcia, 2011). One assumption is that the difficulty of different phases can vary between different groups. In turn, this assumption suggests that a micro-level analysis of SSMR during collaborative processes is required in order to capture the characteristics of different groups. Thus, the value of the present research lies in its scrutiny of the entire collaborative process from the beginning to the very end, instead of only focusing on short periods of time.

Recent criticism has pointed out that research on shared regulation lacks evidence of the role of regulation in relation to learning outcomes (see Panadero & Järvelä, in press). Actually, this is also seen as a validity problem, especially with new constructs (see Veenman, 2007). Moreover, the results of previous studies are somewhat contradictory as to whether regulation in collaboration enhances (e.g. Hurme et al., 2009; Zhao & Chan, 2014) or does not enhance (e.g. Schoor & Bannert, 2012) successful learning performance. This dissertation adds a crucial element to the understanding of this relationship. According to the empirical findings obtained in the present study, one of the arguments of this dissertation is that the amount of SSMR (number of SSMR expressions or the students' participation activity in SSMR) does not seem to explain the quality of the outcome of the collaborative learning process. Rather, the focus of SSMR matters. In other words, SSMR's focus on understanding seems to steer the learning process towards a high quality outcome. If SSMR emerges during collaboration but focuses, for example, merely on incidental matters, it does not seem to steer the process towards a high quality outcome. In light of this finding, it is argued that it is not sufficient to only investigate whether or not SSMR emerges during the process and how often; rather, the SSMR's focus should also be scrutinised.

Different components of metacognition (metacognitive knowledge, metacognitive regulation, and metacognitive experiences) have also been reported to interact with each other (e.g. Efklides, 2006). The important role of metacognitive experiences at the beginning of SSMR, shown in Study II, is in line with this view. Actually, the intertwined metacognitive experiences and SSMR reveal that different components of metacognition cannot be seen as totally separate in the collaborative learning context. This corresponds with findings from studies that examined an individual's metacognition. As has been cautioned, a total separation can lead to oversimplification (see Brown, 1987). It has also been noted that it is dangerous to reduce the inspection of regulation in social contexts merely to the individual level or the social level (see Volet et al., 2009b). The present work attempted to avoid reductionism, so the contributions of individual students were made visible (e.g. using an interaction flowchart that showed the progression of interactions between collaborating students, adapted from Sfard & Kieran, 2001a, 2001b) and the students' contributions to SSMR were examined. These investigations confirm the assumption that all students are not necessarily always involved in SSMR. Instead, regulation can be shared, for example, only between two students in a group comprised of four students. This means that sharing is not constant during the collaboration.

SSMR was also investigated in two different collaborative contexts that validated the use of that concept and its functions and foci. Although it has been seen as challenging to apply coding schemes developed for one context to another (see e.g. Beers et al., 2007; Volet & Summers, 2013), the set of studies in this work shows that it is possible. However, as shown, the application of the SSMR from one context to another is not necessarily a straightforward process. For instance, in the dyads' face-to-face problem solving activities, SSMR emerged as intense episodes, but in the small groups' asynchronous CSCL environment it emerged more as threads where time gaps appeared between written notes within an SSMR thread. Consequently, it is important to study SSMR in different contexts and avoid oversimplified generalisations from one learning environment to another.

Moreover, since SSMR is a rather new line of research within the metacognition tradition, validity and reliability were considered carefully, as suggested in the previous research literature (e.g. Veenman, 2007). For example, two and three coders, as well as different indices, were used as suggested in the previous research (De Wever et al., 2006; Strijbos & Stahl, 2007). However, although high inter-coder agreement can be achieved, for example, in the classification of SSMR (e.g. according to functions and foci), this does not necessarily prove that the emergence of SSMR itself or its starting and ending points are in agreement. In fact, previous research on SSMR (Grau & Whitebread, 2012; Whitebread et al., 2009) has shown differences in the demarcation of SSMR from the data and in the classifications of the demarcated SSMRs into different categories, in which case the latter showed higher agreement. Hence, in the present study, searching for SSMRs from the data was also inter-coded (Study II). Overall, the multifaceted inter-coding system in the present dissertation supports the view that the demarcation of SSMR and the classifications of the demarcated SSMRs (functions, foci, metacognitive experiences, connections between students in SSMR) can be reliably determined.

5.3 Educational implications

This work has several educational implications. As metacognition research has emphasised from its beginning, the findings of research should support the construction of learning environments that would support students' learning in many ways (see Brown, 1983; Flavell, 1979). One of the main educational implications of this dissertation is that, in the collaborative learning environment, it has been suggested that SSMR should be taken into account in a similar way that metacognitive regulation has been suggested in individual learning. This means that, in collaborative learning at school the participants' goal-directed consensual, egalitarian and complementary regulation of joint cognitive processes is supported.

