Processes of metacognitive regulation and knowledge co-construction in case-based collaborative learning at university

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This dissertation is the report of an investigation submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy at Murdoch University.

2014
I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

Deep K. Khose.
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Providing students with professionally relevant critical thinking and life-long learning skills is an important consideration for tertiary level education. Given that it can be argued that professional learning is predominantly collaborative in nature, this necessitates the development of skills that facilitate learning effectively with and from peers. The considerable benefits of collaborative learning are well established in the literature, with the cognitive gains well documented and substantiated. It is also recognised that groups of students simply cooperating to manage a group task is not as effective as engagement in productive collaborative processes to achieve learning outcomes. Group learning activities are often considered a challenge to implement in tertiary level education, as students may prefer and be accustomed to teaching styles that promote individual forms of learning, which may have led to previous academic success.

The research presented here was conducted with veterinary medical students engaged in collaborative clinical case-based learning, where they were required to apply complex medical knowledge to authentic clinical cases. Although effective collaborative learning and case-based learning have attracted much attention in the veterinary medical and broader education literature, little attention has been focused on the effectiveness of facilitating groups of students working on case-based learning, so that they may productively learn from each other. There has also been little research scrutinising the nature and significance of productive cognitive engagement and metacognitive regulation in collaborative learning activities that involve complex medical knowledge.

This research had three primary aims. The first was to investigate the effectiveness of a metacognitive intervention aimed at facilitating groups of students to engage in productive collaborative learning while working on clinical case records. The second was to investigate the extent to which differences in groups’ cognitive engagement and metacognitive regulation can contribute to explaining differences in group learning outcomes. The third aim was to explore students’ and their teacher’s perceptions and reflections on the use of a collaborative concept mapping task. These three aims were addressed in two interrelated studies (Study 1, Study 2 and a follow up to Study 2).
The first aim was addressed in Study 1. In the context of a real-life collaborative clinical case-based learning assignment, a contextualised metacognitive intervention introduced students to strategies aimed at enhancing learning through meaning making in group interactions and high-level questioning. In a comparison of intervention and control cohorts, it was found to be possible to foster veterinary medical students’ engagement in effective learning from and with their peers. Results from self-reported questionnaire data showed that the intervention cohort found their case-based learning task less challenging than the control cohort. The intervention students were also observed spending more of their group meeting time on content-related discussions, a finding that was supported by students’ self-reported estimations of time spent discussing content versus organisational matters. The intervention cohort spent more time discussing content related matters, but there was minimal engagement in the most desired high-level content-related discussions. These findings prompted the question of how students actually engage in effective collaborative learning, addressing the second research aim.

The second aim was addressed in Study 2. In the context of the same collaborative case-based assignment, but with a new cohort of students, two tasks (informal group meeting and concept mapping) were host to the analysis of group learning interactions. The cognitive and metacognitive regulation processes of two groups with disparate learning outcomes were analysed using a fine-grained, theory-based, contextualised coding scheme. Results of these analyses revealed meaningful differences in interactive learning processes. The higher performing group showed evidence of spending more of their overall group efforts in co-constructing knowledge. In comparison, the lower performing group expended more effort simply co-producing the task. While no differences were found in the two groups’ amount of metacognitive regulation, statistically significant differences were found regarding their respective depth of engagement in metacognitive regulation, with the higher performing group directing more of their metacognitive regulatory efforts at high-level meaning making.

The third research aim, addressed in a follow-up to Study 2, was an empirical study analysing students’ and their teacher’s perceptions and reflections of the concept mapping task, but this time embedded in regular teaching (same clinical case-based assignment) and with a new cohort. Two major themes pertaining to learning from concept maps emerged from students’ reflections: the value of concept mapping for
case knowledge understanding; and the use of concept mapping to assess the level and progress of group understanding. Their teacher’s reflections were consistent with the view that concept mapping is valuable in case-based learning to enhance students’ understanding of complex knowledge. The value of concept mapping to address some of the learning challenges experienced by students when tackling case-based assignments was also emphasised.

This research made two important contributions to the rapidly expanding research on productive collaborative learning and interpersonal regulation in collaborative learning. First, it provided evidence that it is possible to enhance the ways in which groups of students work together, increasing the amount of time spent on productive knowledge construction, rather than simply managing and organising the task. This addressed a gap in veterinary medical education research, and contributed to the higher education literature by examining the impact of an intervention that targeted groups of students rather than individual learners who typically have been the focus in the research to date. Second, it addressed the issue of how students engage in effective collaborative learning. A theory-based, contextualised coding scheme was developed, which was sensitive enough to scrutinise and analyse the dynamic and complex nature of interpersonal regulation, helping to explain groups’ differing learning outcomes. This contributed to the nascent but rapidly expanding body of research on interactive data analysis, and research involving interpersonal regulation and its association with learning outcomes.

Educational implications and future directions are discussed. These include the implications of investigating learning interactions in groups with successful learning outcomes, the use of concept mapping in teaching that involves complex medical knowledge, particularly in case-based learning, and the future development of innovative, analytic methodologies to examine collaborative regulation processes in real-life learning settings. Given the increasing use of collaborative learning activities from universities through to the workplace, investigating how to facilitate, and study the nature of productive collaborative learning is likely to dominate the research agenda in years to come.
ACKNOWLEDGMENTS

This PhD journey has been an unforgettable, once in a lifetime experience. This is the occasion to thank the people who helped and joined me on my journey.

I would like to sincerely thank my supervisor Professor Simone Volet. This journey would not have possible without her inimitable support, encouragement, and absolute dedication. I am truly indebted to Professor Volet for all her knowledge, guidance and direction over the years. I will miss our engaging, engrossing discussions, whether they be of a technical, research nature or the more human aspects of life, I can truly say that they were all thoroughly enjoyable. I cannot put into words the immeasurable respect I have for Professor Volet’s knowledge and complete devotion to her teaching and research. Her support, encouragement and belief in what I can achieve has opened up some previously unimaginable pathways for me, and helped me develop as a person and an academic. For that I will forever be grateful.

I would also like to sincerely thank my co-supervisor Associate Professor John Bolton. I am very grateful for all his support, guidance and valuable attention to detailed feedback over the years. Professor Bolton has always been a voice of reason and calm when things were sometimes challenging, this has always been very much appreciated.

My thanks must also go to Joanne Thurman, Mark Summers and Cheryl Jones. These dedicated, professional individuals provided priceless support, intellectual engagement, and laughter over long hours spent collecting and analyzing data. This research would not have been possible without their efforts – thank you; it was my pleasure to work with you. I am also thankful to Dr Caroline Mansfield, Dr Deborah Pino-Pasternak and Professor Marja Vauras for all their encouragement, advice and support over the years.

I am grateful to all the willing participants in this research. None of this would have been possible without their complete trust and eagerness to be involved in data collection.

To my fellow PhD travellers in the ‘office upstairs’, thank you for all the laughs in the good times and support in the down times. I wish you all the very best.
This PhD journey would not have been possible without the unwavering support from my husband. His patience, understanding and unconditional tolerance for my long hours spent working on weekends will forever be appreciated. He has always been by my side on this journey. To our three cats – thank you for being the perfect lap warmers in the colder months of the year and for reminding me when it was feeding time for everyone in the household.

Finally, this research would not have been possible without the Australian Research Council scholarship funded by the Commonwealth Government and Murdoch University and financial support from the Australian Research Council’s Discovery Projects funding scheme (project number DP0986867).
LIST OF PUBLICATIONS

PAPER 1

PAPER 2

PAPER 3

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CONTRIBUTION TO BOOK CHAPTER
For the past twelve years I have been intensively involved in the clinical teaching of junior and senior veterinary medical students in the context of a teaching veterinary hospital. As a practicing veterinarian and clinical educator, this task has proven to be challenging and immensely rewarding in equal measures.

One outstanding challenge that presented over this time was the balance of providing exceptional veterinary care for animals and their owners, while trying to provide the best possible clinical learning experience for students. It appeared that many factors influenced this oft-precarious balance, with students’ clinical learning experiences perhaps being one of the more unpredictable in outcome. Unpredictable because clinical learning in this context involves many aspects, such as students’ engagement in consultations with clients and their animals, hands-on surgical and clinical procedural skills, effective clinical communication with colleagues and clients, and perhaps most importantly, the transition into and integration of often complicated, voluminous undergraduate learning into a real-life, experiential clinical environment.

My experiences and observations led me to believe that if the transfer and transition of textbook knowledge to clinical learning did not occur successfully, it seemed a challenge for students to effectively accomplish other aspects of clinical learning. I also realised that clinical learning had direct implications for continuing professional learning and future successful clinical practice. Also noteworthy is the recognition that thorough clinical learning, professional development and clinical practice rarely occur effectively as a solo activity, and appeared to be more productive when performed successfully in a collaborative setting. The rewards of concurrent clinical practice and teaching occurred when the balance between the two was harmonious, providing the best care for clients and their animals and at the same time supporting students’ learning so that they could navigate confidently through their undergraduate education, and into clinical practice. Based on my clinical teaching experiences and a desire to make a
contribution to veterinary clinical learning and instruction, almost four years ago, I decided to undertake my research into veterinary medical education.

1.1 Collaborative learning in veterinary medical education

Collaborative learning in veterinary medical education has been the subject of considerable research interest in recent decades. Two decades ago, Klemm (1994) proposed that although veterinary medical students are selected on the basis of their competitive performance rather than their ability to cooperate in learning, peer learning had an integral role to play in veterinary medical education because “collaborative learning is the process whereby each member contributes personal experience, information, perspective, insight, skills, and attitudes with the intent of improving learning accomplishments of others” (p. 5). Klemm went on to argue that once students enter veterinary education, competition with peers should not be necessary, as it does not serve the greater interests of the profession. Instead the responsibility lies with the faculty to encourage and facilitate an environment that engenders collaborative learning.

Research into the use of collaborative learning by veterinary students (e.g. Raidal & Volet, 2009; Ryan, Irwin, Bannon, Mulholland & Baird 2004; Thurman, Volet & Bolton, 2009) showed that the majority of students preferred individual forms of learning to collaboration. Only a minority of these students considered collaborative learning to be effective in their undergraduate study. Similarly, Zenner, Burns, Ruby, DeBowes and Stoll (2005) recognised challenges in implementing collaborative learning in veterinary education. These included students displaying indifference or apathy toward helping fellow students succeed, reluctance to participate in group-based assignments, and sometimes the resentment of peers’ success. The authors concluded that rather than abandon collaborative learning (given its significant benefits), veterinary medical educators should understand students’ “psychological dynamics” (p. 247), and create an environment that fosters group achievement where success or failure is a collective student experience.

Despite the challenges, Klemm (1994) and Dale, Sullivan and May (2008) argued that collaborative learning could facilitate critical thinking and problem solving by veterinary medical students. Research has shown that group-based learning has the
potential to improve learning outcomes. A study by Pickrell, Boyer, Oehme, Clegg and Sells (2002) showed that veterinary students who analysed clinical cases as a group had an 8.5% performance advantage over those who analysed clinical cases individually. The researchers concluded that the activation of deep learning processes, due to multiple group members describing treatment and differential diagnoses when discussing the case, explained the performance difference. The positive effects of collaborative learning in facilitating the use of ‘transferable skills’ such as teamwork, interpersonal communication, and decision making (Boud, Cohen & Sampson, 1999) have also been recognised as key components of successful veterinary education, given such skills are considered desirable by the profession as a whole (Schull, Morton, Coleman & Mills, 2011; 2012).

Veterinary students’ attitudes to group work has been examined by Dale, Nasir and Sullivan (2005), who incorporated a cooperative learning assignment into a fourth year veterinary medical course. One notable finding from this study concerned the issue of ‘passenger’ students who may threaten group dynamics, and potentially hinder equal division of labour. They found that pre and post group assignment evaluations of items such as students’ being worried about being held back by others, or about group members not pulling their weight, showed no change. However, students who generally regarded themselves as team players and had reported few concerns before or after the group assignment expressed some critical comments about other matters. These included perceptions of not having been adequately pre-informed of the assessment procedure for the assignment, uncertainty about being comfortable with learning different skill sets from those of their peers (given that working in different groups provided different learning opportunities), and concerns about whether staff facilitators were adequately trained to support the cooperative learning process.

Different career perspectives have also been shown to influence peer learning. Edwards et al. (2004) investigated attitudes towards collaborative learning in groups of veterinary and medical students working together as they participated in an experiment of collaborative teaching and learning about basic surgical skills. They found that the pre and post experiment attitudes towards collaboration remained constant in the veterinary students, while the attitudes of the medical students were significantly more positive after the experiment.
In summary, review of the extant literature on the use of collaborative learning in veterinary medical education revealed that despite the challenges posed by students’ learning behaviours and perceptions, it has generally been considered to be a positive, productive method of learning, problem solving and improving learning outcomes. Additional benefits reported in the literature include the facilitation of transferable skills for future employment prospects, and integration and cooperation among different cultural and career groups. There are, however, gaps in the research about collaborative learning involving veterinary students, such as how students learn in collaboration and what their productive collaborative processes look like, how their productive collaborative processes relate to learning outcomes, and the extent to which it is possible to facilitate veterinary students’ engagement in productive collaborative learning.

It should be noted that there is a considerable body of research pertaining to collaborative learning in the context of veterinary medical problem- and case-based learning, which will be reviewed in forthcoming sections. The aforementioned gaps however are also yet to be addressed in that research. From a broader perspective, it is recognised that research on collaborative learning in the wider higher education context is extensive and has addressed many aspects. One main focus has been on studying the benefits of collaborative learning for deep forms of learning.

1.2 Collaborative learning in higher education

While the need to provide students with the necessary skills for effective decision making, problem solving and knowledge construction has been recognised as an important focus for all levels of formal education, tertiary institutions in particular have experienced increased scrutiny and demand to provide students with critical thinking, teamwork and lifelong learning skills as a part of their undergraduate education (Biggs & Tang, 2011). As emphasised by Eraut (2007), students’ preparation for future professional learning needs to incorporate effective learning with and from peers, especially considering that professional education in the workplace is predominantly social in nature. However, evidence suggests (e.g. Summers & Volet, 2010) that just
putting students in groups and providing a group assignment does not necessarily equate to collaborative learning.

According to Dillenbourg, Baker, Blaye and O’Malley (1996), students may work individually on a group task and come together to collate information, displaying evidence of *cooperative* learning but not genuine *collaborative* learning. Teasley (1995) argued that genuine collaborative learning is attained through interpretive, elaborative talk rather than through collaboration itself. Collaborative learning has been defined as “a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem” (Roschelle & Teasley, 1995 p. 70). According to this definition, students in a group who have worked independently on different parts of a group assignment and then come together to discuss how to compile and organise the information may not have learned collaboratively even though they have successfully managed the learning task. This problem was considered by Dillenbourg (1999), resulting in his observation of the need to differentiate between task management and collaborative learning. Dillenbourg argued that group learning is not just a way of gaining the ‘social’ skills of working with peers, but also provides the opportunity to process information at a deeper level by way of co-constructing knowledge with other members, and to potentially experience significant learning benefits.

The learning benefits of collaborative learning include processes such as discussion, elaboration, explanation and co-construction of knowledge with peers (DeChurch & Mesmer-Magnus, 2010; Springer, Stanne & Donovan, 1999; van Boxtel, van der Linden & Kenselaar, 2000). It is well established that when students engage in these collaborative learning processes, individual cognitive activity may also be enhanced (Ramsden, 2003; Vauras, Iiskala, Kajamies, Kinnunen & Lehtinen 2003; Visschers-Pleijers, Dolmans, de Leng, Wolfhagen & van der Vleuten, 2006). In the interplay between collaborative learning and cognitive activity it is the learning interactions between peers that influence the amount and level of cognitive activity within a group, accounting for the learning taking place (Cohen, 1994; Webb & Palincsar, 1996). One explanation, provided by King (2002), is that there are different types of group learning interactions that produce different types of learning, requiring varying levels of cognitive processing. King also described peer interactions in simple tasks that
involved requesting and providing information, thereby promoting the consolidation of 
skills already mastered by the learner. This required cognitive processing at a lower, 
more superficial level. In more complex tasks, interactions displayed evidence of 
exchanging ideas, asking thought-provoking questions, providing explanations and 
justifications, requiring a deeper, higher level of cognitive processing.

The potential for collaborative learning to promote deep learning (e.g. King, 1998; 
Vauras et al., 2003; Visschers-Pleijers et al., 2006) and knowledge retention (e.g. 
Ramsden, 2003) has been demonstrated by prior research. More explicitly, students 
may develop a “transactive cognitive partnership” (King, 1998 p. 59) in learning with 
other students through the coordinated, synchronous attempts of co-constructing 
knowledge and meaning (Roschelle & Teasley, 1995) thus providing the basis for deep 
learning. Van Boxtel et al. (2000) suggested that it may be the social interactions in 
collaborative learning that stimulate elaboration and depth of conceptual knowledge. 
They observed that student interactions involving questioning, exploration, and 
elaboration of ideas, stimulate an environment within which the expansion of 
knowledge and integration of new knowledge into pre-existing knowledge can occur, 
providing a means of developing a deeper understanding of learning material. These 
types of learning interactions develop a deep understanding of content, which may be 
recognised as an active process in which learners construct meanings and build internal 
and personal representations of knowledge (Vermetten, Vermunt & Lodewijks, 2002).

1.2.1 Deep learning

While Marton and Saljo (1976a; 1976b) formalised the distinction between deep and 
surface learning approaches as the two fundamental ways in which students learn, many 
authors have since made valuable contributions to this ever-expanding area of research. 
Deep learning has been defined as a process whereby the learner has the intention to 
understand ideas for themselves, checking evidence and relating it to conclusions, while 
monitoring their understanding in the progression of learning (Entwistle & Peterson, 
2004). Surface learning has been defined as the intention to routinely memorise facts, 
focusing narrowly on minimum course requirements, and studying without reflection on 
purpose or strategy (Entwistle & Peterson, 2004). According to Biggs (1989), the deep
learning approach is inspired by intrinsic motivation, interest in the task at hand and the desire to develop a wide knowledge base.

Several scholars have observed that desired deep learning practices in clinically orientated courses may be hindered by their typically voluminous content material and stringent assessment requirements (e.g. Blumberg, 2005; May, 2008; Newble & Entwistle, 1986). Consequently, students may adopt a strategic approach, where effective time and effort management becomes their chosen method. Strategic learning, as articulated by Entwistle and Peterson (2004), is based on an acute awareness of learning in context, monitoring efficiency of study methods, and where students are aware of assessment requirements along with a responsibility to oneself and others for consistent achievement. Though a strategic approach can facilitate achievement in a demanding course, it is often not sufficient for reaching the deep level of understanding of content that is requisite for clinical application.

The apparent interplay and sometimes overlap of deep and strategic learning methods led to Biggs (1987) positing a hybrid deep-strategic approach. More recently, Lonka, Olkinuora and Mäkinen (2004) have also argued that a deep approach alone is not sufficient for productive study, and that a strategic approach is also necessary as it is both persistence and achievement that drives deep-learning orientated students towards graduation. Empirical studies provide evidence to suggest that neither the deep nor strategic, self-regulated approaches alone are sufficient to achieve maximum learning benefits in tertiary education. Studies by Beishuizen, Stoutjesdijk and Van Putten (1994) with psychology students, and Lindblom-Ylänne and Lonka (1999) with medical students showed that the most successful students in these contexts used a deep-strategic, self-regulated approach to learning.

According to Entwistle and Tait’s (1990) observations, students who adopted a deep approach to learning were inclined towards seeking out environments and educational courses that were more intellectually challenging and supported deep learning methods, while surface learners were more likely to prefer situations that encouraged rote learning. In clinically orientated courses such as medicine and veterinary medicine, a deep approach to learning is desired and often essential in order to understand the complex, interrelated chains of concepts that link theoretical knowledge to clinical
Fundamental biological knowledge in this instance often requires an in-depth understanding, so that it can be built upon in order to understand more complex knowledge structures. In the context of medical education, as observed by Newble and Entwistle (1986), this provides a basis for future professional learning, where ideas are related to previous knowledge, underlying principles are identified, and evidence is checked and related to conclusions.

In the context of veterinary medical students, Ryan et al. (2004) found that deep learners had an awareness of course objectives and an understanding of their own abilities to achieve them, therefore making a strategic, self-regulated approach an important part of their deep-learning process. Their study, which involved pre-clinical students, showed that grades were associated positively with deep and strategic approaches to learning, and negatively to surface approaches. Similarly, a study by Ruohoniemi, Parpala, Lindblon-Ylänne and Katajavuori (2010) with third year veterinary medical students showed that students who applied a deep approach to learning had greater study success, especially if these students were also organised in their approach to study (Biggs’ hybrid approach).

In summary, deep learning is recognised as the most desired approach in dealing with complex, intertwined knowledge, especially in medically orientated undergraduate courses. However, both researchers and students have recognised that the deep approach alone may not be the best way to achieve successful learning outcomes, and that a strategic approach to learning may also need to be considered. There is evidence in the literature to suggest that collaborative learning may facilitate a deeper approach to learning. In the context of collaborative learning, and especially involving professional courses, problem- and case-based learning are two ways to facilitate deeper forms of learning.

1.2.2 Problem-based learning

Problem based learning (PBL) was initiated in the 1950s at the Case Western Reserve University’s medical school in the United States, and in the 1960s at the McMaster
University’s medical faculty in Canada (Boud & Feletti, 1991). Other medical schools around the world, such as at the University of Limburg at Maastricht in the Netherlands, and the University of Newcastle in Australia, have since adopted the McMaster model of PBL (Camp, 1996). PBL has been introduced into many other professional science educational fields such as optometry, nursing, occupational therapy, dentistry, and pharmacy (Azer, 2001; Camp, 1996), and is attracting increasing interest from educators and researchers in the field of veterinary medical education (Newman, 2005).

In the context of the original method developed at McMaster University, Barrows (1996) defined PBL as learning that occurs in small student groups, with teachers taking the role of facilitators or guides. Problems are used to organise and stimulate learning, as a vehicle to develop clinical problem-solving skills, and where new information is learned through a process of self-directed learning. More recently, Hmelo-Silver (2004) described PBL as an instructional method that involves students learning through a facilitated process of problem solving, working in collaboration to solve complex problems that do not necessarily have a single correct answer. Hmelo-Silver observed that through a process of self-directed learning (SDL), students apply their new knowledge to a problem, reflect on what they have learned and the strategies that they employed to solve the problem, while the teacher facilitates the learning process rather than directly providing knowledge. The key principles of PBL, defined by Dolmans, De Grave, Wolhagen and van der Vleuten (2005) are that learning should be a constructive process, a self-directed process, a collaborative process, and be contextualised in the area of learning. The goals of PBL are to facilitate students to develop effective collaborative learning skills, flexible knowledge, effective problem-solving skills, SDL skills, and intrinsic motivation (Hmelo-Silver, 2004).

In an analysis into the learning effects of PBL in collaborative learning, Dolmans and Schmidt (2006) found that studies focusing on the cognitive effects of PBL demonstrated that activation of prior knowledge, recall of information, causal reasoning and cognitive conflicts leading to conceptual change all appeared to take place in small-group collaborative learning. They also found that in studies that focused on the motivational effects of PBL, group discussions positively influenced students’ intrinsic interest in the subject matter. The extant literature also reports research efforts that have been directed at establishing empirical evidence for the support of PBL, and
comparisons of PBL with more traditional forms of learning such as lecture-based learning, and other collaborative forms of learning such as case-based learning (CBL).

Norman and Schmidt (1992) reviewed the experimental evidence of PBL in supporting students’ learning, and found no evidence that PBL curricula resulted in improvement of problem-solving skills, or performance improvement more generally. They also found that a PBL format may initially reduce levels of learning but may foster retention of knowledge over a longer term, with some evidence suggesting that a PBL curriculum could have enhanced transfer of conceptual learning into clinical problems. Finally, they found that PBL enhances intrinsic interest in the subject matter, and appears to enhance self-directed skills.

In research undertaken by Finch (1999), two cohorts of students studying podiatric medicine were compared, one cohort in a traditional lecture-based curriculum and the other in a PBL programme. The findings showed no significant difference between cohorts in the students’ acquisition of factual biomedical knowledge, but that the PBL cohort performed significantly better in tests of deeper understanding and cognitive skills related to patient management. Similarly, a meta-analysis on the effects of PBL by Dochy, Segers, van den Bossche and Gijbels (2003) found a tendency towards a negative effect on students’ acumen of knowledge, but a positive effect on students’ skills. In line with Norman and Schmidt’s (1992) review of research, Dochy et al. found that students learning in PBL gained slightly less knowledge overall, but were able to recall more of the knowledge that had been acquired.

In veterinary education, PBL has been suggested, and utilised, in varying forms (Blumberg, 2005; Clarke, 2000; Lane, 2008; Newman, 2005) as a means to foster students’ use of SDL to develop skills such as information literacy, time management, evidence-based veterinary medical practice, and self-assessment skills (Blumberg, 2005). Lane (2008) argued that PBL has the potential to provide real-life learning experiences (through the use of actual clinical cases), and the integration of knowledge, and lifelong learning skills, all of which are essential requirements of veterinary medical education. Blumberg’s (2005) presentation of a perspective on veterinary medical education as a whole revealed that veterinary medical education was successful overall, and focused on providing students with a sound knowledge base (mostly through
didactic methods), but was less effective at, and less focused on helping students acquire learning skills that would facilitate awareness of themselves as self-directed learners. PBL has been proposed and applied as a solution for these shortcomings, however as Newman (2005) argued, despite the myriad of claims made for the case of using PBL in professional education, the evidence provided for these claims is sometimes inconclusive.

Clarke (2000) and Lane (2008) both concluded that SDL in the form of PBL should be considered favourably in veterinary medical education, although consideration needed to be given to other elements such as student learning styles, personal teaching philosophies of the faculty, and the financial and staffing logistical pressures of a PBL curriculum. Hyams and Raidal (2013) reported on the development of a “roaming facilitator model” (p.282) of facilitating multiple small teams in a PBL curriculum, arguing that it is one way to circumvent the financial and logistical disadvantages of a PBL curriculum. Further, as Lane (2008) argued, veterinary medical education should include small group, faculty guided, hands-on learning sessions to teach students essential practical skills that are required for day-one professional job competencies since unlike their medical counterparts, veterinary students are not required to undertake post-graduate residency programs to cultivate these skills. Both Clarke (2000) and Lane (2008) suggested that perhaps the best use of PBL in veterinary medical education is in the form of a ‘hybrid’ PBL approach that encompasses both the key principles of a traditional PBL process to encourage SDL, and other well established methods of teaching that facilitate collaborative deep learning, such as case-based learning.

In summary, although the conceptual bases of PBL are well recognised and established in the literature, the research has also revealed some notable shortcomings. These include aspects such as minimal or negative effects of PBL on students acquiring factual knowledge, and no general improvement in students’ performance when learning with PBL. Considerations of financial and logistical pressures on faculty, and the need for the inclusion of hands-on, faculty guided practical sessions to develop professional competencies, are some of the hurdles reported by veterinary medical education in implementing a PBL curriculum. A case-based approach to collaborative learning may be one possible alternative.
1.2.3 Case-based learning

Historically, case-based learning (CBL) methods have been widely used in the fields of law, management, teacher education and medicine (Flynn & Klein, 2001). CBL methods make learning relevant and meaningful for students through actively engaging in analysis, discussion, and solving real-life problems, shifting the focus from rote learning of facts to the application of concepts and theories to real-life, contextualised problems (Flynn & Klein, 2001). Reasoning in CBL involves solving new problems by recalling prior knowledge (Kolodner, 1993), and adapting prior knowledge to establish how this can be used to solve a new problem.

There are few studies that have directly compared a PBL curriculum with one that is based on CBL. One unique study (Srinivasan, Wilkes, Stevenson, Nguyen & Slavin, 2007) compared faculty and students’ perceptions at two major universities (Universities of California, in Los Angeles and Davis), after a shift from a PBL medical curriculum to a CBL format. The authors reported that the shift was undertaken to assess the impact of a guided enquiry approach (CBL) over an open-ended approach (PBL) to small group teaching. The findings revealed that students and faculty alike overwhelmingly preferred CBL to a PBL format of learning.

In reporting on the change in collaborative teaching methodology at the two universities, Srinivasan et al. (2007) discussed the advantages and disadvantages of using CBL in medical education. The advantages were that CBL still has the capacity to provide an open-ended mode of thinking, with the benefits of allowing for debate, discussion and exploration of concepts but with more structure for the learner. CBL also allows learners to focus on key concepts of a clinical case, encouraging a structured approach to clinical problem solving, and allowing facilitators or teachers to correct misunderstandings or inaccurate understandings of learners. Perhaps the greatest disadvantage to CBL reported by the authors was that teachers or facilitators may be tempted to lecture rather than facilitate as they provide guidance for learning concepts, and may give answers to key questions thereby risking the propagation of a ‘spoon-feeding’ approach to learning.
When PBL and CBL approaches to teaching medical students about eating disorders were compared, Katsikitis, Hay, Barrett and Wade (2002) found no significant differences in the two approaches with respect to students’ performance or acquired knowledge. They also found there were no significant differences in the two approaches with respect to group functioning or verbal interactions between students. Their study also elicited student ratings for the tutor’s performance in both approaches to learning, finding no difference between the two. Research by Setia et al. (2011) found that in comparing first year medical students’ perceptions of PBL and CBL, overall, students preferred CBL to PBL.

When considering the selection of types of tasks for CBL, Kirschner, Pass and Kirschner (2008; 2009a; 2009b) and Kirschner, Pass, Kirschner and Janssen (2011) argued that task selection is an important consideration for productive collaborative learning. Their work with high school biology students showed that collaborating learners were more efficient and successful than individual learners when faced with high-complexity tasks, whereas no difference was found with low-complexity tasks. The implication of this finding is that if collaborating groups of students are to gain the most benefit from their social learning context, the chosen task must be sufficiently complex. Therefore, in the context of clinical learning, for collaborative CBL to be most effective and successful, clinical cases should be sufficiently complex to encourage student enquiry and deep learning practices. Typically, clinical cases contain entwined complicated layers of information that students disentangle by using existing background knowledge, and in the process of doing this develop new knowledge to deal with difficult concepts. The level of complexity suggests that while case-based learning may be a challenging prospect for students to tackle individually, a collaborative approach may be more applicable and effective (Monahan & Yew, 2002).

CBL has been utilised and successfully integrated in varying subjects of veterinary medical education (e.g. Eurell, Lichtensteiger, Kingston, Diamond & Miller, 1999 in veterinary histology; and Haynes & Myers, 1999 in veterinary systemic pathology), with students reporting an increase in their understanding of content, and a preference for this method of learning. The afore mentioned study by Pickrell et al. (2002) showed that veterinary students’ CBL in collaboration might also be more effective in improving performance outcomes. Their study showed a performance advantage in
students who analysed clinical cases as a group, compared to those who analysed the cases as individuals.

The potential for CBL to facilitate deep learning has attracted much attention in the veterinary education literature (e.g. Allenspach et al., 2008; Canfield, 2002; Lane, 2008; Monahan & Lew, 2002). As Monahan and Yew (2002) argued, in veterinary medicine, clinical case-based tasks serve to contextualise factual background knowledge, giving students an opportunity to develop a deeper level of content understanding, and potentially performance outcomes. In a comparison of students’ performance after lecture-based and case-based teaching in third year veterinary medical students, Grauer, Forrester, Shuman and Sanderson (2008) showed the CBL students scored higher on more difficult examination questions, with no difference on questions that were of lower and medium difficulty. In another study, second year veterinary medical students’ self confidence in performing three clinical reasoning skills improved when they practiced the skills in a CBL format, however meaningful correlation between skill competence and student confidence could not be drawn (Patterson, 2006).

In sum, the literature indicates that CBL has the potential to provide an open-ended mode of thinking, with discussion and exploration of concepts, while providing more structure for the learner. CBL also allows learners to focus on key concepts of a clinical case, while facilitators or teachers can correct learners’ misunderstandings. When PBL and CBL were compared from a collaborative learning perspective, no significant differences emerged with respect to group functioning or verbal interactions between students. A perceived problem of CBL is the risk of providing too much guidance and perpetuating a ‘spoon-feeding’ approach to learning. In veterinary medical education, investigations into the use and benefits of CBL have revealed that it may be a very effective and desirable method for teaching complex, interrelated concepts that link theoretical knowledge to clinical application, and contextualise factual background knowledge to facilitate a deeper level of content understanding. The literature to date, however, offers limited research reporting how groups of students collaboratively learn when they work on learning from a clinical case in real time.
1.3 Studying collaborative learning processes

As Barron (2003) has succinctly observed, “a close look at research on collaboration and learning suggests the need for a better understanding of how social and cognitive factors intertwine in the accomplishment of collective thinking” (p. 308). Investigating how students jointly negotiate and regulate social cognitive activity is important to the understanding of productive collaborative learning. Vauras and Volet (2013) have argued that understanding the inner workings of collaborative learning and in particular effective collaboration, involves scrutinising interpersonal learning processes related to completing the learning task at hand, or learning the content material (constructing knowledge), as they unfold in real-time. Greeno (2006) and Nolen and Ward (2008) suggested that to understand learning in a collaborative environment, research should pay attention to cognitions and interactions as they occur in a social learning context. For this to occur, learning processes need to be examined in the context of what happens when they occur in social interactive learning, rather than in individual learning.

Rather than focusing on individual learners, Greeno (2006) applied the term “situative” to describe an approach that focuses on the analysis of an activity system (italicised in the original text) that comprises complex social organisations made up of teachers, students, learning tools and the physical environment. Greeno described the situative perspective to learning as combining two types of research in human behaviour, the individual cognitive approach where cognitive scientists examined models of processes that individuals use to store, retrieve and construct patterns of information, and the interactional approach which is focused on how people communicate with each other in the process of planning, evaluating, and coordinating their interactions with the environment and technology. According to Volet, Summers and Thurman (2009a), Greeno’s focus of “learning in activity” (Greeno, 2006, p. 79) is a particularly useful way to frame research on student-led collaborative learning, and especially that involving small group work at university. This is because such activities are typically unstructured in nature, allowing varied forms of student participation, and learning engagement with content material at various levels or depths (Volet et al., 2009a). Put another way, in the context of student-led peer learning, collaborative learning involves
the learning processes of cognitive activity, and the social regulation of this cognitive activity at varying levels and depths.

1.3.1 Cognitive activity in collaboration

Overall, regardless of context or perspective, research in collaborative learning consistently describes high-level cognitive processing (and high-level metacognitive processing) as the most desirable type of learning interactions between learning peers (e.g. Chan, 2012; Cohen, 1994; King, 2002; Vauras, Iiskala, Kajamies, Kinnunen & Lentinen, 2003). Cohen (1994) argued that while limited explanation and exchange of information between peers is sufficient to tackle routine problems at a low level in collaborative learning, elaborated discussion and open exchange of information is required for high-level conceptual learning when problems are ill-structured and of a less routine nature. Similarly, as mentioned earlier, King (2002) argued that when collaborating peers tackle complex learning tasks, they must engage in high-level cognitive processing. This means that their learning interactions involve critical thinking, problem solving, monitoring of thinking, analysing and evaluating alternatives, and decision making to solve the problem at hand. Given the distinct conceptual difference between low and high levels of cognitive processing and the learning situations in which these may emerge, theoretical and empirical research has focused on trying to uncover the cognitive processes that different students use to negotiate different types of learning tasks.

One such study involved high ability and low ability fourth grade dyads learning in a game-based environment designed to support problem-solving skills in mathematics (Vauras et al., 2003). The researchers’ intention was to test the notion that peer-mediated learning was capable of producing high levels of learning (as per King 2002), and transfer of learning. A case analysis of the results in their study supported this notion. In the context of groups of university students negotiating complex clinical-based learning, Volet et al. (2009a) presented a framework that combined the constructs of social regulation and content processing that successfully identified instances of high-level cognitive activity. They argued that the identification of this type of activity is critical given that not all peer interactions are necessarily of the desired high-level
learning and understanding. The theoretical framework presented in their article described cognitive processing in terms of content processing from low- to high-level as a continuum, and social regulation as a continuum from individual regulation of cognition within the group, to co-regulation of cognition as a group. A combination of high-level content processing with co-regulation represented the most effective form of collaborative learning.

In summary, although research has made the distinction between low and high levels of cognitive activity in collaborative learning and demonstrated the importance for its investigation, examining cognitive processing or activity alone may not be sufficient to explain the type or nature of learning dynamics between peers. One way to investigate inter-peer learning dynamics and relationships is through the examination of the social regulatory (metacognitive) processes in the group-learning environment.

1.3.2 Metacognition and social regulation in collaborative learning

Metacognition is most commonly conceived as an individual and conscious process that regulates cognition (Efklides, 2008). There is growing evidence however that metacognition is also involved in the regulation of cognition in the collaborative setting, (Salonen, Vauras & Efklides, 2005). Related to individual and social cognitive and metacognitive regulatory processes are the constructs of self-regulation and social regulation. As described by Volet, Vauras and Salonen (2009b), self-regulation is the use of cognitive and metacognitive regulatory processes by individuals to plan, enact and sustain their course of action, whereas social regulation is the process by which individuals reciprocally regulate each other’s cognitive and metacognitive processes. Self and social regulation have both been studied in the contexts of individual and social learning, and from varied perspectives.

The literature on self-regulated learning (SRL) is extensive (e.g. Boekaerts, 1999; Pintrich, 2000a; Schunk & Zimmerman, 2012; Zimmerman & Schunk, 1989). SRL has been conceptualised as an individual’s conscious process of monitoring, regulating and controlling cognition, behaviour and motivation to accomplish set learning goals. In contrast, research attention in social regulation or interpersonal regulation of
collaborative learning is still incipient, but rapidly evolving (e.g. Allal, 2011; Hadwin, Järvelä & Miller, 2011; Rogat & Linnenbrink-Garcia, 2011; Vauras et al., 2003; Volet, Vauras & Salonen, 2009b). A range of theoretical perspectives, (e.g. a socio-cognitive, or a combined SRL and socio-cognitive perspective) have been used to investigate this emerging phenomenon.

Research by Hadwin and Oshige (2011) has provided an example of conceptualising social regulation from a combined SRL and socio-cognitive perspective. The authors make a distinction between ‘social regulation’ and ‘socially shared regulation’ of learning. They define social regulation as a part of the social elements of SRL, where co-regulated learning is viewed from a socio-cultural perspective and is the “transitional process in a learner’s acquisition of self-regulated learning” (p. 247). Socially shared regulation is seen from a socio-cognitive perspective as the “processes by which multiple others regulate their collective activity” (p. 258) to achieve shared goals.

Research by Vauras et al. (2003); Salonen et al. (2005); and Volet et al. (2009b) has conceptualised social regulation from a socio-cognitive perspective. In the context of student-led learning activities, collaborative learning dynamics may move interchangeably between three modes of social regulation. **Self-regulation** occurs when there is a high awareness and regulation of one’s own thinking strategies in the context of collaborative learning. **Other-regulation** occurs when there is a “momentary unequal situation” (Vauras et al., 2003, p. 35) of one person in the group grasping a critical concept or aspect of a task when other members do not, and consequently taking on an instructional role for the students that do not understand. **Shared-regulation**, considered to be the most effective mode of social student-led learning, occurs when there is a more equal and “egalitarian, complementary monitoring and regulation over the task” (Vauras et al., 2003, p. 35).

In considering social regulation from a socio-cognitive perspective, Volet et al. (2009b) have conceptualised individuals and social entities as concurrent self- and socially-regulating systems. This perspective conceives groups as being composed of “multiple self-regulating agents” (Volet et al., 2009a, p. 129), who individually offer skills, knowledge and understanding to jointly accomplish the task at hand. In the context of real-life collaborative learning activities, the conceptualisation of concurrent self- and
social-regulatory systems appears to be quite complementary. As cogently described by Chan (2012), productive group interactions require students to “self-regulate their own learning, and co-regulate the learning of others in the group and of the group as a whole, and reciprocally, the work of group members influences students’ own regulation and cognition” (p. 63). Chan’s description suggests that productive group interactions do not simply happen, but rather involve a complex, interrelated set of learning processes that not only focus on the cognitive and regulatory processes of an individual learner but also on the learning interactions that are constructed with others in the group. Put another way, it could be said that each learner has the learning responsibility (whether this is conscious or otherwise) of regulating the construction of their own understanding and that of their co-learners to ensure the most effective learning outcome.

As conceptual perspectives for research into the social regulation of collaborative learning have developed, a wide range of methodological approaches to document and analyse social regulation of learning (Volet & Vauras, 2013) have also emerged. Research on social regulation in collaborative learning is challenging since it involves the examination of dynamic, interactive processes that are articulated at the junction of individual and social processes. From a methodological perspective, one notable challenge observed by Volet and Vauras (2013) is to develop ways to analyse interactive data that represent the key generic constructs, while remaining sensitive to the various manifestations in specific contexts. The authors described specific contexts as those that may involve investigating learning processes across tasks and groups, or be more focused on the emergence of interactions within tasks or groups. This consideration is only one example of various methodological issues when investigating social regulation of collaborative learning.

Research on social regulation in student-led collaborative learning is gaining momentum, with various perspectives to frame investigations into the intricate, and intertwined learning processes that drive collaborative learning. Methodologies for capturing and analysing the dynamic nature of social regulation are still emerging, and research has already identified aspects of potential challenge when conducting this type of research. Two aspects that have thus far seen limited attention in the literature are the investigation of learning processes in knowledge that involves complex medical information, and the relationship between the social aspects of metacognitive regulation during collaborative learning and related learning outcomes.
1.4 The theoretical perspective adopted in this research

The theoretical perspective of this research is consistent with the socio-cognitive conceptualisation of individuals and social entities as concurrent self and socially regulating systems (Volet et al., 2009b), where an integrated view of both self and social regulation is taken to analyse and explain real-life collaborative learning interactions. The term *socially shared metacognitive regulation* (SSMR) is used in this research to encompass situations of genuine joint regulation of knowledge construction or task completion. As explained by Volet, Vauras, Khosa and Iiskala (2013), the term SSMR in this context represents an integration of two concepts, that of *socially shared metacognition* as used in research by Vauras et al. (2003) and Iiskala, Vauras and Lehtinen (2004), and the *regulation* of cognitive activity (Brown, 1978; Flavell, 1979), resulting in a term that encapsulates the concept of genuine consensual monitoring and regulation of collective cognitive learning processes.

The use of the term metacognitive regulation in this research refers specifically to the regulation of cognitive activity. This is consistent with the term (meta) cognitive regulation adopted by Kimmel and Volet (2010), who used the term ‘meta’ in parenthesis to emphasise the specific regulation of cognitive activity. The use of this term in this context does not include other forms of interpersonal regulation, which has been referred to by Salonen et al. (2005) as ‘pragmatic’ forms of regulation. Examples of other forms of interpersonal regulation include the regulation of motivation (e.g. Järvelä, Volet & Järvenoja, 2010), emotions (e.g. Järvenoja, Volet & Järvelä, 2013), and social interactions and group dynamics (e.g. Efklides, 2006; Salonen et al., 2005; Goos, Galbraith & Renshaw, 2002).

1.5 Overall thesis structure

The aims and overall structure of this research is presented in chapter 2. Chapter 3 describes the two empirical studies and their conceptual and methodological grounding. Chapter 4 summarises the four empirical papers from Study 1, Study 2 and Study 2 follow-up, and the overview of a book chapter in which some of this research is
reported. Chapter 5 presents the main findings and conclusions of this research, including future research directions.
2. RESEARCH AIMS AND STRUCTURE

This PhD is part of a larger programme of research embedded within a framework of productive collaborative learning. The work undertaken for this thesis focused on small groups of veterinary medical students’ engagement in effective collaborative learning processes whilst tackling challenging real-life clinical case material for the first time in their study.

This research had three primary aims:

- to investigate the effectiveness of a metacognitive intervention aimed at facilitating groups of students to engage in productive collaborative learning while working on clinical case records.
- to investigate the extent to which differences in groups’ cognitive engagement and metacognitive regulation can help to explain differences in group learning outcomes.
- to explore students’ and their teacher’s perceptions and reflections on the use of a collaborative concept mapping task.

These three aims were addressed in two interrelated studies designated Study 1 and Study 2. Study 2 included a follow-up study.

An overview of the work undertaken for this thesis is presented in Figure 1. The links between the empirical studies, the three research aims and the four papers reporting the results are highlighted.

Study 1 addressed the first aim. It involved an instructional metacognitive intervention aimed at encouraging veterinary medical students’ effective collaborative case-based learning. Results from this study are reported in Papers 1 and 2. Paper 1 targeted veterinary clinical educators, and Paper 2 a general higher education readership.

Study 2 addressed the second aim. This study examined how cognitive engagement and metacognitive regulation in collaborative learning, including a concept mapping task, related to group outcomes. As part of this study, a theory-based, fine-grained
contextualised coding scheme was developed. This work, reported in Paper 3, targeted an educational psychology readership.

A follow-up to Study 2 addressed the third aim. This study explored students’ and teacher’s perceptions of learning and teaching in a collaborative concept mapping task. The students’ perceptions of the learning values of concept mapping were related to the researchers’ observations. This work, reported in Paper 4, targeted a health science education readership.

A contribution to a book chapter is related to Study 2. The chapter discussed recent conceptual and methodological developments in metacognitive regulation of collaborative learning. The details of this contribution are outlined in Chapter 4.
Figure 1: A flow diagram representing an overview of this research
This chapter outlines the theoretical and methodological underpinnings of Study 1, Study 2, and the Study 2 follow-up. Methodologies that are theoretically driven (or conceptually based) and empirically *contextualised* to provide a customised approach to address the aims of this research will be described.