In SSMR the difficulty level of the task is important, as shown in Study I and Study II. More difficult tasks in which student dyads or small groups still operate at the boundary of their collaborative ZPD (see Vygotsky, 1978; see also Goos et al., 2002) are seen as beneficial for enhancing the emergence of SSMR. This is also in line with the findings presented in previous metacognition research on individual learning, although with older students (Prins et al., 2006). In average difficulty tasks and easy tasks, SSMR seems to emerge in a more limited way and does not focus so much on the crucial aspects of the tasks, such as on the regulation of the situation model in Study II, which has been seen as crucial in mathematical word problem solving (see Cummins et al., 1988; Verschaffel, Greer, & De Corte, 2000). To support students, it is implied that it is beneficial to focus SSMR on understanding the tasks and situations. However, as shown in the study conducted by Prins et al. (2006), it is important to keep in mind that the problem's difficulty also varies among students. In the present research, the students were high achievers. If students are average or low achievers, difficult problems could extend over their boundary of collaborative ZPD. This means that less difficult problems would have enabled the students to better meet their collaborative ZPD. In terms of the school context, one important implication to address is that, especially in CSCL, there is no particular phase where SSMR emerges across different small groups (Study IV). Instead, in some groups SSMR may emerge in some phase(s) rather than in other groups. This means that a group may need support for SSMR in one phase and another group in another phase. It is challenging for teachers to carry this out in practice. Additionally, in CSCL, SSMR can emerge over a long time period and SSMR threads can be overlapping and intertwined (Study III). This means that teachers should be attentive during the entire collaborative process in order to see if a group needs support.

Furthermore, the findings of Study IV support the critical role of SSMR's focus in relation to the learning outcomes. If SSMR focuses on understanding (such as constructing a situational model) and sometimes also procedural matters (such as planning how to proceed in order to reach the learning goal), it seems to steer the students towards a high quality outcome. However, merely focusing on procedural matters seems to be related to an average quality outcome, while focusing on incidental matters, with or without procedural matters, seems to be related to a low quality outcome. Based on the findings in Study IV, it is suggested that teachers support small groups in focusing on understanding in SSMR. This suggestion is supported by previous research (e.g. Kajamies, Vauras, & Kinnunen, 2010) that has reported that low achievers focus on superficial aspects of the task and also have a low quality outcome in mathematical word problem solving. It is important to note that the amount of SSMR does not seem to explain the quality of the outcome in CSCL. This means that if a small group has many SSMR threads during its process, it is not automatically beneficial for the quality of the outcome if the SSMRs do not focus on understanding. Hence, in educational settings, particularly in CSCL, attempting to encourage the students to increase the amount of SSMR may not be important; rather, it seems to be important to support small groups in regulating their SSMR focus, especially in regard to understanding. This suggestion is supported by previous studies that have shown that the frequency of regulation in collaboration does not differ between higher and lower performance dyads in CSCL (Schoor & Bannert, 2012) or small groups working face-to-face (Khosa & Volet, 2014).

SSMR also has different functions in the collaborative learning process, as shown in both the dyads' face-to-face mathematical word problem solving activities (Study II) and in the small groups' inquiry-based science projects in the CSCL environment (Study III). Study II shows that in the mathematical word problem solving process, the dyads mainly decided to check that their line of thought was appropriate, and they confirmed it. This may cause problems if the direction of the ongoing cognitive process needs to be revised. However, inhibition of perceived inappropriate lines of thoughts was more common in the difficult problems, which also supports the suggestion that easy problems or problems that were moderately difficult are not as good a basis for the emergence of SSMR as difficult problems. Furthermore, the finding that the dyads mostly decided to confirm the correctness of the cognitive process may imply that students within collaborative learning contexts could be directed to inspect their common thoughts critically and be ready to change the direction of the thinking process if needed. It may also be beneficial if the tasks do not always have one correct answer; rather, ill-structured problems in which the solution cannot be reached with a straightforward mathematical calculation may be beneficial if the support of the SSMR's inhibition function is sought out in mathematical word problem solving.