A clinical case-based group assignment was the learning context for all studies. The assignment involved veterinary medical students tackling challenging real-life case material for the first time in their study. A brief summary of the learning context is as follows: groups of students tackled clinical case files as a part of an obligatory physiology assignment; each group was required to generate their own learning objectives from the case files; this set of learning objectives was to guide research on the case; and finally as a means of assessment (group mark), each group presented their findings to the rest of the class and faced questions from clinical teachers.

### 3.1 Study 1

Study 1 addressed the first research aim. It involved an instructional metacognitive intervention aimed at encouraging veterinary medical students’ engagement in effective collaborative case-based learning. This study described an instructional intervention to foster deep-learning practices, with its impact based upon control and intervention cohort comparisons of multiple sources of data. As veterinary practitioners and clinical educators were the intended focus, the primary object of this study was to describe the content and delivery of an instructional metacognitive intervention and the impact this had on facilitating productive collaborative case-based learning. The intention was to present an intervention that may practically be utilised by veterinary medical educators.

This study addressed the general paucity of intervention studies aimed at encouraging deep-strategic, self-regulated learning in real-life, collaborative learning environments. In the literature it is more common to find intervention studies concerned with inducing deep, self-regulated learning in individual students (e.g. August-Brady, 2005 with
nursing students, and Papinczak, Young, Groves & Haynes, 2008 with medical students), with few concerning students working collaboratively in groups.

This study was also designed to address the limited body of research on the facilitation of productive collaborative case-based learning in veterinary education. Thus far there have been few attempts at providing students with formal instructional interventions to improve collaborative learning efforts. One exception is a study is by Dale, Nasir and Sullivan (2005) that reported on providing an instruction sheet to fourth year veterinary medical students outlining the expected benefits of cooperative learning, and outlining information to create an appreciation of teamwork. Their aim was to provide students with information to adequately guide their cooperative learning efforts, however their study was not formally evaluated in any way.

In this study, the impact of the intervention was evaluated using: a beginning and end of assignment matched questionnaire involving both control and intervention cohorts (self-report data); interviews involving both cohorts (interview data); and video recordings of two informal student-led group meetings from each cohort (observational data).

Questionnaire data involved beginning and end measures of personal goals and experiences of the task. The end questionnaire also included measures of distribution of time spent on specific activities during group meetings, and evaluations of sources of learning to achieve the learning outcomes of the group assignment. The interview involved questions to prompt students’ reflections on what they had learned through the collaborative case-based assignment and how this learning had occurred, for example, “What do you think you have actually learned through this project?” and “How would you say you learned this?” Analysis of the observational data was based on the theoretical framework and corresponding coding scheme developed by Volet et al. (2009a). Specifically, this involved coding (and inter-judge reliabilities) of full transcriptions of the video data and distinguishing between talk directed at processing the learning content of the clinical case, and talk directed at other matters, such as task, organisation or off-task (see Study 2 for a full description of the coding scheme).

The metacognitive instructional intervention used in Study 1 was a two-fold strategy specifically designed to foster and facilitate students’ use of meaning-making learning interactions and high-level questioning and to encourage deep learning. The following describes the conceptual basis of the intervention.
Conceptual underpinnings of the metacognitive intervention

As De Corte, Verschaffel and Masui (2004) have argued, using educational interventions to effect change in real-life learning settings is challenging. Few intervention studies using metacognitive strategies are found outside the fields of education or psychology in tertiary education. Examples of studies that have attempted intervention studies outside these fields include: Vermetten, Vermunt and Lodewijks (2002) with law students; August-Brady (2005) with nursing students, and Volet and colleagues (Volet, 1991; Volet and Lund, 1994) with computer science students. These studies were focused on inducing deep-level, self-regulated learning in individual students, rather than on groups of collaborating students.

The collective works of Barron (2003), Greeno (2006), King (1992; 1998), Kollar, Fischer and Slotta (2007), and Volet et al. (2009a), provided conceptual inspiration for the metacognitive intervention used in Study 1. As mentioned above, the metacognitive strategy developed for the intervention was twofold. First, it aimed to foster students’ meaning-making in group interactions and secondly, it provided suggested question stems to encourage high-level questioning in the collaborative setting. The literature considers high-level questioning to be an integral component of effective knowledge construction in collaborating groups. For example, a study by Visschers-Pleijers et al. (2004) that explored methods of analysing group interactions found that in order to stimulate joint construction of knowledge in small learning groups with medical students, it was paramount to pay attention to encouraging students’ generation of questions, reasoning and conflict resolution.

In the context of the present research, fostering and promoting the idea of meaning-making and high-level questioning in group learning was important, as Summers and Volet (2010) have shown that veterinary medical students working collectively on group assignments did not necessarily engage in effective collaborative learning. Research by Thurman et al. (2009) however, had revealed that these same students were able to articulate instances of effective learning from and with their peers in a regular group-based assignment setting. Both of these studies provided naturalistic evidence of veterinary medical students’ usual engagement in collaborative learning, laying the
ground work for the idea that a metacognitive intervention embedded within regular teaching and learning had the potential to encourage deep, high levels of collaborative learning.

Meaning-making in group interactions was inspired by Greeno’s (2006) emphasis on interactional processes in ‘learning in activity’, and by Volet et al. (2009a) who explored the social regulation processes in collaborative knowledge construction with veterinary medical students. The explicit association between meaning-making in group interactions and metacognitive regulation can be explained by Paris and Winograd (1990) who described the regulation of meaning-making in group interactions as being metacognitive in nature, because it referred to the strategic monitoring of learning taking place in a joint activity. In Study 1, meaning-making in group interactions was conceptualised as the groups’ monitoring of their collective understanding of the clinical case file. This involved a range of learning interactions that included exchanging definitions and sharing understanding of content, and using multiple ways to explain the same concept.

Inspiration for high-level questioning came from King’s (1992; 1998) extensive work on question stems. The high-level questioning process and its association with metacognition was explained by King (2002) in terms of the use of generic question stems such as “why”, “how” and “what if”. King argued that the generic question stems provide an opportunity to elicit high-level explanations and elaborations, and therefore provided the opportunity for students to reciprocally monitor and question their understanding of the content material. This also enabled integration of prior knowledge with new knowledge structures, thereby potentially extending learning. In the context of Study 1, high-level questioning was conceptualised as the students’ usage of ‘why’, ‘how’ and “what if” questions when discussing the content of their clinical case files as a group.

An important consideration for the effectiveness of the metacognitive intervention in Study 1 was to ensure that the veterinary students in this research would see the value of the metacognitive strategies and therefore utilise them when working on their collaborative case-based assignments. From a methodological perspective, contextualisation was therefore a very important consideration when designing and delivering the intervention.
**Metacognitive intervention contextualisation**

To ensure the veterinary students’ maximum uptake and utilisation of the twofold metacognitive strategy, it was essential that the instructional message was convincing, easily understandable and considered by the students to have legitimate educational benefit for their case-based assignment. To accomplish this, the strategy was carefully designed with a veterinary context, and presented as ‘a set of tips’ for effective learning from each other. For example, high-level questioning as conceptualised by King (1992), was contextualised to an animal with diabetes, with sample question like, “*what does* gluconeogenesis mean?”, “*why does* it occur?”, “*what would happen to* gluconeogenesis if the animal were diabetic?” Students were told that the use of ‘*what does*…’, ‘*why does*…’ type questions in their discussions of the clinical case would facilitate deeper exploration of the case through reciprocal questioning, and hence develop a better overall understanding of the case.

The contextualisation of this intervention is congruent with the work by De Corte et al. (2004), who outlined major design principles for effective learning environments. They argued that an effective learning setting should “embed students’ constructive acquisition activities preferably in real-life situations that have personal meaning for the learners, offer ample opportunities for distributed learning through social interaction, and are representative of the tasks and problems to which students will have to apply their knowledge and skills in the future” (p. 370). In designing the metacognitive intervention, the phenomenon of ‘over scripting’ as described by Kolar, Fischer and Slotta (2007) was also recognised. Kolar et al. described this phenomenon by explaining that external scripts or strategies can sometimes override acceptable, already existing internal scripts displayed by capable students. To avoid the possibility of this, the strategy was designed to provide contextualised guidance and examples that were sufficiently generic so that students could customise them for their own learning needs.

One other way in which the metacognitive intervention was contextualised involved outlining the short-term and long-term benefits of effective collaborative learning. A short-term benefit included the group’s improved understanding of the case, and a better chance of any student in the group being able to answer questions during the class presentation, thereby improving the prospects of a better group mark. A long-term
benefit involved preparation for effective learning in the clinical years of the veterinary medicine degree, including preparation for the collaborative style of learning that may also occur in clinical practice.

Overall, the findings from Study 1 (reported in Papers 1 and 2) on the one hand showed it was possible to facilitate veterinary students putting more time into meaning-making interactions and engaging in content related collaborative discussions. On the other hand, when content-related learning interactions were coded, it was clear that the intervention had limited success in inducing learning interactions at the desired high-level of knowledge construction. This instigated the question: what type of learning processes do veterinary students actually use when engaged in collaborative learning? This question led to the development of Study 2.

3.2 Study 2

Study 2 addressed the second research aim and examined how differences in cognitive engagement and metacognitive regulation may contribute to an explanation for differences in groups’ learning outcomes. Study 2 had the specific intention of contributing to the burgeoning body of research on interactive learning processes. A fine-grained, theory-based, contextualised coding system to analyse cognitive and metacognitive regulation processes was refined and validated as a part of this study. The theory-based coding scheme was used to analyse learning interactions in terms of cognitive and metacognitive processes in students negotiating two learning tasks: the generation of learning objectives in student-led small group meetings; and making sense of clinical content in a collaborative concept mapping task. Data for this study consisted of video footage of two groups’ interactions while working on these two tasks.

The coding scheme in particular makes a contribution to research in social regulation by presenting a method of analysis to examine real-life interactive, dynamic interpersonal learning processes that are generic enough to address theoretical constructs, and yet sensitive to social regulation in specific contexts. As Volet and Summers (2013) observed, this type of analysis is a significant challenge in research on social regulation.
Other authors (e.g. Azevedo, Moos, Johnson & Chauncey, 2010; Chan, 2012; and Grau & Whitebread, 2012) have also emphasized the importance of rigorous analytical methods to generate reliable findings from coded interaction data. The coding scheme developed to analyse cognitive activity and metacognitive regulation in Study 2 was an elaborated, refined, fine-grained contextualised version of the coding system first described in Volet et al. (2009a), and subsequently validated in Summers and Volet (2010).

**Conceptual grounding and evolution of the coding scheme**

The initial coding scheme as described in Volet et al. (2009a), was grounded in a situative framework that integrated constructs of social regulation and content processing. The goal of the coding scheme was to explore and understand the nature and emergence of productive interactions in collaborative learning activities involving complex veterinary medical knowledge. Barron (2003), Greeno (2006) and Nolen and Ward’s (2008) approach for focusing on the group as an intact activity system for “learning in activity” (Greeno, 2006) was inspiration for the situative framework. Accordingly, the unit of analysis was the group and its activity as whole, rather than individual contributions to a group activity. The initial coding scheme used the construct of content processing to identify levels of cognitive processing or activity, since the activity system involved an unstructured, student-led, university level collaborative activity, where it is possible to have varied levels of cognitive engagement and regulation emerge from interpersonal discussions and interactions. The construct of social regulation was chosen to explain the complex dynamics and inter-personal interactions that arise in collaborative learning activities. The theoretical framework conceptualised two forms of social regulation as a continuum from individual regulation within group to co-regulation as a group. Individual regulation was distinct from self-regulation as it represented a situation in which there is temporary individual (student) regulation of the collaborative learning activity. Co-regulation represented a more balanced, reciprocal regulation of the group’s learning activity, involving more than one group member.
As already alluded to, in order to explicate levels of cognitive processing, the initial Volet et al. (2009a) coding scheme used high- and low-level content processing. High-level content processing referred to elaboration and reasoning about content material, and low-level content processing referred to clarification of content material, without elaboration to include reasoning and justification. The combination of the constructs of content processing (high and low) and social regulation (individual and co-regulation) produced the theoretical framework for socially regulated learning. More specifically, four general categories of collaborative learning activities were identified: low-level individual regulation; low-level co-regulation; high-level individual regulation; and high-level co-regulation. The last category represented the most effective form of group learning.

The insight provided by Thurman et al.’s (2009) work, which showed that veterinary student groups that engaged in high-level content talk were able to recognise the value of doing so, and evidence from Study 1 of this research, which indicated that it was possible to foster students’ engagement in content-related learning with and from their peers, prompted the question of how groups of veterinary medical students negotiate cognitive activity.

Conceptually, cognitive activity could be focused on the completion of the task at hand, or on processing the knowledge (content) of the group learning task. Volet et al. (2013) addressed the way in which students negotiate cognitive activity in group learning by outlining a conceptual framework that described two orientations of cognitive activity, namely, knowledge construction and task production. Knowledge construction refers to the group’s cognitive effort directed at conceptual understanding of content material. Task production refers to the group’s cognitive effort to produce the expected outcome of a group task (e.g. a completed map at the end of a concept mapping task). Similar to the initial coding system (Volet et al., 2009a), both knowledge construction and task production were subsequently categorised as being high- or low-level, indicating the depth of cognitive engagement. Also consistent with the initial coding system, the orientation and depth of cognitive engagement were combined with the construct of social regulation to produce: low or high knowledge co-construction; and low or high task co-production, where co- indicates multiple contributions to engagement in cognitive activity, and high-level knowledge co-construction represents the most effective depth and orientation of collaborative learning.
The complete conceptual framework presented by Volet et al. (2013) further described the function of metacognitive activity in the flow of cognitive activity. The framework outlines cognitive activity as a continuous flow involving knowledge co-construction or task co-production, where it is assumed that students oscillate back and forth between cognitive activity directed at producing a task outcome and cognitive activity directed at constructing understanding of the underlying knowledge. Metacognitive regulation influences the cognitive flow by either producing a change in the flow of cognitive activity (e.g. shifting from low- to high-level or task co-production to knowledge co-construction), or sustaining cognitive activity. An instance of metacognitive regulation may be initiated by an individual’s verbal statement or non-verbal expression (e.g. a puzzled facial expression). The extent to which the individual metacognitive regulation effort is a solo event, or is the instigation for multiple contributions to the regulatory effort, will determine if regulation of cognitive activity remains individually focused or becomes a socially shared regulatory effort to achieve a shared learning goal.

These conceptual ideas led to the development of the refined and elaborated three-stage analytical scheme contextualised for the analysis of collaborative cognitive activity and metacognitive regulation in the present research.

**Coding scheme contextualisation**

The importance of rigorous analytical methodologies capable of producing reliable findings from coded interaction data has captured the attention of researchers across a wide range of studies (e.g. Azevedo et al., 2010; Chan, 2012; Grau & Whitebread, 2012; Iiskala et al., 2011). As Volet and Summers (2013) articulated, one common challenge for social regulation research is the need to make provisions for both the general and context specific application of coding systems. On the one hand, a coding system that is generalised allows for comparison of interpersonal regulation across tasks, varied learning activities and age groups. On the other hand, a coding system that exhibits attributes of specificity or granularity (Azevedo, 2009; Chan, 2012) sharpens the lens for a closer, contextualised inspection of the learning task under scrutiny. This is paramount when intra-group task related differences are of research interest. As a consequence, if a coding system is too generalised, group or task differences are only
captured with a macro lens, potentially providing minimally useful educational information, or information that does not address specific research questions. It may be that significant differences between groups or tasks are only apparent when viewed with a micro lens in the form of a context specific, fine-grained coding scheme, capturing intra-group differences that might otherwise be overlooked.

As mentioned previously, the refined, contextualised coding scheme used in Study 2 involved three stages: coding cognitive activity; coding metacognitive activity; and coding the social nature and function of metacognitive activity. The three stages and an outline of the coding scheme’s granularity are explained below.

The first stage involved coding cognitive activity at episode level (group level), categorized either as talk orientated at knowledge construction or task production. Each orientation was further categorised as either low- or high-level, indicating qualitative differences in cognitive engagement depth with either task production or knowledge construction.

The second stage involved identification of metacognitive regulation at the (individual) turn level of analysis. Specifically, it involved identification of: theoretical codes, contextualised sub-codes; and their associated empirical indicators from the data.

The theoretical codes were consistent with Brown (1978) and Flavell’s (1979) conceptualisation of planning, monitoring and evaluation as executive control processes for individual engagement in regulation of cognition. It was assumed that planning, monitoring and evaluation would serve the same role when applied to task production or knowledge construction in the collaborative learning context. Theoretically, it could be expected that planning, monitoring and evaluation control cognitive activity. Conceptually, it is possible that control of low and high levels of task production and knowledge construction could also involve low and high levels of planning, monitoring and evaluation. For example, low-level metacognitive regulation could refer to planning the next step without conceptual justification, monitoring cognitive activity in terms of clarifying facts without elaboration, or evaluating cognitive activity without conceptual reasoning. High-level metacognitive regulation, on the other hand, may refer to planning, monitoring and evaluating cognitive activity with conceptual justification and elaboration. Empirically, the present research involving complex clinical scientific knowledge showed no evidence of students displaying evidence of
high-level planning or evaluation. Therefore, from a methodological perspective, contextualised sub-codes were only generated for monitoring.

As theorised in Volet et al. (2013) and inspired by Iiskala et al. (2011), who used empirical indicators in their research with fourth grade students solving mathematical problems, contextualised sub-codes were developed to specifically address transition points at the turn level between instances of monitoring low-level and monitoring high-level.

The specific contextualised sub-codes of low- and high-level monitoring were developed when (individual) turn level data analysis revealed specific, rather distinct ways in which the veterinary medical students monitored their learning activity at hand. Their specific monitoring process could be designated into instances where it was clear that students interacted to seek information (SI), add information (AI), reflect on the task (RT), or stop the discussion at hand (SD), all reflecting attempts at low-level monitoring. In contrast, there were instances where the students clearly demonstrated attempts at seeking meaning (SM), volunteering meaning (VM), exploring ideas (EI), question meaning (QM), concluding from discussion (CD), justifying their decisions (JD), or reflecting on meaning (RM). These types of verbal interactions were more consistent with efforts directed at monitoring at a high-level. As well as contextualising the coding scheme, the specific sub-codes enabled a precise method of highlighting exact turn level points in the data where there was a shift or transition from low to high levels of monitoring (or vice versa), therefore facilitating precise identification of fluctuations in cognitive orientation and depth in the group learning task. Using the coding scheme to analyse the differences in learning processes between two very differently performing groups of students in this study identified significant variation in their cognitive activity and metacognitive activity. As an example of the issue of granularity, the difference in metacognitive activity in this instance was not apparent at the macro-level when only planning, monitoring and evaluation were considered. Divergent metacognitive activity between the two groups was only brought to light when the micro-level contextualised sub-code analysis was undertaken, showing the better performing group engaging in high-level monitoring.

The final stage of coding involved the social nature and function of metacognitive regulatory talk in the contextual flow of cognitive activity. This stage distinguished
between the individual’s regulation of the group’s cognitive activity, that is, evidence of one student regulating the group’s cognitive activity; and socially shared metacognitive regulation (SSMR) of the group’s cognitive activity, that is, more than one student’s contribution to regulate the group’s cognitive activity. This regulatory function is consistent with the concept of executive control or “executive processes” (Brown, 1987). Conceptually, it was possible that one student could start regulating the group’s cognitive flow, with no further regulation attempts by the same or other students (individual isolated attempt at regulation). It was also possible that one student instigates regulation, and other students join in to contribute to the regulatory effort (SSMR). Finally, it was also possible that one student sustained regulatory efforts in controlling cognitive activity without contribution from other students (individual regulation).

Overall, findings from Study 2 (reported in Paper 3) showed that the refined theory-based coding scheme was conceptually and methodologically useful to determine how group differences in cognitive activity and metacognitive regulation can contribute to explain differences in two groups’ collective understanding of a clinical case. The findings showed that when a group’s iterations included a substantial amount of high-level cognitive engagement and monitoring of case content, this was associated with evidence of better overall conceptual understanding of the case, as evidenced in the end group product (construction of a concept map). Differences in the metacognitive regulation of the two groups’ tasks were only uncovered when the second stage of the coding system (contextualised sub-codes) was applied. Analysing the data at the macro level (frequency and type of metacognitive regulation) revealed no significant difference between the two groups.

Concept mapping was one of the two learning tasks used in Study 2. The findings from this study supported the use of concept mapping as a productive research tool to uncover the nature of productive collaborative learning. One question that was not addressed in Study 2 involved how students and their teacher perceived the value of concept mapping as a learning tool and teaching tool. This question was addressed in the follow-up to Study 2. To ensure its success in both studies, it was imperative that concept mapping was fully contextualised for veterinary medical students’ use, providing both learning benefits for students, and meaningful data collection for
research. The following sections provide a review of concept mapping, and the methodology underlying contextualisation of the concept map task in this research.

**Concept mapping review**

Since Novak & Gowin’s (1984) first use of a concept mapping technique to observe and record changes in children’s understanding of scientific concepts, concept mapping has been utilised in a wide range of professional education fields involving complex scientific information (e.g. Beitz, 1998 in nursing education; Edmondson & Smith, 1998 in veterinary medicine; Slotte & Lonka, 1999 in medical education).

A substantial body of research has explored the benefits of concept mapping for students’ learning. Kinchin (2000) and Hay, Kinchin and Lygo-Baker (2008) described perhaps the most notable benefit of providing a visual and spatial display of intertwined and often abstract scientific knowledge. Structural learning and conceptual organisation to facilitate leaning that is meaningful (Kinchin, Hay & Adams, 2000), is another recognised benefit. Kinchin et al. (2000) and Hay (2007) also conceptualise concept mapping as a way of organising fragmented knowledge, that may help learners identify previously unrecognised connections between scientific concepts. Concept mapping may also be considered as a metacognitive tool (Daley, Shaw, Balistrieri, Glasenapp & Piacentine, 1999; Kinchin et al., 2000), where new material may converge with existing cognitive structures to enhance learning. It is also considered to be a valuable summary and revision tool when a copious amount of information needs to be condensed.

When concept mapping is used in a collaborative learning setting, it provides a communal learning site where participants’ co-constructed meanings and knowledge are made visible, facilitating effective collaboration. Empirical studies (e.g. Fischer, Bruhn, Gräsel & Mandle, 2002; Haugwitz, Nesbit & Sandman, 2010) have shown concept mapping to be a highly productive way of increasing students’ engagement in collaborative knowledge construction and reciprocal scaffolding. Other studies (e.g. Roth & Roychoudhury, 1993; van Boxtel, van der Linden, Roeleofs & Erkens, 2002) describe concept mapping as a powerful task to facilitate, and overtly make visible the processes of meaning making and knowledge construction. Roth and Roychoudhury
(1993) describe collaborative concept mapping as a “metacognitive tool” (p. 505) since the process of constructing a concept map makes learners externalise their propositional learning frameworks.

As a collaborative research tool, Curşeu, Schalk and Schruijer (2010), in research involving undergraduate psychology students, demonstrated concept mapping as a stable and powerful tool to reliably understand and evaluate a representation of group cognition. Group cognition in this instance was the combined knowledge representations emerging from peer interactions, and their transformations during group discussions and learning. This same study also provided evidence to support the use of concept mapping to reliably examine group cognition at a holistic group level, rather than relying on an aggregation of individual level cognitions to determine a group level outcome.