Metacognitive experiences seem to be important starting points for SSMR episodes according to the findings of Study I and Study II. As shown in Study I (e.g. 'Hey, wait a minute', 'How so?') and Study II (e.g. 'I'm confused...'), even small signs of the individual's observable metacognitive experiences can be important in producing SSMR if other students react to them. These findings imply that teachers should support students in making their thinking, confusion for example, visible in face-to-face contexts, leading other students to react to these visible metacognitive experiences. This is important because metacognitive experiences are inner activities and may not automatically be visible (see Efklides, 2006, 2008). Supporting students in expressing metacognitive experiences in collaboration with others is also important, since Study II indicated that SSMR episodes with observable metacognitive experiences focus on the situation model more often than episodes without observable metacognitive experiences at the beginning of the episode. However, students must do more than make metacognitive experiences visible in the collaboration. It is equally important that other students react to them. It was defined that SSMR has to at least consist of two turns from two different students. If no one reacts, SSMR cannot exist. As Molenaar (2011) has documented, 'ignored metacognitive activities' occur in cases where a student tries to regulate a common cognitive learning activity but other members of the group ignore that effort. Therefore, while it is important to support making metacognitive experiences visible it is also important to ensure that other members respond to them. However, as shown in Study IV, from a learning outcome point of view it does not seem to be important that students in a small group in a CSCL context have many connections with each other. Rather, the quality of the connections, focusing especially on situation model/understanding, as highlighted in this dissertation, is crucial.

5.4 Future directions

This dissertation arises from the metacognition research tradition. This means that other issues, such as motivation or emotions, fall outside the scope of the present work. Learning is a complex process that cannot be explained through a single concept. Hence, it has been suggested that the scope of the investigation be widened in future to other fields in addition to metacognition, for example to motivation and emotion. This suggestion is also in line with earlier proposals in the field of metacognition (e.g. Brown et al., 1983) that have advised that it is important not to reach simple conclusions about complex learning processes. Actually, in addition to SSMR, previous research has implied that shared motivation (e.g. Vauras et al., 2003) and emotions (e.g. Salonen et al., 2005) also play an important role in students' collaborative learning processes (see also Hurme, 2010). Thus, this line of research is also proposed.

An important theoretical notion is that the metacognition research tradition is not the only field interested in people's minds. For example, although theory-of-mind research also focuses on the area of cognition-of-cognition, theory-of-mind and metacognition research have been conducted separately; probably one reason for this is that metacognition research has traditionally focused on the subject's own mind, studied older children and been more problem-centred and goal-oriented than theory-of-mind research, which is a kind of 'applied theory-of-mind' (Flavell, 2000). However, these two research fields have some commonalities, in which case SSMR research could benefit from theory-of-mind research. Previous research also supports the notion of the relationship between theory-of-mind and metacognition. For example, Lockl and Schneider (2006) have shown the relationship between theory-of-mind and metacognitive vocabulary among young children. Hence, the kinds of studies that take into account metacognitive vocabulary may have an additional value in research on SSMR where verbal interaction is studied. Moreover, as has been acknowledged in previous studies (e.g. Hacker & Bol, 2004; Hurme, 2010; Tindale & Kameda, 2000), Mead's (1934) thoughts create associations when metacognition in social interaction is studied. However, in this dissertation, not only Mead (1934) and symbolic interactionism (see e.g. Blumer, 1969), but also Berger and Luckmann (1966) and social constructionism are seen to emphasise the role of social interaction when the mind and knowledge are considered. Thus, in the future, it may be worthwhile to explore these commonalities in greater depth from the theoretical point of view. Furthermore, social perspective-taking (e.g. Selman, 1980) highlights interpersonal understanding and coordination between the self and other. Social perspective-taking describes developmental levels and it models the growth of interpersonal understanding. According to social perspective-taking, mutuality and coordination are needed in order for understanding and resolution to be genuine and effective (Selman, 1980). Thus, ideas drawn from social perspective-taking may be noteworthy for future attempts to also explain students' interactions in SSMR research.

Additionally, Tindale and Kameda (2000) stressed that transactive memory is one example of metacognition in groups. The transactive memory system is drawn from the theories of group mind and it attempts to understand how groups process and structure information (Wegner, 1987). In the transactive memory system, interdependency enables group members to use and access more and better information than individuals in the group; hence, in that sense, a group cannot be traced only to individuals (Wegner, 1987). Hinsz (2004) also addressed how metacognition (especially regarding metamemory and mental models) is applicable to groups, while Tindale and Kameda (2000) viewed shared metacognition from the information processing system standpoint; in particular, they were interested in shared metacognitive knowledge. All of these studies examine group processes although they are not always labelled according to the terms used in metacognition research (Hinsz, 2004; Hurme, 2010; Tindale & Kameda, 2000). However, although many of these conceptualisations have been made in contexts that are different from the contexts studied in students' collaborative learning or metacognition research, they can enhance the understanding of SSMR. For example, metacognition research lacks studies on shared metacognitive knowledge. Therefore, based on Tindale and Kameda (2000, see also Hurme, 2010), studying socially shared metacognitive knowledge could be one possible line of research. As Tindale and Kameda (2000) proposed, 'social sharedness' could be used as a unifying theme that could link different topics in the research on small groups.