Medicine and veterinary medicine are two fields of health science in which concept mapping has been particularly useful. This is because the learning material involved is typically quite voluminous, complex, and with multi-interwoven connections, which may not be initially obvious or recognised as being important. Some examples of the ways in which concept maps have been used in medical education include: using concept mapping as an assessment tool to assess in-training physicians’ development of clinical expertise (West, Pomeroy, Park, Gerstenberger & Sandoval, 2000); and assessing the use of spontaneously constructed concept maps in a medical school entrance examination (Slotte & Lonka, 1999). In veterinary medical education, examples of concept mapping use have included: facilitating students’ understanding of fluid and electrolyte disorders (Edmondson & Smith, 1998); and the use of concept maps to represent and develop a veterinary curriculum to create interdisciplinary courses and case-based exercises (Edmondson, 1995). The concept mapping task used in this research was specifically contextualised for veterinary medical students negotiating complex scientific knowledge.

**Concept map contextualisation**

In the present research, the complex scientific knowledge involved clinical case material, which by nature comprises complicated concepts that are inter-linked and often difficult to decipher. Concept mapping was an ideal tool to assist students in
piecing together complicated clinical case knowledge, given that the desired outcome from the clinical case-based assignments was to develop a comprehensive understanding of individual case concepts, and an understanding of the links and relationships between concepts. To facilitate student acceptance and utilisation of the activity, it was crucial to contextualise the exercise to the clinical case material. Contextualisation involved tailor making a set of concepts for each group and each separate clinical case. Specifically, this involved choosing strategic case concepts (established through their generation of learning objectives) that represented the major components of each case and covered aspects students would be researching for their assignment.

Selecting strategic concepts from the case overall and having knowledge of the groups’ research direction allowed for generation of a personalised, contextualised set of concept cards for each group. The selected concepts were deliberately kept simple with either one or two words on each card. This gave students the full opportunity to develop a concept map story line that matched their specific case. Using contextualised concepts meant that case understandings and misunderstandings could be visually displayed and clarified for the benefit of the entire group. Contextualisation of the concept mapping exercise in this instance facilitated ‘buy-in’ for students and allowed collection of genuine group level research data that was immediately relevant to investigate students’ perceptions on this type of learning activity, which was addressed in the follow-up to Study 2. An example of the type of concept map constructed by students can be seen in Figure 1 from Paper 3.

3.3 Study 2 follow-up

A follow-up to Study 2 addressed the third research aim. This study explored students’ and their teacher’s perceptions of learning and teaching in a collaborative concept mapping task. This follow-up study highlighted the considerable learning benefits of concept mapping in negotiating complex, inter-related knowledge in science education, and the research benefits of using concept mapping as a visible, communal work space that enabled collection of group level data concerned with knowledge construction and interaction learning processes.
The focus of this study was to provide an ecologically valid and relevant insight into concept mapping learning processes (findings from Study 2), and how these related to individual perceptions and reflections on using concept mapping in a clinical case-based assignment. In doing so, this study contributes to three areas that have received limited attention in research on collaborative concept mapping. First, highlighted by Nesbit and Adesope’s (2006) meta-analysis, is the identification of the need to investigate learning processes involved in concept map construction as it unfolds in real time. Second, extant research on students’ views of concept mapping appears to be generally under-represented in the literature, with some exceptions (e.g. Buntting et al., 2006; Heinze-Fry & Novak, 1990; Roth, 1994; Santhanam, Leach & Dawson, 1998). The teacher’s perspective of how students learn from concept maps also appears to be under-explored. Third, is the use of authentic clinical case material in science based collaborative concept mapping, where most prior research (e.g. Buntting et al., 2006) has been conducted in the context of textbook and lecture knowledge.

Overall, the findings from this study revealed that there were meaningful differences in learning processes when two groups with divergent learning outcomes from a concept mapping task were compared. When related to the students’ and their teacher’s perceptions of concept mapping, it appeared that they held some congruent and divergent notions about the value of concept mapping.

The next chapter provides an overview of all four papers from the aforementioned studies, and the contribution to the book chapter.
4. OVERVIEW OF EMPIRICAL PAPERS AND BOOK

CHAPTER

4.1 Paper 1

An Instructional Intervention to Encourage Effective Deep Collaborative Learning in Undergraduate Veterinary Students


The summary of Paper 1 below is a condensed version of the full manuscript. Pertinent sections of the introduction, methodology, results and discussion sections have been extracted to provide a synopsis of the paper. The full-accepted version of the published manuscript, including tables and figures, is in Appendix A.

Introduction

The learning benefits of deep learning, problem-based learning, and case-based learning have attracted much research attention in the veterinary education literature. Limited research has addressed the extent to which veterinary students engage in collaborative learning processes, and how these processes can be fostered.

This paper addressed the limited body of research on the facilitation of productive collaborative case-based learning in veterinary education. The study included the design and delivery of an instructional intervention to a class of undergraduate veterinary medicine students. The instructional strategy was grounded in the collaborative learning literature and prior empirical studies with veterinary students (King, 1992; 1998; Summers & Volet, 2010; Volet et al., 2009a). The aim was to foster and encourage deep learning practices as a part of a collaborative case-based assignment. The impact of the intervention on students’ group learning was evaluated using questionnaire and interview data.
Method and procedures

Participants were two cohorts of veterinary medical students enrolled two years apart in the same physiology unit. The first (earlier) cohort of 81 students formed the control cohort, and the second (latter) cohort of 88 students formed the intervention cohort.

Both cohorts completed the same case-based group assignment in self-selected groups of five or six students. The metacognitive instructional intervention was delivered to the intervention cohort before they started the group assignment. The impact of the intervention was assessed by matched pre- and post-task questionnaires given at the beginning (before the intervention for the intervention cohort) and at the end of the assignment for each cohort. Focus group interviews to establish an insight into the students’ subjective experience of their learning were conducted at the end of the assignment with 11 of the 16 small groups from the intervention cohort. These were compared with similar group interviews conducted with the previous control cohort of students.

The clinical case-based group assignment was a regular feature of the second year veterinary physiology unit in which this research was conducted. It required students to work on the group case assignment in their own time over several weeks with guidance from the teacher in the form of two mandatory meetings three to four weeks apart. All groups were required to set their own learning objectives for each specific case, undertake research to learn about the parts of the case selected, and present the research findings to the whole class at the end of semester, at which time they also answered questions related to their clinical case. Veterinary medical clinical instructors with a varied range of expertise posed questions and assessed the groups’ presentations and response to questions. Each group was given a collective mark based on the group’s demonstration of having fulfilled their self-generated learning objectives. This mark constituted 10% of the final mark for the unit.

The intervention was presented to students as guidance for effective group learning from a clinical case. The nature of the intervention was presented in terms of: conditions for effective learning; strategies (presented as tips) for effective collaborative learning; and benefits for effective collaborative learning from a clinical case. The
intervention was presented to the intervention cohort by the first author in the form of a 20-minute PowerPoint presentation, followed by the distribution of a one-page handout summarising the range of strategies for effective collaborative learning at the end of the intervention presentation. The intervention was presented before the case files were distributed to the intervention cohort. Students in the control cohort completed exactly the same assignment but were not presented the metacognitive intervention.

The intervention contained three parts; a set of social conditions for achieving effective collaborative learning was presented first, the twofold metacognitive strategy comprising meaning making interactions and high-level questioning components was presented second, and finally the benefits of effective collaborative learning from a case-based group assignment was presented. Where possible all aspects of the intervention were put specifically into a veterinary medicine context, for example ‘What does gluconeogenesis mean?’, ‘What would happen if the animal were diabetic?’, ‘Why does this occur?’, highlighting the use of question stems in the veterinary context. It was recommended that the groups spend the majority (50-70%) of their meeting time using meaning-making interactions and high-level questioning.

The pre and post task questionnaire data included the following measures: Experiences of the collaborative case-based learning assignment (pre and post) for perceived task difficulty and interest in the case (experiences of the task); evaluation of sources of learning to achieve the learning outcomes of the case-based group assignment (pre and post) in terms of students’ own research of the case, research done by other members, and discussions during face-to-face group meetings; and self-reports of the distribution of time spent on specific activities during group meetings (post only) such as sorting out organisational matters, and discussing and sharing understandings of the case.

The groups’ focus group interviews used questions such as “What do you think you have actually learnt through this project” and “How would you say you learnt this” to prompt students’ reflections.

**Results**

**Questionnaire Data**
Experiences of the task. Results showed a significant interaction effect of Cohort x Time for task difficulty, and no significant interaction effect of Cohort x Time for interest in the case.

Evaluation of sources of learning. A significant difference between the two cohorts was found for the discussions during face-to-face meetings with group members. A positive trend, although not significant, was found with the questionnaire item examining research done by other members of the group. The difference between the two cohorts on students’ own research on aspects of the case was not significant.

Distribution of time. There was a significant difference between the intervention and control groups. Intervention students reported a greater proportion of meeting times spent discussing the case relative to discussing group organisational matters, whereas the opposite was found for the control students. An independent samples t-test was used for this measure.

Interview Data
Students’ accounts and reflections on learning in the group assignment were organized into four categories: Professional relevance of learning from a clinical case file; Acknowledgement of task difficulty; Group learning processes; and Conditions supporting effective group learning.

Professional relevance from a clinical case file. A number of intervention students explicitly acknowledged the relevance of learning from a real-life clinical case file for future clinical practice. Students’ statements highlighted the appreciation that the case-based assignment was not just about understanding a complex clinical case file but represented invaluable preparation for their clinical years ahead.
Acknowledgment of task difficulty. As expected, both cohorts of students stressed the difficulty of tackling complex, heavily detailed case files. They also acknowledged that each case file contained voluminous information, which needed to be read through several times in order to understand and extract the relevant information. Despite acknowledging the difficulty of the task, the students concurrently expressed an appreciation for, and voiced the benefits of having the opportunity to learn from authentic case material.

Group learning processes. Several students from the intervention cohort reported that they found collating information as a group played an essential part in developing a collective understanding of the entire case. The intervention students also frequently made mention of reciprocal teaching as part of their group learning processes, adding that they learnt valuable things from each other through the process of explaining their understanding to one another. In contrast, some control students thought the group approach to learning about the clinical case potentially restricted individuals’ full understanding of the case. Many control students reflected on individual reading and research being the predominant source of learning in the group assignment.

Conditions supporting effective learning as a group. Intervention students reflected on what they thought were necessary conditions to learn effectively as a group, such as explaining that they were determined to work as a group, where each member took responsibility for their own part but also others’ part. Several students in the intervention cohort also explained that they alerted their peers to information relevant to their sections as they were researching their own field, conveying a sense of responsibility and commitment to learning as a group rather than just taking responsibility for their own background research. In contrast, the control students showed no evidence of reflections related to conditions supporting effective learning as a group.

Discussion

The evidence emerging from this study presented an encouraging picture of effective, motivated individual learners who appeared to develop themselves by learning how to learn effectively from and with their peers, and for the group’s benefit. The evidence
showed that students in the intervention cohort acknowledged the importance of taking full responsibility for their own research as well as co-responsibility of identifying research resources for fellow group members, and directed more of their group meeting time to discussing the case versus organising the task.

In sum, the evidence based on students’ accounts is promising, demonstrating that veterinary medical students are able to recognise and appreciate the value of collaborative learning, reciprocal teaching, and questioning for achieving a deeper understanding of clinical cases. One limitation of this paper was the reliance on self-reported data as evidence of the intervention’s impact. Paper 2 addressed this limitation by providing observational data to corroborate students’ accounts of their collaborative learning processes.

Erratum: Figure 1 on p. 372 contains incorrect percentage figures within segments of the pie charts, while the segment dimensions are correct. The correct figures are listed below.
Control cohort: understanding – 33.2%, organisation 49%, other discussions 12.3%, frustrated listening 5.5%
Intervention cohort: understanding – 52.9%, organisation 26.7%, other discussion 16%, frustrated listening 4.4%.
4.2 Paper 2

**Promoting effective collaborative case-based learning at university: a metacognitive intervention.**


The summary of Paper 2 below is a condensed version of the full manuscript. Pertinent sections of the introduction, methodology, results and discussion sections have been extracted to provide a synopsis of the paper. The full-accepted version of the published manuscript, including tables and figures, is in Appendix B.

**Introduction**

This article reported on the findings of a metacognitive intervention aimed at promoting effective collaborative case-based learning at university. The higher education literature overall displays a paucity of intervention studies aimed at fostering deep-strategic, self-regulated learning in real-life, collaborative learning settings, reflecting the challenges faced in using educational interventions to effect change in real-life learning settings (De Corte et al., 2004). As with Paper 1, the metacognitive instructional intervention presented in this paper was designed to investigate the impact of a twofold metacognitive strategy aimed at inducing groups of veterinary medicine students to engage in productive learning from each other while working on a clinical case-based assignment. The metacognitive intervention was presented to the intervention cohort of students while a previous student cohort provided control data. Based on the nature of the intervention the following outcomes were expected:

1. **Personal goals** – it was expected that in comparison to the control students, the intervention students would report learning from each other as greater importance than the control students. It was also expected that achieving high marks in the assignment would be equally important to both cohorts.
2. Experience of the group assignment – it was expected that the intervention students would find group dynamics and managing the task less challenging than the control cohort. It was also expected that the intervention students would consider the clinical case study as being less difficult than the control students.

3. Distribution of time spent within student-led informal group meetings – it was expected that the intervention cohort would spend a greater proportion of their meeting time (observational data) and report spending a greater proportion of their meeting time (self-report data) discussing the case rather than dealing with organisational and other matters.

4. Evaluation of sources of learning to achieve the stated learning outcomes of the case-based assignment – it was expected that intervention students would not rate their individual research differently, but would rate their learning from others’ research and learning from group discussions more highly than the control students.

Two cohorts of veterinary medical students enrolled two years apart in the same second year physiology unit taught in the same way and by the same teacher formed the control cohort (2006) and the intervention cohort (2009). On both occasions, students were required to form self-selected groups of five or six students to complete a case-based assignment. Participation in the research project was completely voluntary. Ten of the 14 groups ($n = 59$) from the control cohort volunteered to participate in the research, and 11 of the 16 groups ($n = 63$) from the intervention cohort also volunteered.

The clinical case group assignment
As for Paper 1.

Content of metacognitive intervention
As for Paper 1.

Data collection and instruments
Two matched sources of data from intervention and control students were used to evaluate the effectiveness of the metacognitive intervention: questionnaires completed at the beginning and end of the group assignment, and video recordings of two group meetings (student-led, no teacher) from each group in each cohort.

The beginning and end questionnaires completed by the intervention and control students included measures of personal goals and experiences of the task. The end questionnaire also included measures of distribution of time spent on specific activities during group meetings, and evaluations of sources of learning to achieve the desired learning outcome of the clinical case-study group project.

The first round of video recording took place in the first or early in the second week of the seven-week-long assignment, when students met to discuss their clinical case and start generating their learning objectives. The second video recordings took place around the fifth week, after the groups had the opportunity to research selected aspects of their case.

Data analysis

As with Paper 1, a comparison of intervention and control students’ questionnaire data (self-report data) was undertaken by carrying out repeated measures multivariate analysis of variance for the data, involving beginning and end measures and t-tests for the end measures only. In regard to the distribution of time measure, an index of the relative proportion of time spent on organisational matters versus discussing and understanding the case was created. Positive scores indicated a greater emphasis on content-related discussion and negative scores indicate a greater emphasis on organisational matters.

The analysis of the video footage meetings (observational data) of 40 meetings across both control and intervention cohorts was based on the theoretical system and coding system developed by Volet et al. (2009a) (as described in Chapter 3). A satisfactory level of inter-judge agreement in coding was achieved for all groups. The two judges were in agreement for 82.7% and 77.3% of the total length of time across all meetings respectively for the intervention and control cohorts.
Results

The impact of this metacognitive intervention was examined by comparing control and intervention students’ personal goals and experiences of the group assignment (self-report data); distribution of time during group meetings (observation and self-report data); and evaluations of sources of learning to achieve the stated learning outcomes of the group assignment (self-report data).

Personal goals

Contrary to expectations intervention students did not rate ‘that we all learn from each other’ as a more important goal than their control counterparts by the end of the group assignment. While for the second goal, ‘to get the highest mark possible for the group assignment’, control students had lowered their achievement expectations by the end of the assignment, in contrast to the intervention students who had marginally increased their expectations of getting a high mark.

Experiences

Group challenge - the expectation that the intervention students would perceive their group social dynamics as less challenging overall than the control students was supported. Handling different work standards within the group became less of a challenge for the intervention students compared the control students. In terms of group members’ interpersonal connectedness, no change was experienced for the control cohort. The intervention students however initially expected this aspect to present a moderate challenge, and ended up reporting this as being less of a concern at the end of the assignment.

Task challenges - the expectation that the intervention students would experience the task as being less challenging overall than the control cohort was also supported. More specifically, the intervention students reported that the time and effort required by the project at the end of the assignment was less of a concern, in contrast to the control students who reported that this was actually more of a concern.
Difficulty of and interest in the clinical case – the intervention students’ ratings of task difficulty was lower at the end of the clinical case assignment than at the beginning. The opposite pattern emerged for the control students. There was no change in the evolution of the two cohorts’ ratings of their interest in the case assignment, supporting the research expectation that all students would value this opportunity to learn from an authentic case file, regardless of its difficulty.

Distribution of time during group meetings

Observation (video data) - video data of control and intervention groups’ actual engagement in the two meeting sessions revealed six of nine control groups and six of the eleven intervention groups spent more than 30% of their times discussing the clinical content of their case in the first meeting. In the second meeting, only three of the nine control group but eight of the eleven intervention groups spent more than 30% of their meeting time discussing clinical content. The mean percentage of meeting time spent on discussing the clinical case over the two sessions decreased from 36.8% to 26.3% for the control group and increased from 39.6% to 44.5% for the intervention groups. The extent to which intervention students spent in high-level content discussion of their clinical case was also compared to their control counterparts two years earlier. No significant differences were found between cohorts in either session.

Self-report (questionnaire) data – an independent-groups t-test comparing intervention (n = 88, M = 26.19, SD = 29.07) and control (n = 83, M = -15.81, SD = 42.47) cohorts self-reports on the proportion of time spent on organisational matters versus discussing and understanding the case were significantly different, t (169) = -7.583, p < .001.

Evaluations of sources of learning

The expectation that intervention students would find the group discussions during face-to-face meetings to be more useful to achieve the learning outcomes of the clinical case assignment, in comparison to the large combined control cohort (2007-8 data) was supported.

Discussion
The use of a semi-experimental research design, combined self-report and observational data, and rigorous methods of analysis, which included theory-based coding and inter-judge agreement, were critical to gauge the effectiveness of this metacognitive intervention.

Consistent with the research expectation, differences in content-related discussions between cohorts only emerged in the second recorded session, after students had completed some background research on their cases. More than double the number of groups from the intervention cohort, compared to the control cohort, spent 30% or more of their time in content-related discussions, providing support for the effectiveness of the intervention. This finding was consistent with the two cohorts’ own estimates of the time spent on content discussion versus organisational matters in their group meetings.

The lack of significant differences in high-level content-related discussions between cohorts indicates that the metacognitive intervention was not sufficient to achieve this aim. One explanation is that the metacognitive intervention even though presented in the most credible and contextualised way was not sufficient for high-achieving oriented students. This suggests that perhaps students should be shown a demonstration of effective, high-level meaning-making interactions.

In regards to students’ experiences of the group assignment, the intervention students finding the task less difficult overall demonstrated the impact of the intervention. They also found task management and group dynamics less challenging than control students. The impact of the intervention was also highlighted in the significant difference between intervention and control cohorts’ evaluations of their learning from face-to-face group discussions.

In sum, this study provided evidence that it is possible to enhance the way groups of students work together, increasing the amount of time spent on discussing and explaining the case, rather than simply managing, organising and delegating tasks. Content related discussions were however not at the desired high-level. This led to the investigation of the nature and significance of productive engagement in veterinary students’ collaborative learning, which was the focus for Paper 3.
4.3 Paper 3

Productive group engagement in cognitive activity and metacognitive regulation during collaborative learning: Can it explain differences in students’ conceptual understanding?


The summary of Paper 3 below is a condensed version of the full manuscript. Pertinent sections of the introduction, methodology, results and discussion sections have been extracted to provide a synopsis of the paper. The full-accepted version of the manuscript, including tables and figures, is in Appendix C.

Introduction

This paper explores the nature and significance of productive engagement in cognitive activity and metacognitive regulation involving collaborative learning tasks that negotiate complex scientific knowledge.

Meaningful insight into the inner workings of collaborative learning calls for scrutiny of interpersonal interactions related to the task and knowledge as they unfold in real-time. Research on social regulation in collaborative learning is challenging because it is recognised as being located at the articulation of individual and social processes, and involves the study of dynamic, complex interactive and evolving processes. One major challenge noted by Volet and Vauras (2013) is to develop methods of analysis that represent generic theoretical constructs, while at the same time are sensitive enough to capture manifestations of social regulation in specific contexts. To date, limited research attention has focused on the extent to which group differences in metacognitive regulation during collaborative learning can help to explain difference in group learning outcomes. The research presented in this paper aimed to address this gap.
A situative framework, combining the constructs of social regulation and content processing as described by Volet et al. (2009b) and Volet et al. (2009a), provided the theoretical basis for a comprehensive, contextualised coding scheme to analyse student interactive data (see Chapter 3 for a full description). The purpose was to empirically explore the theoretical distinction between joint cognitive content processing, and joint regulation of cognitive content processing, or socially shared metacognitive regulation (SSMR).

There were two specific aims for this paper. The first aim was to examine the extent to which group differences in cognitive activity and metacognitive regulation during a collaborative learning activity could contribute to explaining differences in group learning outcomes. Based on Volet et al.’s. (2009b) theoretical perspective that groups consist of multiple self-regulating members who are able to productively negotiate their respective knowledge and understandings to accomplish the task at hand, it was predicted that group differences in learning outcomes while negotiating a collaborative learning activity would be associated with qualitative differences in the groups’ cognitive engagement and metacognitive regulation during the activity.

The second aim was methodological in nature and involved validation and further articulation of the theory-based coding scheme to analyse cognitive activity and metacognitive regulation processes in collaborative learning.

**Participants and design**

As with Paper 1 and 2, the study presented here was conducted with second year undergraduate veterinary medicine students enrolled in a mandatory physiology unit and involved the same clinical case-based assignment, which was host for the research. In the year this research was undertaken, there were 15 groups, of which 12 volunteered for the research.

The research team selected two groups for in-depth analysis: Group A (six students), and Group B (five students). These two groups were specifically chosen because their overall grades in physiology did not differ significantly (comparable aggregate marks and within group variation), but they differed markedly in their collective understanding
of the clinical case at the end of the group assignment. Group A scored the lowest with 56% and Group B the highest of all 12 groups with 92%. The groups’ collective understanding of the case was inferred through assessment of a concept map that was constructed at the end of the assignment. The selection of these two groups was based solely on the groups’ collective understanding of the clinical case as represented by their concept map construction.

Given the two very different outcomes of the collaborative learning task, it was predicted that these two groups would display substantial differences in cognitive activity and metacognitive regulation (addressing the first aim), and that these differences would provide useful data to validate the theory-based coding scheme (addressing the second aim).

Data

Data for this research consisted of video footage of the two groups’ interactions while they worked on two tasks: Generate learning objectives; and Construct a concept map.

Task 1: Generate learning objectives for the clinical case at the start of the assignment

The first video footage showed the groups’ first informal meeting interaction after receiving their clinical case files. The teacher was not present at this meeting. This meeting was recorded to gain access to students’ early cognitive and metacognitive engagement in the group assignment. No special instructions were provided and no time limit imposed.

Task 2: Construct a concept map of the clinical case near the end of the assignment

The second video footage showed the students’ joint construction of a concept map to represent their overall understanding of the clinical case. This was done towards the end of the assignment after the opportunity for groups to complete background research. The specific purpose of this recording was to gain access to groups’ cognitive engagement and metacognitive regulation processes at a more advanced stage of the assignment.
To complete this task, each group was given a set of concept cards taken directly from their specific case and related learning objectives (see Chapter 3 for details of concept selection). Students were asked to arrange the concepts in a manner that made sense to the entire group, leaving aside any cards that were deemed irrelevant or did not make sense, and link concepts either with a unidirectional or bidirectional arrow to indicate a cause-effect relationship or inter-related relationship. For educational purposes the PhD candidate provided feedback on the choice of concept cards and their links. All video recordings were fully transcribed with all non-verbal interactions or body language included in the transcripts.

**Concept map analysis to assess groups’ collective understanding of their case**

A fair and rigorous three-stage assessment procedure was used to analyse all completed maps. First, the clinical cases were divided into either small animal or large animal content. Two small and large animal veterinary medical experts were invited to independently construct concept maps of each case using the same clinical case files and concepts given to the students. The two expert maps for each case were compared, any discrepancies discussed and consensus reached regarding appropriate links between concepts. A final “expert concept map” (combination of the two expert maps) was produced for each case clinical case. Each group’s concept map was assessed against the expert map. Based on the proportion of links that were exactly the same in the student and expert maps, each group was given a percentage score. The two groups with the extreme scores of 56% and 92% were specifically chosen for this research.

**Coding scheme for analysing cognitive activity and metacognitive regulation**

The three stage coding scheme presented here was an extension and elaboration of the initial scheme described in Volet et al. (2009a) and validated in Summers and Volet (2010). This elaborated scheme is grounded in a combination of socio-cognitive, metacognitive and situative theoretical perspectives, and integrates group and individual analysis. A full description of the conceptual underpinnings of the coding scheme, its evolution and contextualisation can be found in Chapter 3. A summary of each stage is presented below.
Stage one – Coding cognitive activity

The first stage involved coding cognitive activity at episode level and was categorised into talk orientated at either knowledge construction or task production. Each orientation was further categorised at either low or high levels, indicating qualitative differences in depth of knowledge construction or task production. Using this first stage, two independent judges coded 26% of all data from the two groups and were in agreement for 74.3% of the coding.

Stage two – Coding metacognitive activity

The second stage involved coding metacognitive activity at the turn level. Low and high levels respectively, of planning, monitoring and evaluation were used to indicate instances where there was metacognitive regulation of the cognitive flow. Given no instances of high level planning or evaluation were found, contextualised sub-codes for only low and high levels were generated for monitoring. Each turn that displayed evidence of metacognitive activity was assigned a sub-code. In instances where the same turn may be characterised in multiple ways, the code that reflected the main regulatory function of that turn was assigned.

Stage three – Coding the social nature and function of metacognitive activity

The third stage of the coding scheme focused on the social nature and function of metacognitive regulatory talk within the contextual flow of cognitive activity. This stage distinguished between individual regulation of the group’s activity, and multiple students’ contributions to the regulatory efforts, referred to in this paper as SSMR.

Both stage two and three coding were undertaken separately by the two co-authors, and followed extensive discussion to decide if a turn level occurrence of metacognitive activity represented evidence of change in the flow of cognition. Metacognitive turns that were instigated by one student and subsequently taken up and pursued by other students were taken as evidence of SSMR.
Results

**Task 1 – Generate learning objectives for the clinical case**

*Cognitive activity*

When considering the two groups’ orientation of cognitive activity (task co-production and knowledge co-construction): Group A spent the majority of their time on task co-production (68.7%), whereas Group B spent the majority of their time (82.2%) on knowledge co-construction.

When comparing the orientation and level (low and high level of task co-production and knowledge co-construction) between the two groups: Group B showed three times greater high-level engagement in both task co-production (3.5% vs. 0.4%) and knowledge co-construction (16.5% vs. 5.0%)

*Metacognitive regulation*

When considering frequency and type of metacognitive regulation: there was no difference between the two groups for the total number of metacognitive turns, and no statistical difference ($\chi^2 (1) 1.285, p = .52$) when planning, monitoring and evaluation were considered.

When quality of metacognitive regulation was considered (low and high level of monitoring): the two groups were statistically different ($\chi^2 (1) 43.49, p < .001$). Most strikingly Group B spent 39.3% of their efforts at high-level monitoring while Group A only spent 4.4%. Group B showed evidence of spending a noticeable amount of time volunteering meaning, exploring ideas, and drawing conclusion from high-level conceptual discussions.

**Task 2 – Construct a concept map of the clinical case**

*Cognitive activity*

When comparing the two groups’ orientation of cognitive activity (task co-production and knowledge co-construction): Group A spent all their efforts in co-producing the task, while Groups B spent a substantial amount of time co-constructing understanding of their case (29.3%), alongside co-constructing their map.
When comparing both groups based on level of engagement (low and high): Group B spent a greater proportion of talk at high-level (58.3% high vs. 41.7% low), while Group A directed more effort at the low-level (24.6% high vs. 75.4% low).

**Metacognitive activity**

When considering frequency and type of metacognitive regulation: there was no difference in the two groups for the total number of metacognitive turns; and no statistical difference ($\chi^2 (1) 1.307, p = .25$) when planning, monitoring and evaluation were considered.

When quality of metacognitive regulation was considered (low and high level of monitoring): the two groups were statistically different ($\chi^2 (1) 16.16, p < .001$), with Group B spending the greatest proportion (76.2%) of their monitoring at high-level, in contrast to only 37.8% for Group A. The breakdown of monitoring into metacognitive regulation sub-codes revealed *exploring ideas* was a noteworthy way (27%) in which Group B engaged in high-level monitoring.

**Illustration of an episode of high-level cognitive engagement with SSMR**

This section of the paper provides an example of how the three-stage coding scheme was applied to an episode of high-level cognitive engagement and SSMR. The full illustration and accompanying text can be found in Figure 3 of the manuscript. To briefly explain the SSMR episode: the five students from Group B are discussing the term *anorexia* in a cat with kidney disease, two students (Blanca and Winnie) have an incorrect understanding of the term and try to change placement of arrows on the concept map to reflect their incorrect understanding. Another student (Renee) has the correct understanding of the term, realises the misunderstanding held by the other two students and provides the correct definition. The example illustrates Renee exhibiting evidence of concurrent self and social regulation as she first realises her peers’ misunderstanding, and then regulates their understanding by correctly defining the term.

**Discussion**

The theory-based coding scheme presented in this study was conceptually and methodologically useful to show how group differences in cognitive activity and metacognitive regulation during case-based collaborative learning helped to explain
differences in the groups’ collective understanding. This was made possible through a clear demarcation between group engagement in low or high levels (quality) of knowledge construction and task production (orientation), and low and high levels of monitoring these cognitive orientations. The systematic coding of these revealed that when a group’s interactions and discussions included a substantial amount of high-level engagement in and monitoring of case content, this was also associated with evidence of better overall conceptual understanding of the case, as evidenced by the end group product (concept map).

Explaining why one of the groups displayed persistent attempts at high-level conceptual understanding through the case-based assignment, while the other focused on producing task outcomes, is speculative. The possibility of problematic group dynamics or extensive prior knowledge can both be excluded as possibilities, since there was no visible evidence of interpersonal challenges, and learning from real life clinical cases was a novel and challenging task for all students, excluding the possibility that some students may have had prior knowledge or understanding of the clinical content. One explanation for better engagement and performance may be differences in implicit or explicit goals, where Group B may be aiming to maximise the learning opportunity while Group A pursued the goal of simply completing the task at hand.

The research presented in this paper has contributed to the literature on productive social learning and interpersonal regulation in two important ways. From a theoretical perspective, evidence of concurrent self and social regulation of learning, as conceptualised by Volet et al. (2009b), was identified. From a methodological perspective, the theory-based coding system further developed and validated in this paper was found to be sensitive enough to scrutinise and analyse the dynamic and complex nature of inter-personal regulation of learning. There are, however, many factors yet to be unravelled in the intricate inner workings of productive collaborative engagement and interpersonal regulation, especially as small group collaborative learning is increasingly utilised in all levels of education.
4.4 Paper 4

Making clinical case-based learning in health sciences visible: Analysis of collaborative concept mapping processes and reflections


The summary of Paper 4 presented below is a condensed version of the full manuscript. Pertinent sections of the introduction, methodology, results and discussion sections have been extracted to provide a synopsis of the paper. The full manuscript, including all tables, is in Appendix D.

Introduction

A number of researchers in science education (e.g. Salomon & Almog, 1998; Love, Medin & Gureckis, 2004) have argued that scientific knowledge is best learnt as inter-related knowledge networks, rather than listed facts. Research has also identified students’ perceptions of learning science as disconnected facts and ideas (Gulyaev & Stonyer, 2002), and students’ displaying fragmentary understandings of complex knowledge structures (Kinchin, Hay & Adams, 2000; Hay, 2007), with an inability to integrate concepts for meaningful understanding.

Given the interwoven nature of learning scientific knowledge, concept mapping has historically been recognised as a meaningful learning tool to facilitate the construction of inter-related concepts, and as a productive research tool to explore the interconnectedness of students’ knowledge representations. Less attention has been directed to the investigation of students’ cognitive and metacognitive learning processes while constructing a concept map. Students’ and their teacher’s own accounts and reflections of co-constructing science knowledge using concept maps is also under-researched. Two studies presented in this paper addressed these issues.
The studies in this paper addressed two research aims:

- To determine the extent to which students’ engagement in cognitive and metacognitive processes while collaboratively completing a concept map of a clinical case can explain differences in their collective understanding of that case (Part 1).
- To explore students’ accounts and reflections on the value of collaborative concept mapping to enhance their understanding of a clinical case, and their teacher’s views of the potential of concept mapping as an instructional tool to facilitate students’ understanding of clinical cases (Part 2).

Both studies were investigated in the context of the same clinical case-based assignment as Papers 1, 2 and 3. Part 1 involved the same cohort of students from Paper 3. Part 2 involved students from a subsequent cohort.

**Part 1**

As Nesbit and Adesope (2006) highlighted in their meta-analysis of concept mapping, there are few fine-grained micro-analyses of concept mapping in the literature. In particular, studies exploring how students regulate their collaborative cognitive and metacognitive activity to complete a concept mapping task, are under represented. Given the considerable attention directed at the importance of social regulation in collaborative learning in recent years (Iiskala et al., 2011; Salonen et al., 2005; Volet et al., 2013), this study aimed to address this gap.

This study reported the same methodology and results from the concept mapping task in Paper 3, involving the same two disparate learning outcome groups. More specifically, the methodology included describing the collaborative case-based assignment context, how the students completed the concept mapping task, the data that were collected, how the concept maps were scored, and finally how students’ learning processes were coded. The results involved describing the two groups’ engagement in cognitive activity in terms of task co-production and knowledge co-construction, and their engagement in metacognitive regulation of cognitive activity, in terms of low and high levels of planning, monitoring and evaluation. This study was included in this paper to provide
support for the value of concept mapping as a research tool, particularly to uncover the nature of productive and less productive group learning processes. To establish an educational purpose for concept mapping in case-based learning, how students and their teacher perceived the value of concept mapping for learning and teaching was investigated in Part 2 of this paper.

**Part 2**

Studies of students’ views of concept mapping are under-represented in the literature, some exceptions being Santhanam et al. (1998), Roth (1994), and Bunting et al. (2006). For Roth, eliciting students’ reflections on concept mapping in physics was important since “As teachers, we have often implemented teaching-learning strategies without asking students whether these strategies make sense to them, whether they find them helpful as they try to learn in our subject areas, or whether and what they learn about learning as they engage in constructing new knowledge” (p. 25). This study is also based on the rationale that insight into how students learn and what students themselves think of the learning process is paramount if learning tools such as concept mapping are to be used successfully in everyday science education.

Similarly, little research has explored teachers’ perspectives of how students learn from concept maps. Research by Kinchin (2001) has explored teachers’ perspectives on using concept maps in classrooms, and Webb et al. (2008) has observed the role of teachers in concept mapping, but little attention has been given to teachers’ views about how students learn from participating in collaborative concept mapping.

**Methodology**

Part 2 involved a different student cohort from Part 1, and involved concept mapping as an embedded learning task in the clinical case-based assignment. There was no filming, research observations, or assessment of completed maps. The concept mapping task was presented to the students in their second obligatory meeting with the teacher, and offered as a useful learning exercise to consolidate their understanding of the case and prepare for the class presentation. The teacher provided detailed feedback at the end of mapping task to address any inaccuracies in understanding content.
**Students’ data collection and analysis.** Individual student’s accounts on the value of learning from the concept mapping exercise were elicited in a mandatory written reflection exercise also embedded within the clinical case-based assignment. The exercise contained a number of questions and formed 5% of the unit mark. The question addressing the concept mapping exercise was: “In regards to the concept mapping activity (during the second meeting with your teacher), how useful do you consider such an activity was, to gain a better understanding of the case as a whole? Also, how useful is it for students to bring their thoughts together at the time they are putting their presentation together? Please explain your answer.” The question was designed to elicit reflections on two aspects of the concept mapping task: task production (completing the activity); and knowledge construction (learning content with and from each other while constructing maps). All 87 students completed the exercise and 80 gave consent for their reflection to be used for research purposes.

A direct thematic content analysis (Hsieh & Shannon, 2005; Braun & Clark, 2006) was used to gain a comprehensive view of all responses. To establish familiarity with the data, the process involved multiple readings of all 80 responses by two coders to generate the initial codes. The next step involved generation of themes that were refined, defined and named for coding purposes. Inter-judge reliability through double coding of 10/80 or 12.5% responses achieved a satisfactory 80% agreement. The teacher was not involved in any aspect of the coding, and the teaching evaluation of the reflection exercise was undertaken separately to the research.

**Teacher’s data collection and analysis.** A conversational style interview was used to elicit the teacher’s perceptions of the instructional value of asking students to collaboratively construct a concept map of their clinical case file. The 70-minute interview was audio recorded and fully transcribed for analysis.

**Results**

**Students’ perceptions of the usefulness of concept mapping.** Five thematic categories emerged from the data. Three learning-related themes consisting of, big picture of knowledge, focus and flow of knowledge, and management of understanding. Two
task-related themes consisted of completion of concept map and/or assignment, and completion of class presentation.

The process of categorisation of data into themes was relatively straightforward but occasional overlaps emerged. For example, a student’s single statement could reflect on the development of a big picture of their knowledge but also mention, in passing, the focus and flow of knowledge. Where it was not possible to clearly demarcate a single theme at statement level, the predominant theme was given precedence for coding purposes.

Overall 32.5% (26/80) students mentioned at least two learning related themes, these students being mostly focused on learning case content and understanding concepts. Only 13.7% (11/80) students were exclusively focused on task-related aspects. These students appeared to be predominantly focused on meeting instructional requirements and not making reference to learning-related notions.

The five thematic categories with examples of students’ comments are illustrated below.

**Big picture of knowledge (learning-related theme).** This theme captured students’ views that the mapping task was a useful way to visualise their clinical case as a whole, integrate complex and sometimes confusing case content, and highlight any missing information. 35% (28/80) of students mentioned gaining a big picture of knowledge as a useful aspect of concept mapping.

As an example, two students commented … *first time the case could be projected as a whole instead of just fragments* (S56) and *It also helped us to link various parts together and to take a step back to look at the case as a larger picture since we were only looking at our individual chunks of information prior to that* (S1).

**Focus and flow of knowledge (learning-related theme).** This theme refers to students’ views that the concept map exercise helped them visualise connections and relationships of key concepts involved in the clinical case. 42.5% (34/80) of students mentioned such notions.
Examples of comments related to this theme included … simplifying the whole case into a few main points, and by connecting these points, the case could be understood in a simple way (S8), and … see clearly which parts related to what and that, of course, some were related to many factors (S11).

**Management of understanding (learning-related theme).** This was the most frequently mentioned theme, with 48.8% (39/80) of students making comments related to this theme. Students mentioned concept mapping to be a useful tool for the group to assess their progress and collective understanding of the material.

Examples included some students mentioning concept mapping being useful in building their confidence … a great tool for bringing information to the table … some had different views of how the case was put together and this gave an opportunity for discussion … allowed those who knew the case better to share their opinions (S15). I feel that the mind map gave us confidence that we had a pretty good idea what we were talking about (S29).

**Completion of concept map and/or assignment (task-related theme).** This theme captured students’ reflections related to the completion of the concept map or the case-based assignment as a whole. Students often declared that completing the concept map was part of completing the assignment. Half (40/80) of the students made statements consistent with this theme.

An example included one student reflecting on the approach used by their group to construct their concept map … when we were made to decide where to place the cards on the board, and how they should be linked … we were undecided on where a particular card should go … at the end we just made a decision and left it as it is, but we all went back to do more research on it, and came up with a conclusion (S54).

**Completion of class presentation (task-related theme).** With 63.8% (51/80) of students mentioning this theme, it unsurprisingly predominated all students’ responses. This is because the class presentation was to a large extent the main way groups were assessed on their clinical case-based assignments.
One student stated … In order for an intelligible, smooth flowing speech the presentation must have a degree of unity, which is made easier if people’s thoughts are in harmony. The final presentation should sound like a single speech that is broken up into a number of parts, rather than several speeches brought together with only a somewhat tenable connection … the mapping exercise was useful in bringing our thoughts together, which is of great importance to the proper presentation of the case as a whole (S73).

Teacher’s perceptions of the usefulness of concept mapping

The teacher’s reflections stressed the value of concept mapping for both student learning and instructional purposes, showing an acute awareness of the complexity of the assignment and the value of concept mapping to address some of the learning challenges experienced by the students. Noteworthy, were numerous references to his observations of students’ discussions while constructing their maps, and how his observations had improved his feedback. When prompted to comment about whether the mapping exercise helped students prepare for their (assessed) class presentation … my perception was that it didn’t help their presentation … just looking at the marks, and the general quality of talks, I can’t see that they have really changed over the years …

Discussion and conclusions

The fine-grained, comprehensive coding system used to analyse cognitive and metacognitive learning processes was effective in highlighting differences in two groups with divergent learning outcomes in a collaborative concept mapping task. More specifically, high-level engagement in cognitive and metacognitive learning processes was evident as students attempted to understand the clinical case, to elaborate and discuss case material, and to add conceptual justifications when selecting concepts and their links. Given that high-level knowledge co-construction is considered to be the most effective type of learning process in peer learning (King, 2002; Volet et al., 2009a), and that analysing the quality of cognitive and metacognitive regulatory activity in students’ collaborative interactions is especially useful in uncovering differences in the way students engage in effective and less effective peer learning (Rogat & Linnenbrink-Garcia, 2011; Summers & Volet, 2010), the findings from this paper
showed that it was possible for some students to do this when they used concept mapping to negotiate complex case-based learning.

The thematic responses from students’ perceptions of using concept mapping to learn from clinical case files were generally in line with past research. Consistent with past research on concept mapping, the students in this research showed that they thought concept mapping was beneficial to structure learning, see connections and relationships of key concepts in the clinical cases, and provide an opportunity to discuss the flow, direction and order of the clinical concepts. Surprisingly (given the hint in the question), and contrary to the literature reporting that concept mapping is an excellent means of providing a visual and spatial ‘big picture’ display of knowledge (e.g. Hay et al., 2008; Kinchin, 2000), the students in this research reported this aspect less than other thematic categories.

Consistent with students’ reflections, the teacher stressed how case content understanding could potentially be enhanced using concept mapping. The teacher’s opinion that the concept maps would not necessarily help students in their preparation for the class presentation was in contrast to students’ views that the maps were very helpful in preparing their presentations. The teacher’s comments about providing feedback to correct factual errors after listening to interactions a students constructed their maps, provided evidence that the teacher placed more emphasis on concept mapping for understanding of content than preparation for the class presentation.

Findings from this paper provide evidence to suggest that concept mapping may be extended to situations in which students are required to learn from case files or clinical case-based material. In conjunction with textbook- or lecture-based learning, the very nature of complex, entangled medical case-based material might best be disentangled and made sense of when displayed as a concept map.
4.5 Book Chapter

Metacognitive regulation in collaborative learning. Conceptual developments and methodological contextualisations


Related to Study 2 of this research, is a contribution to a book chapter discussing recent conceptual and methodological developments in metacognitive regulation processes of collaborative learning.

This chapter examined new ways of conceptualising, capturing, analysing, and representing evidence of metacognitive regulation in collaborative learning. The conceptual and methodological underpinnings of metacognitive regulation in collaborative learning were explained, along with empirical illustrations from two different contexts. The first context involved young students’ collaborative problem-solving and inquiry learning at school. More specifically, this involved exploring metacognitive regulation in high achieving young students engaged in face–to–face problem solving interactions, and young students in computer supported, collaborative inquiry learning environments. The second context involved veterinary medical students negotiating complex scientific knowledge. The investigation of metacognitive regulation in this context was discussed in terms of tracing high-level co-regulation of content knowledge, capturing the focus and function of metacognitive regulation, and identifying group and task-related differences in metacognitive regulation. The primary aim of this chapter was to present detailed analyses of the nature and function of interpersonal metacognitive regulation in social learning contexts by illustrating theory-based, empirically contextualised methodologies that reveal group and task differences.
My contribution to this chapter involved working with the lead author to refine the conceptual framework and coding scheme that was first presented in Volet et al. (2009a). The explanation and discussion of the refinement process, and three-stage coding scheme is presented on pp. 86 – 90. I also contributed to the empirical study presented on pp. 92 – 95 to identify group and task related differences in metacognitive regulation. In terms of actual writing, I prepared the presentation of the two examples of coded metacognitive regulation in a collaborative learning task presented in Figure 4.7 (p. 91), and drafted the associated text. I also contributed to sections of the methodology related to the aforementioned empirical study. Paper 3 in this thesis elaborates further on the conceptual and empirical work presented in this book chapter, and presents the work that was unique to the present research.
5. DISCUSSION: IMPLICATIONS, LIMITATIONS AND FUTURE DIRECTIONS

There were two major findings of this research. The first contributed to veterinary medical education by providing evidence that it was possible to enhance the ways in which groups of students learn together, increasing the amount of time spent on productive knowledge construction. The second made a contribution to research on social regulation of learning by developing and validating a theory-based contextualised coding scheme to examine the issue of how veterinary students engage in effective collaborative learning, and contributed to explaining groups’ differing learning outcomes. These findings are discussed in light of conceptual and empirical contributions to research in social regulation, rigorous methodologies to analyse interactive data, and educational implications for veterinary medical education. The limitations of this research and future directions are also presented, including implications for design-based research in veterinary medicine and research on interpersonal regulation of collaborative learning.