Metacognitive experiences are interesting from the SSMR point of view because, based on the results of the present dissertation, they were found to play an important role at the beginning of SSMR. Although metacognitive experiences provide students with information about the quality of cognitive processing, such as progressing on a task and the outcome produced, they have gained little attention when their implications for the learning processes are considered (Efklides, 2006). Since metacognitive experiences are important for executing metacognitive regulation during the learning process, it is essential to conduct a more in-depth study of metacognitive experiences during collaborative learning than has been done in the present dissertation. For example, metacognitive experiences include metacognitive feelings, judgments/estimates and online task-specific knowledge, and all of these consist of a variety of manifestations (see Efklides, 2006). Specifying different feelings, judgments/estimates and online task-specific knowledge would provide detailed information about the role of metacognitive experiences in collaborative learning processes. Furthermore, although metacognitive experiences are inner subjective experiences (Efklides, 2006, 2008), it would be interesting to examine whether observable metacognitive experiences can become shared among collaborative students.

In the present work, metacommunicative rules were referred to, especially in Study I and Study II. However, it would be worthwhile to explore their role regarding SSMR in greater detail. For example, a previous study (see Salonen et al., 2005) has shown how participants try to shape interactions and repair the communicative imbalance (or not), giving signals to their collaborators, and how this is related to SSMR. These metacommunicative signals (e.g. looks, gestures, body movements) are present at the verbal and/or nonverbal level and they can be interpreted as an invitation to convergence or divergence, or as a signal to the other partner to stay away when partners coordinate their behaviours in an interaction (see Branco, Pessina, Flores, & Salomão, 2004). In the present research, for example, nonverbal behaviour was used only as complementary information when the face-to-face collaborative learning processes were scrutinised. However, Whitebread et al. (2007, 2009; see also Whitebread & Pino-Pasternak, 2013) have found that shared metacognitive regulation can also be evidenced by nonverbal indicators among young children. Although nonverbal behaviour has been infrequently utilised in the research on SSMR, this line of inquiry would be promising. For example, students' joint reflections on thinking processes have been found to also occur nonverbally in the construction process of complex mathematical knowledge (Lehtinen & Repo, 1996). Methodologically, one way to study nonverbal indicators could be eye-tracking, which has been used in metacognition research on individual learning (e.g. Kinnunen & Vauras, 2010). In research on SSMR, eye-tracking could uncover the direction of the students' gazes and, for example, in a CSCL environment, the students' focus on the computer screen.

As has been argued in the present dissertation, metacognition research has mainly focused on the individual viewpoint. This means that the methods traditionally used in metacognition research may not be sufficient in research on SSMR. In the present work, for example, the State Space Grid (SSG) was applied to study the students' participation in SSMR. The SSG has been used successfully in earlier research on teacher–student interactions (e.g. Vauras, Kinnunen, Kajamies, & Lehtinen, 2013) and, in the future, it could also be used in research on SSMR in more versatile ways than was done in the present dissertation. Overall, the application of the methods from other topics to SSMR research is encouraged. For instance, one promising method, process mining, which was developed in a business context, has already been applied to research on shared regulation to reveal sequences found in event logs in CSCL (see Schoor & Bannert, 2012). Furthermore, a combination of different methods is suggested because in the present research they revealed complementary information about the students' contributions to SSMR. In fact, this suggestion is in line with previous suggestions for using a multi-method design in SSMR research (see Hadwin & Oshige, 2011). However, the present research mainly used concurrent methods and, as a retrospective method, a stimulated interview in Study I. In the future it would be useful to compare prospective, concurrent and retrospective methods in order to identify the aspects they reveal regarding SSMR. Based on comparisons of prospective, concurrent and retrospective methods in individual metacognitive regulation research, concurrent methods are favoured (see Veenman, 2005). However, these kinds of comparisons have not been conducted in research on SSMR.