5.1 Methodological, conceptual and empirical contributions

The theory-based contextualised coding scheme developed in Study 2 provided a methodological contribution to highlight differences in cognitive and metacognitive learning processes in groups of students negotiating complex scientific learning. The coding scheme proved sufficiently sensitive to scrutinise and analyse the dynamic and complex nature of interpersonal regulation and identify group differences in engagement. It provided detailed information for analysing low and high levels of task production and knowledge construction (cognitive activity), along with low and high levels of planning, monitoring and evaluation (metacognitive activity). Analysing the quality or depth of cognitive and metacognitive activity is important because high-level cognitive and metacognitive processing is recognised as being the most desirable focus of group learning interactions (e.g. Cohen, 1994; King, 2002; Vauras et al., 2003).
Empirical evidence however has shown that not all student interactions lead to desired high-level content processing (King, 2002; Rogat & Linnenbrink-Gracia, 2011; Summers & Volet, 2010), prompting researchers to point to the critical issue of addressing the quality or depth of learning processes in students’ learning engagement (Chan, 2012; Rogat and Linnenbrink-Garcia 2011). The coding scheme developed in this research was based on Volet et al.’s (2009a) theoretical framework for socially regulated learning. That framework addressed the issue of quality of engagement in collaborative learning by combining the constructs of high and low levels of content processing, and social regulation to examine the nature of collaborative learning.

In this research, identifying the nature of low-level engagement in learning included evidence of such interactions as exchanging and sharing definitions of key scientific concepts, or reading from textbooks sections that were relevant to the clinical case. Identification of students’ interactions that involved elaborating, justifying, and explaining key concepts was evidence of high-level learning engagement. Consistent with van Boxtel’s (2000) observation that social interactions in collaborative learning stimulate elaboration and depth of conceptual knowledge, investigating the quality of students’ learning interactions in this research was important given that student interactions involving questioning and elaboration of ideas can provide opportunities for knowledge expansion and integration of newly learned knowledge into prior knowledge, developing deeper understanding. A deeper approach to learning, especially in the context of a clinically orientated course, is especially important as this is recognised to be an essential way to understand the complex, interrelated chains of concepts that link theoretical knowledge to clinical application (Allenspach et al., 2008; Monahan & Yew, 2002; Newble & Entwistle, 1986). In the present research, a deeper approach to learning would have been the ideal method for students to use in the case-based assignment because the clinical cases contained complex medical knowledge, and it was their first exposure to this type of learning.

From a conceptual perspective, the empirical research conducted as part of Study 2 provided evidence of the articulation between self and social regulation of learning. This has significant educational implications when students are grappling with complex medical knowledge. The theoretical case made by Volet et al. (2009b) that individuals and social entities are concurrently self and socially regulating systems is a complex psychosocial phenomenon, which is often difficult to articulate, and frequently appears
to be confounded in empirical data (Rogat & Linnenbrink-Garcia, 2011). Evidence of this phenomenon was provided in this research (Study 2). It involved one group members’ self-regulation of the definition of a central medical concept, and the use of this self awareness to realise the misunderstanding of other students in the group. The cognisant student then regulated other members in the group toward the correct definition. This finding can be related to Chan’s (2012) concept of “social metacognition” (p. 68, italicized in the original text), to describe a situation in which students self-regulate their own learning, co-regulate the learning of others in the group, and are aware of what others in the group do not understand. The implication for the students in this research was that formulating the correct definition was integral for the group as a whole to continue understanding other aspects of their case, as this was a fundamental concept. Without this regulation, the group may have persisted with the misunderstanding, and consequently continued to construct further knowledge based on erroneous information. This is consistent with the argument by Dochy, Moerkerke and Segers (1999) that it is necessary for students to have an accurate, prior understanding of basic knowledge before new knowledge can be correctly learnt and understood.

The rigorous theory-driven, contextualised coding scheme used in this research also made a contribution by providing a methodology to scrutinise specific cognitive and social regulatory processes in a learning situation that involved complex knowledge. This is congruent with Volet and Summers’ (2013) and Whitebread and Pino-Pasternak’s (2013) claim that coding systems should be sensitive to the contextual features of the activity under observation. Specificity or granularity affords a close, contextualised inspection of the activity under scrutiny, which is necessary to explore task related differences within groups (Azevedo, 2009; Chan, 2012). However, the challenge in developing a coding system often lies in capturing both macro level differences between groups or tasks, and contextualised features to examine differences within groups and tasks at the micro level (Volet & Summers, 2013). In this research, contextualisation of the coding scheme meant recognising students’ different learning characteristics, tasks, and engagement would produce variable types and levels of discussion and interactions. As an illustration of granularity in this research, differences in the two groups’ tasks in Study 2 were only uncovered when the second stage of the coding system was applied. While no difference was detected at the macro level of planning, monitoring and evaluation, using the contextualised sub-codes to analyse the
data revealed significant differences at the micro level when considering quality and depth of metacognitive regulation.

Investigating social regulation of learning in face-to-face, real-life educational activities, presents challenges of not only analysing, but also tracing and representing the dynamic interactive processes. According to Derry et al. (2010), video data collection affords a minimally intrusive, visible and audible documentation of real-life social learning interactions. It also provides the opportunity for multi-viewings for coding and analysis. Narrative descriptions of video data presenting rich “play-by-play” (Derry et al., 2010, p.22) descriptions of dynamic and interactive data are recognised as the best way to represent the fluidity of social engagement. Derry et al. (2010) however also posited that narrative accounts may be considered “less credible to many experimentally minded social scientists” (p. 23), and proposed that one solution may be to use multiple methods of analysis and representation when narrative accounts are included. To use an example from this research, Study 2 used both quantitative and qualitative analysis to investigate the learning process differences in two groups. Quantitative analysis involved reporting the frequency of cognitive activity by orientation and level, and frequency, type, and levels of metacognitive regulation. In terms of qualitative analysis, an example of a coded extract was included when reporting the findings, to illustrate both an episode of SSMR, and the three stages of coding, thus addressing methodological transparency (Volet & Summers, 2013, italicized in original text). Full disclosure is imperative with respect to how data are collected, but also for analytic methods used to draw conclusions from coded data. It provides an open means of comparison with other analytical methods, and perhaps even inspiration for other researchers in the field to continue developing rigorous analytical methods. Authors across a range of studies have also recognised the importance of using rigorous analytical methods to generate reliable findings from coded interaction data (e.g. Azevedo et al., 2010; Chan, 2012; Grau & Whitebread, 2012; Volet & Vauras, 2013). Alongside the theory-based, contextualised nature of the coding system presented in this research, it was paramount that the coding process displayed methodological rigour. Two experienced researchers were involved in the coding process at all times, producing inter-judge reliabilities that were satisfactory in all instances.

In addition to the use of videotaped data collection and analysis, the use of multiple modes of data collection and analysis for construct validity and facilitation of reliable
research outcomes has been advocated (Chan, 2012; Volet & Summers, 2013). The empirical research conducted in the two studies used multiple modes of data collection in terms of observational videotaped data, self-reported questionnaires and written guided reflections, and student and teacher interview data (and transcription). This approach afforded a rich, in-depth analysis of how students engaged in their learning. It relied not only on what students reported, but also on what was observed in their group meetings, and what they said in face-to-face interviews, all complementing one another to provide a more comprehensive picture of students’ learning engagement and processes.

In the context of research that includes an intervention study, this type of multi-data collection is scarce in the higher education literature, where most studies rely only on student self-report data. Multiple modes of data collection is an important aspect of investigating the intricacies of collaborative learning as it could be argued that this provides a means of verifying the consistency of findings, or alternatively serves to highlight discrepancies in findings, for example, the comparison of students’ self reports in a questionnaire and researchers’ observations from video data demonstrating different findings. In terms of conducting an intervention study in real-life teaching, the use of a control and intervention cohort from different years (2006 and 2009) in Study 1 allowed for a sound basis for a comparative analysis, as the two groups were not enrolled simultaneously so the intervention did not pose an ethical dilemma.

5.2 Educational implications

Study 1 provided evidence that it is possible to enhance the ways in which groups of veterinary students learn collaboratively, increasing the amount of time spent on productive knowledge construction, rather than simply managing and organising the learning task. This finding makes an important contribution to veterinary medical education as thus far there have been limited attempts in using metacognitive interventions in facilitating and enhancing veterinary students’ collaborative learning.

Veterinary medical students have been described as highly capable, achievement-motivated learners (Zenner et al., 2005), although previous research (e.g. Summers &
Volet, 2010; Volet et al., 2009a) has shown that when these students work in a group, they do not necessarily spontaneously engage in effective forms of learning. Given these students are typically committed to high academic achievement and dedicated to pursuing professional learning, introducing them to a set of theory-based strategies for effective collaborative learning and informing them about the learning benefits may have been sufficient to increase the amount of time they would normally spend on discussing and understanding the case, hence contributing to the success of the intervention. Yet, the findings from this research also demonstrated that the metacognitive intervention had limited success in fostering deep learning engagement. A similar finding was reported in research by Vermetten et al. (2002) involving law students, and by Volet, McGill and Pears (1995) with computer science students. Vermetten et al.’s study reported limited success in an instructional intervention that attempted to foster deep and self-regulated learning. The authors speculated that the instructional measures were not “powerful” enough to create deep learning strategies, and that the students might have used the instructional measures in different ways, accommodating for their own personal habits, ideas and preferences of learning. Volet et al. (1995) came to the same conclusion when interpreting the findings of their intervention with computer science students.

It could be speculated that the veterinary students in the present research might have used the metacognitive intervention to selectively guide their inherent methods of learning, and perhaps only used aspects of the intervention they thought might be productive in their learning, thus limiting the intervention’s full potential.

Students’ interviews in Study 1 also showed it was possible for effective, motivated individual learners to not only take responsibility for their own learning, but also to take on the responsibility of helping other members in the group to learn, for example, by helping with finding research resources. Students’ acknowledgement and frequent reference to the clinical relevance of case-based learning provided encouraging evidence that despite the assignment’s complex and challenging nature, they recognised and viewed it as valuable preparation for clinical practice. This may have contributed to the students’ motivation in spending more time discussing content in their group, and speculatively, perhaps also contributed to the intervention’s overall success. The educational implications are that motivated, individual learners can be guided into group learning practices that have the potential to promote deep learning, and are able to
recognise and associate current learning with future clinical application. This is an important aspect for students to appreciate when they have to negotiate large volumes of complex medical knowledge.

The use of prior knowledge is one way for students to consolidate large bodies of complex content knowledge. It has been suggested that prior knowledge could be particularly beneficial for students in the early stages of learning (Dochy et al., 1999), and that group discussion encourages activation of prior knowledge and facilitates recall of information (Dolmans & Schmidt 2006; King, 1992). Fostering activation of prior knowledge is especially useful in pre-clinical years when students have to acquire and make sense of large volumes of complex knowledge. Knowledge recall is crucial in clinical years when students must call upon their pre-clinical education and apply it to the clinical setting. The early introduction of clinically relevant group-based assignments therefore has the potential to foster prior knowledge activation, promote a collaborative style of clinical enquiry, and facilitate recall of information when required in the clinical setting.

A significant finding from Study 2 was the association of high-level metacognitive regulation (monitoring) with instances of high-level cognitive activity. This is consistent with Lajoie and Lu’s (2011) research involving students in collaborative medical decision-making. Lajoie and Lu’s interpretation of their finding was that “metacognitive activities led to co-regulatory actions, where high-level content knowledge was discussed” (p. 59), implying that metacognitive activities were used when more complex content was discussed. It may be speculated that the veterinary medical students in this research responded in much the same way, that is to say, students exhibited high-level metacognitive regulation when high-level knowledge construction was needed to understand the challenging, complex content in the clinical case files. This suggests that learning involving complex knowledge requires learners to engage in high-level cognitive activity and to effectively regulate that activity. Fostering or scaffolding high-level metacognitive processes when knowledge construction involves complex medical information therefore may be of value.

One other important educational implication arising from this research is the use of concept mapping in negotiating knowledge associated with clinical case-based learning. Perhaps the greatest advantage that concept mapping provides in enhancing science
learning is the ability to provide a visual and spatial display of intertwined and often abstract knowledge (Hay et al., 2008; Kinchin, 2000). Concept maps also provide structural learning and conceptual organisation, therefore facilitating learning that is meaningful (Kinchin et al., 2000). Case-based learning typically involves potentially voluminous, complex concepts with multiple, intricately interwoven connections that may not be initially apparent or appear to be significant in the first instance. The current research provided evidence that concept mapping may be a productive learning tool when case-based knowledge is involved, since it provides a method of constructing meanings and knowledge that may clarify overall understanding.

To illustrate the subjectively perceived value of concept mapping in case-based enquiry, students’ reflections on using concept mapping (Study 2 follow-up) revealed that it facilitated their visualisation of key case concepts as a ‘big picture’, and understanding of how individual concepts were linked, thereby providing the impetus to explain and clarify understanding or misunderstandings with each other. This suggests complex, entangled medical case-based material may be best disentangled, and made sense of, when displayed as a concept map, making connections, understandings and even misunderstandings clearer, thereby potentially facilitating students’ overall understanding of the case. In terms of students’ future clinical practice, dealing with a real-life clinical case involves many of the same processes. It is not unlike constructing a concept map. This starts with the collection of presenting information/concepts (the presenting signs and symptoms of disease), linking these presenting concepts with underlying causes (what specific diseases may cause the presenting signs and symptoms), explaining underlying causes with physiological or pathophysiological principles (why the disease occurred), and finally gaining an overview of the entire disease process to make appropriate clinical decisions regarding treatment, management and prognosis.

From an instructional perspective, the teacher’s reflections on the use of clinical case-based concept mapping in this research emphasised the learning benefits (compared to performance benefits) of using concept mapping to understand the entangled, complex nature of real-life clinical cases. This is consistent with the findings of Edmondson and Smith (1998) who investigated the use of concept mapping to facilitate veterinary students’ understanding of fluid and electrolyte disorders. The teacher in that research mentioned concept mapping as providing an opportunity to listen to students’
interactions to assess their understanding of key concepts, identify any errors or misunderstandings, which then aided in giving appropriate immediate feedback. Similarly, the teacher in the present research stressed how listening to students interactions as they constructed concept maps of their case provided valuable information on students’ understanding of key concepts and any errors or misunderstandings, also enabling relevant feedback. This adds weight to the value of using concept maps to facilitate and support students’ learning.

5.3 Limitations of this research

The research presented in this thesis should be considered to be exploratory in nature. As such, a number of limitations warrant discussion.

Within the present research, examining learning in real-life settings involved students grappling with learning from case files in an undergraduate physiology unit. One limitation of this focused approach in one subject of veterinary medicine was the difficulty to generalise about learning processes and the potential impact of a comparable intervention in other subjects of veterinary medicine, such as histology, pharmacology or anatomy. Conducting this same research in other subjects may have been one way to compare the effects of the intervention and explore the nature of learning processes across multiple disciplines. This would have provided a more complete examination of learning in real-life veterinary educational settings, and allow an effective means for one to generalise about veterinary students’ learning processes and their responses to interventions.

One other design limitation in Study 1 of this research revolved around the inclusion of broad measures of learning (Collins, Joseph & Bielaczyc, 2004). Similar to the study by Pickrell et al. (2002) in which there was an outcome performance advantage in veterinary students who analysed clinical cases as groups rather than as individuals, Study 1 could have included performance outcomes of the control and intervention cohorts. This may have been useful in investigating the possibility that the metacognitive intervention might have influenced students’ marks in the final class presentation, or in the overall physiology unit.
The use of video recording students’ learning interactions in the student-led group meetings or constructing concept maps raises the question of whether this research is a true reflection of ‘real-life’ learning, since it was not known whether students would necessarily interact in a naturalist way if they knew they were being recorded. As already discussed, the literature (e.g. Derry et al., 2010) cites video data collection as a minimally intrusive, visible and audible documentation of real-life social learning interactions, that allows for multiple viewings, transcription and analyses. Given the technical and logistical constraints placed on trying to collect data in other ways (e.g. constant video recordings of all student interactions at all times to establish a baseline measure for natural interactions), the present method of data collection appeared to be the best available method to provide an account of verbal and non-verbal learning interactions. Overall, it appeared that the students’ interactions were minimally affected by the video recording. The highly structured nature of the learning tasks (especially the concept mapping task) may have contributed to the students’ concentration on the task at hand. Coding the video data also revealed that there was minimal evidence of ‘off-task’ interactions, confirming veterinary students’ commitment to effective study.

Reporting the comparison of only two groups (highest and lowest performing) constructing concept maps in Study 2 also was a limitation in the research presented in this thesis. Analysing the learning interactions of all groups would have provided a more complete picture of the nature and significance of the learning processes in these students. Including self-report data in the form of a questionnaire, or an interview to gauge students’ evaluations of the types of learning processes used in constructing the concept maps, would also have afforded greater empirical insight into the inner workings of collaborative cognitive and metacognitive processes. Relating these insights to the observed interactions would provide a more holistic picture of the intricacies of effective collaborative learning.

Another limitation was the use of a different cohort to explore students’ perceptions of concept mapping in the follow-up to Study 2. Being able to relate the observed learning processes and the reported perceptions of a concept mapping task of the same cohort of students would have been ideal. The effects on the findings of uncontrolled external influences that are a part of research in real-life learning contexts, for example, the way in which the concept mapping task was presented to the students, or the type and style of feedback, would have been minimised.
The inclusion of formative evaluation may have been one way to improve the research design of the metacognitive intervention in Study 1. In the context of health care research, Stetler et al. (2006) defined formative evaluation as “a rigorous assessment process designed to identify potential and actual influences on the progress and effectiveness of implementation efforts” (p. 2), and stressed the importance of researchers addressing critical issues about implementing intervention strategies, such as eliciting feedback or response from project participants and making adaptations to research design to achieve the desired change. Formative evaluation in the present research may have been in the form of formal feedback from students by a questionnaire addressing what the students themselves thought about the impact and usefulness of the intervention. In a more informal way, this same feedback could have been in the form of a guided reflective interview, in much the same way an interview was used in Study 1 to elicit responses on how students learned, but aimed at eliciting students’ thoughts about the effectiveness of the metacognitive intervention, with suggestions for improvement. Students’ suggestions for improvement may have been particularly useful for the modification and adaptation of the intervention for future use, potentially increasing its positive impact. These limitations naturally lend to directions for future research.

5.4 Future research directions

The finding that differences in students’ regulation of their learning may help to explain group learning outcomes has promising prospects for future research. As already alluded to, when students are required to deal with content that involves complex medical knowledge, one way to facilitate this may be to foster and scaffold high-level metacognitive processes. This may involve design-based research that involves scaffolding the processes of high-level monitoring, similar to the study by Hogan (1999), who designed an intervention to stress the metacognitive regulatory aspects of knowledge construction in eight-grade students. In the context of the present research, future research direction might involve providing students with a set of strategies that explain how to seek meaning, explore ideas, or question meaning when learning in collaboration, and even to make explicit when it would be appropriate to use these strategies. This is similar to Schraw’s (1998) case for promoting and scaffolding
metacognition. His argument was that learners need to be aware “that metacognition exists”, that it is different from cognition, and that it increases academic success. He emphasises that it is not only important to teach strategies, but also to provide students with knowledge about when and where to use strategies. Further to this, peer modelling (e.g. Bull & Ngheim, 2002; Schunk & Hanson, 1985; 1989) may also be appropriate, where students are shown how these interactions may feature in a realistic collaborative learning setting. Similarly, peer modelling may also involve demonstrating particular transferrable skills (Boud et al., 1999) that are especially applicable to clinical practice. Such skills may involve interpersonal qualities, like being respectful of differing opinions, and being receptive to other ways of dealing with challenges in the work place.

Similar to the idea that specific high-level metacognitive processes should be scaffolded, another future research consideration may be to provide students with the idea to voice their misunderstandings in collaborative learning. The rationale for this type of strategy is based on the notion that voicing incorrect or misunderstood ideas may improve overall understanding and be of significant learning benefit for the group as a whole. Successful implementation of this type of strategy may pose some challenges. One such challenge involves convincing students that it is socially appropriate and safe to voice and explain misunderstandings in collaborative learning settings.

Students may be reticent to articulate misunderstandings on the grounds that voicing incorrect understandings makes them seem unpopular with their peers, or breaches social etiquette that involves the ‘professional politeness’ of not voicing the fact that there is an idea that has been misunderstood, especially in situations where adult learners are engaged in social learning. Gunawardena, Lowe and Anderson (1997) discussed a similar idea. In their analysis of an online debate discussing distance education, the participants appeared to seldom question or correct contradictory viewpoints but rather would make suggestions based on personal experiences. In the context of veterinary students, the lack of confidence in their own understanding might explain reticence in voicing misunderstandings when they occur in other students. This may be related to the fact that many students have prior experiential knowledge (e.g. from seeing clinical practice) but may not necessarily believe they have sufficient textbook knowledge to correct misunderstandings of others.
The role that each individual plays in the groups’ collective effort to regulate their learning warrants future research. As evident from other research (e.g., Iiskala et al., 2011) and indicated in the present research, a single individual may have profound influence on the group’s level of engagement with the learning task and content. The extent to which an individual’s strong positive influence within a group could be traced to that person’s superior background knowledge, or alternatively their goals or motivation to learn, should be explored. Prior research has shown the quality of explanations in collaborative discussions was higher in groups containing high-ability individuals (Webb, Nemer & Chizhik, 1998). Webb (1991) also found that individual students who used elaborate explanations in a collaborative learning activity produced positive learning outcomes, while the opposite was true for students who did not, though elaborations and outcomes were not related to cognitive activity or background knowledge in Webb’s study.

The examination of interpersonal regulation processes contributed to explaining why two groups in Study 2 had very different learning outcomes in this research. There may be other reasons why the groups differed in their learning outcomes. Future research should consider factors concerning motivation to learn or perform well in a task (e.g., Ames & Archer, 1988; Järvelä, Volet & Järvenoja, 2010), individual or collective interest in the learning task (e.g., Ainley, 2006; Harp & Mayer, 1997), personal goals (e.g., Mansfield, 2009; Pintrich, 2000b), or social goals (Wosnitza & Volet, 2009). There is also a need for more empirical studies to document the link between interpersonal regulatory behaviours and learning outcomes. The extant literature shows that these types of studies are limited, with some exceptions being Winters and Alexander (2011), and Janssen, Erkens, Kirschner and Kanselaar (2010). In terms of methodology, further development of detailed fine-grained analysis of interpersonal regulatory processes is also needed to expand theories and further develop coding schemes to examine the complex nature and dynamics of co-regulation, or as Janssen, Kirschner, Erken, Kirschner and Pass (2010) describe it, the “black-box of collaborative learning” (p. 139).

Analysing argumentative discourse in the construction of collaborative knowledge construction may be another way to reveal how the productive nature of collaborative learning is best supported. Argumentative discourse focuses on the interactions of groups or individuals in trying to convince one another of the acceptance of differing
ideas (Clark, Sampson, Weinberger & Erkens, 2007). To date, this type of analysis has received limited attention in collaborative learning involving veterinary medical students, but has been used in other medical learning settings such as investigations involving students negotiating medical decision making (e.g. Lu & Lajoie, 2008), and nurses working in critical care units (e.g. Hagler & Brem, 2008). Alongside knowledge co-construction, argumentation and collaborative discourse are considered important tools for collaborative learning. From a cognitive perspective, both are thought to encourage conceptual understanding and deep learning practices (Nussbaum, 2008). To investigate collaborative discourse, Weinberger and Fischer (2006) introduced a framework for argumentation in knowledge co-construction, describing categories such as *elicitation* (questioning or eliciting a reaction from a learning partner), *quick consensus building* (accepting the contributions of learning partners to enable progression with the task), and *conflict-orientated consensus building* (disagreeing or modifying the perspectives of learning peers). This framework was used in the setting of computer-supported collaborative learning but may equally apply to situations involving face-to-face learning interactions, such as the concept mapping or group meeting tasks in this research.

The use of concept mapping as a learning and instructional tool in the clinical years of a veterinary medicine degree is also an exciting direction for future research. Concept maps may play a major role in facilitating students’ understandings of involved real-life cases that present to a veterinary clinic or hospital. Students’ initial exposure to real-world clinical cases involving real-time patients often creates confusion of clinical concepts, directions, and outcomes. Concept mapping may assist students’ thinking, helping them order clinical (disease) concepts, identify the links between them, and appreciate the outcomes of different disease pathways. Through this process they may be in a better position to suggest treatment options and prognoses for their patients.

In conclusion, there are a number of highly promising ways to further investigate the intricate complexities of interpersonal learning processes in collaborative case-based learning. The continuing development of theoretical constructs and innovating methodologies is critical if productive collaborative learning is to be used to its full potential in higher education, and especially so in veterinary medical education.


Learn? *Educational Psychology Review*, 16(3), 235-266.


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An Instructional Intervention to Encourage Effective Deep Collaborative Learning in Undergraduate Veterinary Students

**PAPER 1**


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An Instructional Intervention To Encourage Effective Deep Collaborative Learning In Undergraduate Veterinary Students.

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KEYWORDS

Case-based teaching

Educational approaches for learning

Collaborative learning

Deep learning
ABSTRACT

In recent years, veterinary education has received an increased amount of attention directed at the value and application of collaborative case-based learning. The benefit of instilling deep learning practices in undergraduate veterinary students has also emerged as a powerful tool in encouraging continued professional education. Research, however, into the design and application of instructional strategies to encourage deep, collaborative case-based learning in veterinary undergraduates has been limited. This study focused on delivering an instructional intervention (via a 20 minute presentation and student handout) to foster productive, collaborative case-based learning in veterinary education. The aim was to instigate and encourage deep learning practices in a collaborative case-based assignment, and to assess the impact of the intervention on students’ group learning. Two cohorts of veterinary students were involved in the study. One cohort was exposed to an instructional intervention, and the other provided the control for the study. The instructional strategy was grounded in the collaborative learning literature and prior empirical studies with veterinary students. Results showed that the intervention cohort spent proportionally more time on understanding case content material compared to the control cohort, and rated their face-to-face discussions as more useful in achieving their learning outcomes than their counterparts. In addition, the perceived difficulty of the assignment evolved differently for the control and intervention students from start to end of the assignment. This study provides encouraging evidence that veterinary students can change and enhance the way they interact in a group setting to effectively engage in collaborative learning practices.

INTRODUCTION

A common aim of veterinary schools is to produce graduates well grounded in the latest theories and applications of veterinary medicine, and who have the ability to extend their learning beyond graduation through continuous professional learning. In this regard, it is well established in the broader education and veterinary education literature that social forms of learning are particularly effective ways of facilitating clinically applicable knowledge transfer. In the context of veterinary education, clinical case-based group assignments are particularly relevant social forms of learning. Discussing a clinical case with peers is a constructive, self directed, collaborative and contextual
learning process. This makes it a powerful tool to integrate and consolidate clinically relevant knowledge, with the added benefit of practising teamwork skills.

Another significant area of inquiry in the veterinary education literature is the development of methods that promote deep learning practices in veterinary undergraduates. Ryan et al. describe deep learning approaches in pre-clinical veterinary students as learning that involves discussion and reflection, understanding the underlying concepts and integrating knowledge across disciplines. This facilitates knowledge retention and ultimately application in the clinical setting. Deep learning practices are widely recognized as having the potential to encourage continuing learning as they provide a clinically relevant knowledge foundation on which students can build upon. In the context of medical education, Newble and Entwistle suggested that adopting a deep learning approach was of most benefit to future practitioners as it formed the basis of continued, lifelong professional education. In combination, collaborative case-based learning and deep learning practices provide a powerful instructional environment for inducing veterinary undergraduate students’ development of sound, clinically relevant knowledge that lays the foundation for continuing professional learning.

The benefits of deep learning, problem-based learning and case-based learning have attracted increased research attention in the veterinary education literature. Surprisingly, there appears to be limited research examining the extent to which veterinary students spontaneously engage in collaborative learning practices that lead to deep forms of learning, and how such practices can be fostered. Volet and colleagues’ recent research documented the actual collaborative learning processes of groups of veterinary students in the naturalistic setting of a real life case-based learning assignment. The study, which involved comprehensive analysis of video data, revealed limited group engagement in productive content-related discussions, one of the prerequisites of deep learning. While some groups spent part of their group meeting time discussing the clinical case and learning content from each other, the majority of the other groups spent most of their time managing the task and the group. The authors
concluded that it should not be assumed that by giving students collaborative case-based assignments, they will necessarily engage in deep level content discussions.

The clear implication is that more should be done to promote collaborative learning than simply assigning group projects. This highlights the importance of designing forms of instruction that induce deep learning practices in collaborative case-based assignments. The veterinary education literature shows a paucity of research in this area. A study by Dale, Nasir and Sullivan\textsuperscript{18} went some way to providing guidance to a group of fourth year veterinary undergraduate students working on a cooperative learning assignment. In that study, students were provided with an instruction sheet outlining the expected benefits of cooperative learning and information aimed at creating an appreciation of teamwork. The authors’ rationale was that students needed to be adequately informed and guided in their cooperative endeavours but the impact of the message was not formally evaluated.

The aim of the present study was to address the limited amount of research on the development of productive collaborative case-based learning in veterinary education. It involved the design and delivery of an instructional intervention to a class of undergraduate veterinary students. The specific aim was to instigate and encourage deep learning practices as an integral part of a collaborative case-based assignment. The impact of the intervention on students’ group learning was evaluated using questionnaire and interview data.

**METHODOLOGY**

**Participants**

Participants in this study were two cohorts of veterinary students enrolled two years apart in their second physiology unit. The earlier cohort (81 students) formed the Control cohort and the more recent cohort (88 students) formed the Intervention cohort.
The two cohorts completed exactly the same group assignment in self-selected groups of five or six peers. The instructional intervention was delivered to the Intervention cohort of students prior to them starting the group assignment. Matched pre and post task questionnaires were given at the beginning (before the intervention for the Intervention cohort) and the end of the assignment. Focus group interviews were also conducted at the end of the assignment with 11 out of the 16 small groups from the Intervention cohort. Human ethics approval and students’ consent were obtained prior to the study commencing for both the Control and Intervention cohorts.

Procedure and Instruments

**Clinical Case-Based Group Assignment**  This assignment is a regular feature of a second year veterinary physiology unit. The aim is to expose students to authentic clinical case material early in their study. The specific learning objectives of the assignment are to provide students with an opportunity to integrate and apply the pre-clinical knowledge they have studied in other units, more specifically, to apply primary physiological principles to a real life clinical case, extract relevant clinical material and explore the underlying concepts that define management and treatment of the disease. The clinical cases are carefully selected to represent small and large animal material and to ensure that the material is at an appropriate level for this stage of their learning. A variety of cases are chosen to avoid significant overlap of case material. The case files are a complete record of real-life clinical cases, providing students with the clinical history, presenting signs, investigations, diagnostics and outcomes.

Students work on this group assignment in their own time (no teacher) over a period of seven weeks. Each group is required to set their own learning objectives based on their specific case, to undertake research to learn about selected parts of that case, and to present their findings to the whole class at the end of semester. Guidance is provided through two mandatory meetings with the teacher three to four weeks apart. The aim of these meetings is to ensure that the groups generate workable, relevant and concise learning objectives, and that group progress is satisfactory.
Students’ work on this assignment is not assessed individually but attracts a group mark, based on the group’s demonstration of having fulfilled their self-generated learning objectives. This is established based on their class presentation and follow-up questions to the group. The group mark is worth 10% of the final mark for the unit.

**Content of the Intervention.** The intervention was presented to students, as guidance on effective group learning from a clinical case. Students were told that learning from each other in a clinical case setting did not happen automatically. They were advised that effective group learning was not just about gathering information individually and putting a set of slides together, nor about being ‘good citizens’, dividing up workload equally and everyone doing their part. It was stressed that they could have great slides with evidence of good research and have managed their group project very well but “learnt nothing from each other”.

The nature of effective group learning from a clinical case was presented in terms of:

- *Conditions* for effective learning as a group,
- *Strategies (presented as tips)* for effective collaborative learning and
- *Benefits* of effective collaborative learning from a clinical case.

The three conditions for effective learning as a group were outlined as follows: first, all members fully committed to learn and help each other learn; second, a respectful learning atmosphere in the group; and third, research preparation prior to the group meetings. It was emphasized that a respectful learning atmosphere meant an environment where peers would feel free to admit that they did not understand without the risk of feeling embarrassed, and the creation of an opportunity for each person to explain their research. In this regard, it was recommended that everyone took turns in presenting their researched material, that during these presentations group members became active listeners, leading to active, continuous discussion and input from everyone in the group with a view to better understanding the case as a whole.
The main focus of the intervention was on a set of strategies for effective collaborative learning from a clinical case during meetings. Two types of strategies were introduced, those focusing on group learning interactions expected to lead to deep understanding of the case as a whole, and those promoting questions expected to show the connections to physiological principles, alternative explanations and speculative case development. Examples of group interactions leading to deep learning were, “bouncing ideas off each other, other ways to explain the same concept, throwing in multiple explanations and teach others in your own words - best way to clarify your own understanding”. These, among others, were illustrated as useful learning interactions that may lead to further inquiry of physiological principles and therefore a deeper understanding.

Coupled with the group learning interactions, it was explained to students, questions that generate explanation of physiological principles, connections between clinical signs, and understanding of diagnoses and treatments would be particularly helpful to achieve a collective understanding of the case as a whole. The extensive research by King 19,20 on stem questions and their usage, provided the inspiration for the sample questions presented to students as leading to enhanced learning. All questions were customised to the veterinary physiology assignment, for example, “What does [gluconeogenesis] mean? Why does it occur? How does it relate to [glycolysis]”? The purpose was to induce students to ask each other such questions as they worked through the case file. It was stressed that questioning would lead to deeper exploration of the case material and hence a better understanding of the entire case. Students were advised they should spend the majority of the group meeting time (50-70%) on such interactions and questions, if they wanted to optimise learning during meetings.

Finally, short-term and long-term benefits of effective group learning from a clinical case were outlined. The short-term benefits were presented as allowing group members to answer any question posed to them at the time of their presentation, hence improving their chances of getting a better mark. The long-term benefits were presented as entailing excellent preparation for future impending clinical years in professional practice.
Procedure The intervention described above was carried out as a 20-minute PowerPoint presentation to the whole class just before the groups received their clinical case files. One of the authors, a veterinarian with extensive experience as a professional teacher in clinical settings, gave this presentation thereby ensuring credibility of the message. While introducing the clinical case study group assignment, the physiology unit teacher also highlighted the value of peer learning to enhance understanding of the case, and as a preparation for veterinary professional life. This reinforced the value of the ideas introduced in the intervention. A one-page handout summarising the range of strategies for effective collaborative learning was distributed at the end of the instruction session.

Control Cohort The Control cohort completed exactly the same assignment as the Intervention cohort two years earlier, the only difference being that students were not given any specific instruction regarding effective collaborative learning. It should be noted that an alternate Control cohort was used for the Distribution of Time outcome measure. An alternate Control cohort was used because the Distribution of Time measure was introduced in the year following the Control cohort students’ participation in the study. The alternate Control cohort of students completed the same physiology assignment under the same conditions as the Control and Intervention Cohorts.

Evaluation of this intervention The impact of the intervention was determined by comparing Intervention and Control students’ responses to a questionnaire given at the beginning and end of the group assignment. Follow-up interviews with all Intervention groups were conducted at the end of the assignment. These aimed at providing insight into students’ subjective experience of their learning.

Questionnaire Questionnaire data included the following measures:

- Experiences of the collaborative case-based learning assignment (pre and post)
- Evaluation of sources of learning to achieve the learning outcomes of the case-based group assignments (pre and post)
• Self-reports of Distribution of time spent on specific activities during group meetings (post only)

*Experiences of the collaborative case-based learning assignment* (anticipated at the beginning, and retrospectively at the end) were elicited for perceived Task Difficulty and Interest in the Case. These single items were rated from 1 = not at all to 4 = very.

*Evaluation of sources of learning outcomes* involved students’ rating of how each of the following three activities had helped them achieve the formal learning outcomes for the group assignment: “Your own research on aspects of the case”, “Research done by other members of your group” and “Discussions during face-to-face meetings with your group”. All items were rated on a scale of 1= a little amount to 4= a huge amount.

*Distribution of Time* spent on different types of interactions during group meetings involved students’ estimation of the percentage of time they personally spent on the following types of interactions: Sorting out organizational matters; Discussing and sharing understandings of the case; Active listening of others discussing the case; Listening to the group interactions in frustration and Engaging in other discussions. Of particular interest for the present study was the percentage of time the Intervention students would report spending on organizational matters in comparison to discussing and sharing understandings of the case in comparison to the Control students. This analysis was carried out by creating an index of the relative proportion of time spent on those two types of interactions. This was obtained by subtracting students’ estimated percentage of total meeting time spent on organizational matters from their estimated percentage of meeting time spent on content-related discussions. Positive scores indicated a greater emphasis on content-related discussion during group meetings, which has been linked to more effective and beneficial collaborative learning practices and negative scores a greater emphasis on organizational matters.
Interviews with Intervention students  The focus group interviews invited students to reflect on what they had learnt through the collaborative case-based learning assignment and how this learning had occurred. Questions were used to prompt students’ reflections, for example, “What do you think you have actually learnt through this project?” “How would you say you learnt this?”

RESULTS

Comparisons of Intervention and Control students’ experience based on questionnaire data

Experiences of the Task. Separate repeated measures MANOVAs (Cohorts by Time) were carried out in turn for the two experience measures as dependent variables. Within subject multivariate test results revealed a significant interaction effect of Cohort by Time for Task Difficulty, Pillai’s Trace= .028, F(1,165)= 4.94, p<0.05 and no significant interaction effect of Cohort by Time for Interest in the Case. These findings reveal that while students’ perceptions of interest in the case were not affected by the intervention, perceptions of the task difficulty evolved in different directions for the two groups. Students’ ratings are presented in Table 1.

INSERT TABLE 1 ABOUT HERE

Evaluations of Sources of Learning. Independent samples t-tests were carried out to compare the ratings of the Intervention and Control cohorts. A significant difference between the two groups (t(171) = -3.90, p<.001) was found for the measure, “Discussions during face-to-face meetings with your group” (Intervention, M=3.26, SD=.73; Control, M=2.89, SD=.82). This finding provides strong support for the impact of the intervention, which was aimed at fostering productive collaborative learning processes during group discussions.
A trend in the expected direction, although not significant, was found for “Research done by other members of [their] group” (t(160) = -1.82, p=.07); Intervention, M=3.02, SD=.71; Control, M=2.86, SD=.74). Finally and as expected, there was no significant difference between the two cohorts for “Own research on aspects of the case”. The means and standard deviations for the three measures and the two cohorts are presented in Table 2.

INSERT TABLE 2 ABOUT HERE

_Distribution of Time._ In an independent samples t-test comparing the Intervention (N = 88, M = 26.19, SD = 29.07) and Control cohort (N = 83, M = -15.81, SD = 42.47) there was a significant difference between the two groups (t(169) = -7.583, p <.001). Intervention students reported a greater proportion of meeting time spent discussing the case relative to discussing group organizational matters, while the opposite was found for Control students. Figure 1 illustrates the distribution of time spent on organizational matters and understanding of the clinical case for the two cohorts.

INSERT FIGURE 1 ABOUT HERE

_Insight into Intervention and Control students’ experience based on interview data_  

Students’ accounts and reflections of learning in the group assignment were organised into four categories:

- Professional relevance of learning from a clinical case file
- Acknowledgment of task difficulty
- Group learning processes
- Conditions supporting effective group learning.
Professional relevance of learning from a clinical case file  A number of Intervention students explicitly acknowledged the relevance of learning from real life clinical case files for future clinical practice.

When we do become vets we are not going to have someone giving you all the information. We will get essentially what we got and you have to go through it yourself so you can pick things up and deduce from all that, it’s (a) good start of trying to learn to do that (I-1003).

When we get the case in practice it’s not going to be like find out the cause, find out this and that, like we are going to have to create this information kind of thing, it’s not like it’s given to us, well yeah like relating the clinical signs to the physiology and then the cause and then how to fix it, which is a good way to go about solving the problem (I-0504)

These statements highlight students’ appreciation that this case-based learning assignment was not just about understanding a complex clinical case file, but represented valuable preparation for their clinical years and beyond, a long-term benefit that had been stressed to them in the intervention.

Similarly, some Control cohort of students expressed an appreciation of the relevance of the clinical case based assignment to their future learning, but in this instance it was in relation to their subsequent years of study as undergraduate students.

There are so many levels of things, you have an understanding and consideration of when we are in fifth year, we will have a case and level of more to it than I initially thought (C-1003)
It’s also been interesting to actually have a case that’s actually come out of the hospital as well, to see what we might be doing when we are big fifth year (students) (C-0302)

Acknowledgement of task difficulty Given this was Intervention and Control students’ first exposure to a real life clinical case file, it was expected that they would find the task challenging. The Intervention and Control students’ accounts stress how difficult they found the task of having to go through complex, highly detailed case files.

Students from both cohorts highlighted the sheer size of the case file and the need to read it through several times to understand and extract relevant information.

We are given this folder of a gazillion pages for us to be able to analyse what is actually relevant, what is important and useful and what we can do with this case (I-0502),

Reading the file 200,000 times and not knowing what it meant the first 500, just reading it and going over it. Well the first 3 times I read this file I had absolutely no idea, everything was so confusing (I-0501).

Just how much actually goes into the case in the hospital, like how many pages, like 70 or something…but obviously it was a big case…reading the case and seeing how much detail they go into, and just then also by trying to understand it all, realize how much there is to it that you need to know (C-1002)

In addition, the Intervention students went further to describe how they made sense of the clinical jargon within the case files. They reported their efforts to decipher clinical
jargon and to distil and sort out information in order to understand the key aspects relevant to the case.

*Looking through like actual reports and diagnoses from the vets and all that, that is something new for us, and decoding hand writing as well. And some terms that they use which we are not that familiar with, so that was pretty interesting* (I-1002).

“*Eyeballing! Eyeballing, we didn’t know what that meant!*” (I-1003).

Whilst acknowledging that the task presented to them was complex, these students simultaneously expressed appreciation and voiced the benefits of having the opportunity to learn from a real life clinical case file.

*Group learning processes*  As reported above, Intervention students indicated spending a greater proportion of meeting time spent on discussing the case relative to organizational matters in contrast to Control students where a reverse pattern was found. In their accounts of group processes to learn from the clinical case files, a number of students emphasized that collating information as a group played an essential part in developing a collective understanding of the entire case, “*to bring the whole picture together, ya, because you only know a small part of it, then you discuss, you start to get the big picture of it*” (I-1403), “*it’s just a pooling of everybody’s research and thoughts on the issue*” (I-1402).

Another group learning process frequently mentioned by Intervention students was a form of reciprocal teaching.

*I think if we feel like we each teach each other stuff then we all have the grasp on it and will feel more confident when we are answering the questions* (I-0303).
We had kind of a basic understanding, so we had to have done some individual research, but then we all came together when we could all explain it to each other, um, that really, really helped out. If we had been doing it all by ourselves, I wouldn’t have any idea what was going on (I-1502).

I can read a text and it sounds complicated but then we will have a discussion, like with us three when we were doing our research and then you explain it, and oh yeah, it just makes things a bit clearer, you can talk it through with people (I-0301).

Similarly, some Control students made a reference to reciprocal teaching but only as a plan, “we’ve divided into 3 groups and our plan is to thoroughly teach each other in the group what we learned but that will depend on time, hopefully we will” (C-1401) and reflected on the anticipated benefits of this process, “you can remember it quite well when it is a story told by someone else” (C-1401)

In addition to reciprocal teaching, Intervention students also reported valuable learning from each other through the process of explaining their understanding to one another, “because different people understand different things, so when you discuss you share your ideas…things we are unsure of, then we voice our doubts, then like eventually one of us is able to answer” (I-1403). This displays awareness that grasping difficult concepts sometimes involved multiple inputs of understandings from different group members. In contrast, some Control students’ perceived the group approach to learning about the clinical case as potentially restricting individuals’ full understanding of the case, “I think there were some limitations in the group research part of it, we are definitely saving time but because you have different people researching different topics, I think they will with that topic get a greater understanding of that from their research and other people have different areas of research…so you would not have had the same learning experience as the people who have had that area to research, so I think if you are one individual researching the entire topic by yourself, then I think your
understanding would be much better at this point than mine currently is having done one part of it” (C-0203).

This comment highlights that students had not shared with each other what they had learnt from their own research. Other students’ accounts were quite explicit in that regard, “We haven’t actually sat down and exchanged things” (C-0205). Many Control students pointed to individual reading as the greatest source of learning in this group assignment.

**Conditions supporting effective learning as a group**  In addition to describing their group learning processes, Intervention students also pointed to what they saw as necessary conditions to learn effectively as a group. Some of these accounts simply reflected the strategies presented to them at the start of the group assignment, but others went further, showing evidence of students’ determination to work on the project as a group, where each member took responsibility for their own part but also others’ parts.

*Everyone was taking responsibility for their own section um, and knuckled down and at least did some preliminary research if not more, um, so that was really good* (I-1001).

*Doing our own research and not just reading in general, we were looking up specifics, finding answers to our questions* (I-0502).