The findings of the present dissertation suggest that, in SSMR, the focus is connected with the quality of the process outcome. However, more evidence is needed regarding this relationship in different contexts and with different groups of students. In this work, the results of the SSMR, as well as the relationship between focus and outcome, are based on case studies that were conducted among high achieving students. In the future, it would be important to widen the contexts and increase the number of dyads and small groups to generalise the findings. In this present study, the students in the dyads and small groups were selected to be above average achievers, because the new concept of SSMR was being explored. However, the next step would be to explore SSMR among average achievers and low achievers to see if similar phenomena are observed among them. Previous research has indicated that SSMR can be found among different age groups from young children (e.g. Whitebread et al., 2007, 2009) to university students (e.g. Khosa & Volet, 2014). These findings show that SSMR is not only limited to some cases. However, the achievement level of students has not necessarily been a special selection criterion in the previous research, although research on individual metacognition has reported that metacognition differs between high achievers and low achievers (see e.g. Meichenbaum & Biemiller, 1998). For example, low achievers have been reported to have difficulties in evaluating their solution processes in mathematical word problem solving activities (Kajamies et al., 2010). This is also one reason why the results of the present study cannot be generalised to include low achievers. Furthermore, only the relationship between SSMR focus and outcome was studied. In the future, the relationship between SSMR function and the quality of the groups' outcome should also be investigated to specify the meaning of SSMR's function in learning. This question remains unanswered for now.

In addition, although the present research focused on dyads and small groups, it would be important to scrutinise whether SSMR can be found at the classroom level. Previous research (Webb et al., 2014) has shown that students commonly engage in other students' ideas just by repeating what another student has said or done, but they do not develop the other student's explanation. Teachers have also been shown to play an important role in determining whether students engage with the ideas of others at a high level (Webb et al., 2014). Hence, it would be innovative to widen the SSMR research to the classroom level and to also investigate the teachers' role in this process. In addition, as discussed earlier, in other research areas (e.g. social and organizational psychology, see Hinsz, 2004; Tindale & Kameda, 2000; Wegner, 1987) there is interest towards similar phenomena to the ones studied in SSMR research. Nevertheless, they do not specifically study SSMR. Therefore, in-depth and micro-level SSMR research could add value to research in other fields, such as teams in the work place. This view concurs with Lehtinen, Hakkarainen, and Palonen (2014) who suggested that researchers use approaches from different fields of learning research to meet future challenges in professional and work place learning, when the focus is on collective learning processes in addition to individual learning. From the SSMR point of view this means that SSMR research should be expanded beyond the school context.

In the present study, the individual's contribution to SSMR was investigated and the different roles that students played in SSMR were revealed (e.g. one student contributed at the beginning of the process more than at the end and another student was more involved in SSMR, which inhibited rather than facilitated the current direction of the learning process), but background information on the individual student's metacognition was not investigated. However, Anderson and Nashon (2006) have shown that metacognitive characteristics of individual students are crucial in the groups' collective knowledge construction. A further area of study would be to investigate the interplay between the group and the individuals, for example, an individual student's metacognition as background information as well as its role in SSMR during the collaboration. Additionally, in SSMR's definition, the common goals among collaborators are built-in, just as goal-directed regulation is built into the definition of individual metacognition (see e.g. Flavell, 1976; Wertsch, 1977). However, one possibility for future research would be to interview students to investigate whether they really share common goals or to identify how the possible co-construction of common goals is regulated during the collaboration. In the present work, the small group's knowledge of the science topics was not controlled in the CSCL inquiry. This means that some students and/or small groups could already be more knowledgeable than others at the beginning of the learning process. Therefore, an experimental design with pre- and post-tests may be useful in the future.

Finally, the small groups decided on their research topics in Study III and Study IV; thus, some of the topics might have been easier than others. When students collaborate, there is a danger for misconceptions. For example, students can co-construct knowledge that is not in line with current scientific knowledge. In fact, the conceptual-change research tradition has revealed major misconceptions in crucial concepts in which individual students explain the world, for example, concerning photosynthesis (e.g. Mikkilä-Erdmann, Penttinen, Anto, & Olkinuora, 2008). However, only a few studies (e.g. Whitebread & Grau Cárdenas, 2012) have connected SSMR research to the conceptual change tradition. Hence, linking research on SSMR and conceptual change at the small group level would be important when studying whether SSMR supports groups in moving towards conceptually oriented learning. This is an important issue since it has been argued (e.g. Griffin et al., 2012; Lehtinen, 2010; Sawyer, 2006) that school settings should provide a foundation for the regulation of learning and aim at intentional and conceptually oriented learning. In summary, the emergence of the concept of SSMR has been theoretically, methodologically and empirically considered in the present work. As the next step, it is suggested that its detailed meaning be investigated so that its scope in the field of learning research can be widened.

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