For some Intervention students, independent research carried with it a sense of responsibility that each individual was taking for the group’s research as a whole, “yeah even when we were researching (on our own) we were kinda researching as a group anyway” (I-1501).
Another form of responsibility to the group was through feeding useful information to other group members. A number of Intervention students mentioned that if they found information relevant to their peers’ section while researching their own, they would bring it to their attention.

*Even though we researched on our own, we kept our eye out if something came up from someone else’s section, we would say read this paper, here’s this book, because we see each other everyday anyway* (I-1505).

*We kind of were able to talk about what we found and also cross over some information that we found from other topics, like oh, when I was researching this, I found out about yours, this, you know, it was just helpful* (I-1004).

The above comments conveyed students’ sense of responsibility and commitment to learning as a group that was over and above the expectation that they should take full responsibility for their own background research.

Some Intervention students also recognized they did not have enough expertise to fully understand their clinical case. This recognition reinforced their view that everyone in the group should be entitled to have some input into the case discussion.

*None of us are experts in the field therefore no one has the right to say that they are right, so I suppose maybe if vets were to dissect the case, each one will think their expertise grants them the right to make conclusions, draw conclusions for the case, and they will conflict because they think, each one thinks that they are experts in their own field, so they will try to force each other down their own track. But at least for us no one knows that much about the case, we are not experts in the field, so everybody’s input counts, because everyone could be right* (I-1402).
Finally, some Intervention students volunteered that when they were amongst themselves – no teacher present - they felt more comfortable to tentatively explain complex concepts in their own words to each other, a strategy that they argued, benefited everyone’s learning, “cos I guess it’s in our own language, not some textbook professor language, yeah” (I-0303).

Control students’ accounts showed no evidence of reflection on the conditions supporting effective learning as a group.

DISCUSSION

This study aimed to promote effective collaborative learning in a clinical case-based group assignment. The effect of the instructional strategy was evident in the intervention students’ self-reports of the proportion of meeting time spent understanding the case relative to dealing with organizational matters in comparison to the control group. In addition, the intervention students evaluated face-to-face discussions as being more useful in achieving the learning outcomes when compared to the control cohort of students.

The interviews with intervention students confirmed that the clinical case-based group assignment was perceived as highly relevant to their study but also challenging given their current limited clinical knowledge. Most importantly, students’ accounts displayed how they interacted with each other while engaging in content discussion during their meetings, and the perceived outcome from their engagement. Consistent with the main message of the instructional intervention, most students had realized that all members had to take the responsibility of researching their own part prior to the meetings, and that everyone should engage as a group in deep level discussions and reciprocal teaching during the meetings. The students themselves highlighted that it was most desirable that all members of the group understood the clinical case. This would have been facilitated through their spending more time discussing and understanding the case and less time sorting out the practical aspects of the presentation.
Veterinary students are widely described in the literature and by their teachers as highly capable, achievement motivated individual learners. We believe that these qualities would have contributed to the success of the intervention. Previous research had shown that veterinary students working as a group do not spontaneously engage in productive forms of collaborative learning such as reciprocal teaching, questioning and elaboration on a sustained basis. Since these students are not only committed to high academic achievement but also dedicated to professional learning, introducing them to a set of strategies for effective collaborative learning and convincing them of the learning benefits, is likely to have been sufficient to increase the amount of time that students would have normally spent discussing and understanding the case. The educational value of group learning practices in the veterinary context is widely documented and this study contributes to this growing body of literature. Encouraging greater group meeting time to be spent on discussing and understanding the case additionally has the potential of fostering deep learning practices in veterinary students. describe discussion and reflection of clinical case material as two important criteria for achieving deep learning.

The empirical evidence emerging from this study presents a very encouraging picture of effective, motivated, individual learners, who further develop themselves by learning how to learn effectively from and with their peers for the group’s benefit. This was evidenced in students not only acknowledging the importance of taking full responsibility for their own research, but also taking on the responsibility of finding research resources for other members in the group. A productive learning outcome for the whole group was the overall goal for the students. Engagement in effective collaborative learning may form a solid basis for fostering continuing professional education for themselves and their peers. A professional collaborative approach has the potential to be an essential component of clinical practice and should be investigated further in veterinary education research.

Students’ frequent reference to the clinical relevance of the case-based group learning assignment was another positive finding of this study. There was evidence that despite its challenging nature, students viewed the assignment as valuable preparation for
clinical practice. From an educational perspective, collaborative learning activities enhance content understanding and promote application of knowledge. Previous research has found that group discussion encourages activation of prior knowledge and facilitates recall of information. Fostering activation of prior knowledge is particularly useful in the pre-clinical years when students have to acquire and consolidate a large body of content knowledge. In turn, knowledge recall is essential in the clinical years when knowledge has to be applied appropriately in the clinical setting. Early introduction of clinically relevant group-based assignments has the potential to promote a collaborative style of clinical inquiry in the workplace.

One limitation of this study was the reliance on self-reports as evidence of the impact of the intervention. Observational data would be useful to corroborate students’ accounts of their collaborative learning processes during meetings. Nevertheless, the evidence based on students’ accounts is promising. It demonstrates that veterinary undergraduate students can be persuaded of the benefits of collaborative learning, reciprocal teaching and questioning for achieving a deeper understanding of clinical cases.

ACKNOWLEDGMENTS

This research was supported under Australian Research Council’s Discovery Projects funding scheme (project number DP0986867).

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Table 1: Intervention and Control cohorts’ ratings of their perceptions of Task Difficulty and Interest in the Case at the beginning and end of the group assignment

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Beginning Mean (SD)</td>
<td>End Mean (SD)</td>
</tr>
<tr>
<td>Task difficulty</td>
<td>2.65 (.59)</td>
<td>2.74 (.66)</td>
</tr>
<tr>
<td>Interest in case</td>
<td>3.33 (.61)</td>
<td>3.23 (.67)</td>
</tr>
</tbody>
</table>
Table 2: Intervention and Control cohorts’ evaluation of three activities as sources of learning to help them achieve the stated learning outcomes of the group assignment.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N= 240</td>
<td>N=88</td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own Research</td>
<td>3.21 (.67)</td>
<td>3.19 (.54)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Research by others</td>
<td>2.86 (.74)</td>
<td>3.02 (.71)</td>
<td>p=.07</td>
</tr>
<tr>
<td>Discussions</td>
<td>2.89 (.82)</td>
<td>3.26 (.73)</td>
<td>p&lt;.001</td>
</tr>
</tbody>
</table>
Figure 1: Intervention and Control cohorts’ self-report of the distribution of time spent on various activities during their group meetings.
APPENDIX B

Promoting effective collaborative case-based learning at university: A metacognitive intervention

PAPER 2


To comply with copyright laws, the following version of the above paper is the accepted version and not the published version.
Promoting effective collaborative case-based learning at university: A metacognitive intervention

Deep K. Khosa and Simone E. Volet

Abstract
The use of student-led collaborative learning activities at university level has increased dramatically in recent decades. However, whether such activities foster engagement in self-regulated, deep-learning practices remains contentious, with evidence that desirable learning outcomes are often not achieved. A metacognitive intervention was designed to induce groups of students to engage in productive learning from each other, while working on a clinical case-based group assignment. The intervention introduced students to a two-fold metacognitive strategy aimed at enhancing learning through meaning making in group interactions and high-level questioning. The research involved a semi-experimental design with a previous student cohort providing control data. Observation and self-report data converged to show that the intervention led to increased time spent on case content-discussion, but not at the desired deep level. The intervention’s positive impact was also evident in self-reports of personal goals, perceived difficulty of the assignment, group and task challenges, and evaluations of learning.

Introduction
Increasingly universities are under greater pressure to ensure that students develop skills for independent problem solving, critical thinking, teamwork, and lifelong learning as part of their undergraduate study (Biggs and Tang 2007). However, recent research indicates that these desirable outcomes are not always achieved (Barrie 2007; Cranmer 2006), and particularly so in science education where inquiry based learning, collaborative support, problem solving and critical thinking are imperative for effective instruction (Schraw, Crippen and Hartley 2006). Schraw et al. argued that promoting students’ use of self-regulated learning would not only improve their content learning
and achievement, but also provide valuable preparation for lifelong professional learning. Preparing students for future learning should include effective learning with and from peers, since workplace learning opportunities are predominately social in nature (Eraut 2007).

Implementing group learning activities at university is challenging (Blumenfeld, Marx, Soloway et al. 1996), and evidence of their effectiveness in enhancing content understanding remains contentious (Hmelo-Silver, Duncan and Chinn 2007; Kirschner, Sweller and Clark 2006). In the field of health sciences, research has shown that students overwhelmingly prefer teacher regulated and solo forms of learning to collaborative learning settings and only a minority consider collaborative learning as effective in undergraduate study (Raidal and Volet 2009; Ryan, Irwin, Bannon et al. 2004; Thurman, Volet and Bolton 2009). Furthermore, there is evidence that in student-led group learning activities a minimal amount of time is spent on high-level meaning making (Summers and Volet 2010). In other words, while the cognitive benefits of effective collaborative learning are well articulated in the literature (Ramsden 2003; Visschers-Pleijers, Dolmans, de Leng et al. 2006) students may need instruction in the use of learning-enhancing strategies to optimise deep learning in collaborative activities. This article reports the findings of a metacognitive intervention aimed at promoting effective collaborative case-based learning at university.

The usefulness and benefits of collaborative learning among peers of the same level of understanding have attracted much research attention (Blumenfeld, Marx, Soloway et al. 1996; Dillenbourg 1999; Hogan 1999; Terenzini, Cabrera, Colbeck et al. 2001; van Boxtel, van der Linden and Kanselaar 2000). Putting groups of students together and giving them group tasks does not, however, necessarily lead to collaborative learning (Summers and Volet 2010). Students who work on a group assignment individually and then come together in a perfunctory fashion to collate individual research findings cannot be said to have learned collaboratively but rather to have cooperated to complete the task (Dillenbourg, Baker, Blaye et al. 1996). The considerable learning benefits of discussing, explaining, elaborating, and co-constructing conceptual knowledge at a deep level with peers are foregone, since genuine collaborative learning is achieved through interpretive, elaborative talk rather than through collaboration itself (Teasley 1995).

The potential of collaborative learning to promote deep learning (Visschers-Pleijers, Dolmans, de Leng et al. 2006) and knowledge retention (Ramsden 2003) is
highlighted in the literature. In clinically orientated courses (e.g., medicine, veterinary medicine) a deep approach is essential to understanding the complex chain of concepts that link symptoms to theoretical knowledge, and as a basis for future professional learning (Newble and Entwistle 1986). It involves a search for understanding, relating ideas to previous knowledge and experience, looking for patterns and underlying principles, checking evidence and relating it to conclusions. These features are clearly aligned to meet the requirements of clinical undergraduate courses, where learning requires in-depth understanding of basic biological concepts that can be built upon as the content becomes more complex.

The stringent requirements and assessment procedures of most medicine and veterinary medicine courses often do not allow sufficient time for consistent engagement in deep learning (Blumberg 2005; May 2008; Newble and Entwistle 1986). As a result, students adopt a strategic approach, where effective management of time and effort becomes their main study tool. According to Entwistle and Peterson (2004) effective strategic learning is based on an acute awareness of learning in context and alertness to assessment requirements, leading to monitoring efficiency of study methods but also responsibility to oneself and others for consistently achieving. While a strategic approach may be sufficient for passing tests successfully, it is not sufficient for achieving the depth of understanding required for clinical application. This implies that undergraduates need instruction and guidance in strategic learning.

The value of a hybrid deep-strategic approach to university study was posited years ago by Biggs (1987). More recently, Lonka, Olkinuora and Mäkinen (2004) argued that a deep approach is a necessary but not sufficient condition for productive study. They claimed that a strategic approach is also necessary on the ground that persistence is what sustains deep orientated students towards graduation. There is empirical evidence suggesting that neither the deep nor the strategic, self-regulated approaches of learning are ideal on their own to achieve the desirable learning outcomes expected in higher education. Beishuizen, Stoutjesdijk & Van Putten (1994) and Lindblom-Ylänne and Lonka’s (1999) research with psychology and medical students respectively, revealed that the most successful students indeed used a deep-strategic, self-regulated approach to learning. In the context of veterinary medicine, Ryan et al. (2004) found that deep learners displayed “an awareness of the course objectives and a consciousness of their own ability to achieve them” (p. 248), making the strategic, self-regulated approach a crucial part of effective deep learning. All these studies point to
the potential benefits of promoting strategies to monitor the process of deep learning, instigating the idea that a metacognitive strategy may help in this process.

Several intervention studies have attempted to induce students’ use of metacognitive strategies to enhance deep learning but few are found outside the disciplines of education or psychology. Volet and colleagues (Volet 1991; Volet and Lund 1994) were successful in inducing undergraduate computer science students to use contextually metacognitive strategies, but a follow-up study with minimally trained tutors did not replicate the findings (Volet, McGill and Pears 1995). Other attempts at inducing students’ use of metacognitive strategies were reported by Vermetten, Vermunt & Lodewijks (2002) with undergraduate law students; by Papinczak, Young, Groves & Haynes (2008) with medical students; and by August-Brady (2005) with nursing students. All these studies, however, were concerned with inducing deep, self-regulated learning in individual students. None investigated the potential of metacognitive strategies to enhance deep-strategic collaborative learning. One recent study by Molenaar, van Boxtel and Sleegers (2010) examined the benefits of metacognitive scaffolds on learning outcomes in a collaborative environment, but the study was conducted with elementary school children. Overall, the higher education literature displays a paucity of intervention studies aimed at fostering deep-strategic, self-regulated learning in real-life, collaborative learning settings and moreover acknowledges the challenges faced in using educational interventions to effect change in real-life learning settings (De Corte, Verschaffel and Masui 2004).

The metacognitive intervention presented in this article addresses this gap. It was designed to investigate the effectiveness of a two-fold metacognitive strategy aimed at inducing groups of university students to engage in productive learning from each other while working on a clinical case. Based on the nature of the intervention, the following outcomes were expected:

1. **Personal goals** - it was expected that intervention students would consider learning from each other as more important than their control counterparts. No difference was expected in regard to getting high marks since most veterinary students (the specific student population in this study) are high achievers.

2. **Experience of the group assignment** - it was expected that intervention students would find their group dynamics and the task less challenging to manage than their control counterparts. Additionally, it was expected intervention students would perceive the clinical case study as less difficult than control students. No
difference was expected in regard to interest in the clinical case since all preclinical students are interested in early exposure to authentic clinical materials.

(3) *Distribution of time* spent within student-led informal group meetings - it was expected that intervention students would spend a greater proportion of their meeting time (observation data), and also report spending a greater proportion of their meeting time (self-report data) discussing the case rather than dealing with organisational and other matters. Since control students had reported a greater proportion of meeting time spent sorting out organisational matters compared to discussing and sharing understandings of the case two years earlier, it was of specific interest to this study was to establish whether this proportion would be reversed for intervention students, following the metacognitive intervention. It was also expected that intervention students would spend a greater proportion of meeting time engaged in high-level content processing of their clinical case, in comparison to their control counterparts (observation data).

(4) *Evaluation of sources of learning* to achieve the stated learning outcomes of the case-based assignment - it was expected that intervention students would not rate their individual research differently but that their ratings of learning from others’ research, and learning from group discussions would be more positive than their control counterparts.

**Methodology**

**Participants**

This semi-experimental study involved two cohorts of Veterinary Science students enrolled two years apart in the same second physiology unit taught in the same way by the same teacher who was not a part of the research team. The earlier cohort \( n = 81 \) formed the control cohort (2006) and the most recent cohort \( n = 88 \) formed the intervention cohort (2009). The two groups were not enrolled simultaneously so the intervention did not pose an ethical dilemma.

As an integral part of this physiology unit, students are required to form self-selected groups of five or six members to complete a case-based group assignment. On both occasions, participants for the research project were recruited in class, when the teacher presented the case-based group assignment. Students were informed that the aim
of the research project was to develop a better understanding of students’ experience of clinical case-based group assignments. Ten of the 14 groups ($n=59$) from the control cohort volunteered to participate in the research, and 11 of the 16 groups ($n=63$) from the intervention cohort. However, due to the poor quality of the video recording, data from one control group could not be used, thereby reducing the control cohort to nine groups ($n=53$). All intervention and control groups were intact groups, with all members participating in all aspects of the research. Ethics approval from the university and consent from both student cohorts were obtained prior to the start of the study.

**Procedure**

*The case-based group assignment*

The clinical case-based group assignment is a regular feature of the curriculum in the second physiology unit of the Veterinary Science degree program. This assignment has the specific learning objective of providing students with an opportunity to apply primary preclinical knowledge learnt to date to a real-life clinical case. This first exposure to a real-life clinical case also has the objective of encouraging students to extract relevant physiology based clinical concepts and explore the underlying principles that make up treatment and management of the disease processes presented in the cases. A variety of complete real-life clinical cases are used to ensure that material for each group does not overlap.

Each group works on a different clinical case in their own time over a six to seven week period. Groups are required to set their own learning objectives based on their specific case, undertake research to learn about selected aspects of that case, and present their findings at the end of the semester. The teacher provides guidance through two mandatory meetings three to four weeks apart. The teacher’s role is to guide students into formulating concise, case relevant learning objectives and to ensure the groups are progressing in a satisfactory manner. Students are given a group mark based on their class presentation and a follow-up question and answer session led by the teacher. The assessment is based on the groups’ demonstration of having fulfilled their self-generated learning objectives. The group mark for this assignment constitutes 10% of the overall mark for the physiology unit.

*Conceptual grounding of the metacognitive intervention*
Conceptually, the metacognitive intervention was inspired by the collective works of Barron (2003), Greeno (2006), King (1992; 1998), Kollar, Fischer & Slotta (2007), and Volet et al (2009). The specific metacognitive strategy developed for the intervention was two-fold in that it aimed to foster students’ meaning making in group interactions and high-level questioning.

The focus on meaning making in group interactions was inspired by Greeno’s (2006) emphasis on interactional processes in “learning in activity” and Volet and colleague’s (2009) elaboration on social regulation processes in co-construction of knowledge. Regulation of meaning making in group interactions is metacognitive in nature since it refers to the strategic monitoring of learning taking place in a joint activity (Paris and Winograd 1990). In the present study, meaning making in group interactions was conceptualised as group monitoring of the collective understanding of the clinical case. Promoting meaning making in group interactions was important since prior research with the same student population had revealed that group work does not necessarily equal effective collaborative learning (Summers and Volet 2010). However, these students were able to describe instances of effective learning from each other in naturalistic settings (Thurman, Volet and Bolton 2009). In combination, these bodies of research provided useful contextual insight into how veterinary students typically engage in collaborative learning, generating the idea that a metacognitive intervention embedded within regular instruction should have the potential to foster deep-strategic learning in a group setting.

King (1992; 1998) provided the inspiration for the additional focus on high-level questioning. It is in the use of question asking and answering that King describes the association with metacognition (King 2002). According to King, high-level questioning in small cooperative groups provides students with opportunities to reciprocally monitor their understanding of the content material, and to integrate prior knowledge with current knowledge thereby extending their learning. King argues that generic question stems, such as why, how, what if, elicit high-level explanations and elaborations, thus providing the impetus and opportunity for students to monitor and most importantly question their understanding of the content material.

To maximise students’ adoption of the two-fold metacognitive strategy, the instructional message needed to be convincing, expeditious and contextualised to the veterinary context. Moreover, it needed to be presented in everyday understandable terms in order to be readily accepted and utilised. Accordingly, the strategy was
presented to students as “a set of tips” for effective learning from each other. The contextualised nature of this intervention affiliates itself well with the work of De Corte, Verschaffel & Masui (2004), who outlined major design principles for effective learning environments. The authors argue that an effective learning setting should “embed students constructive acquisition activities preferably in real-life situations that have personal meaning for the learners, offer ample opportunities for distributed learning through social interaction, and are representative of the tasks and problems to which students will have to apply their knowledge and skills in the future” (p. 370).

The phenomenon of “over scripting”, described by Kollar et al. (2007), where external scripts or strategies override acceptable, sufficient internal scripts displayed by good students was considered when developing the metacognitive strategy in the present setting. To avoid this phenomenon, the strategy was designed to be sufficiently generic, to allow students to customise them to their own needs and requirements. In other words, scaffolding was provided but without overriding any internal learning strategies students may naturally possess.

**Content of the metacognitive intervention**
The metacognitive intervention was presented to students as guidance for effective collaborative learning in their case-based assignment. To set the scene and capture students’ interest, they were told that effective collaborative group work was not just about gathering information as individuals and putting a set of slides together, nor was it just about being good citizens who divide the workload fairly and ensure that everyone does their own part. It was stressed that groups might show evidence of good research and efficient group management, but nevertheless learn nothing from each other. With the scene set, the intervention was presented in terms of a set of conditions that provided a social basis for effective collaborative learning, a two-fold metacognitive strategy (presented to the students as a set of tips) for effective collaborative learning, and the benefits of effective collaborative learning from a case-based group assignment.

The set of social conditions for achieving effective collaborative learning was presented first: All members to undertake adequate research preparation prior to the group meetings; full commitment from all group members to learn and help each other learn; respectful group learning atmosphere so that all members feel comfortable to admit lack of understanding without embarrassment; and all members to present their
research in turn, actively listen to the contribution of others, and engage in overall discussions of the case. It was stressed that these conditions formed the required social basis for initiating and maintaining productive group learning activities, for providing opportunities for all members to participate, and for developing a better understanding of the case as a whole.

The two-fold Metacognitive strategy formed the main part of the intervention. Firstly, students were provided with a range of examples of meaning making interactions, “Exchange definitions, share understandings”, “Other ways to explain the same concept”, “Teach others in your own words”. It was emphasised that such interactions would facilitate further inquiry and provide the potential to achieve a deeper understanding of the clinical case. Then, to introduce students to the nature of high-level questioning, as conceptualised by King (1992), they were presented with a range of sample questions, all aimed at meaning making and all contextualised to a veterinary context, for example, “What does [gluconeogenesis] mean? What would happen to gluconeogenesis if the animal were diabetic? Why does it occur?”. The meaning making question stems (e.g. What does … mean? What … if …? Why …?) were highlighted and discussed. Students were told that asking “what if”, “why” or “how” types of questions within their group would aid in the deeper exploration and understanding of the clinical case, allowing all members to question their knowledge and develop a better understanding of the case as a whole.

It was recommended that groups spent the majority (50-70%) of their meeting time using meaning making interactions and high-level questioning, in order to maximise their learning. This percentage time was suggested as a reasonable research expectation to achieve a deep level understanding of the case.

The Benefits of effective collaborative learning from a clinical case-based assignment were presented as the final part of the metacognitive intervention. Students were told that a short-term benefit would be everyone’s overall better understanding of the case, allowing any member of the group to answer any question about the case at the class presentation, and in turn enhancing the chance of the group getting a higher mark. The long-term benefit of developing effective collaborative learning strategies was promoted as excellent preparation for the type of learning required in the clinical years of a Veterinary Science degree.

*Presentation of the metacognitive intervention*
The intervention was presented in the form of a PowerPoint presentation to the whole class, after the teacher had introduced the case-based group assignment and before the case files were distributed to groups. An experienced veterinary clinical teacher (one of the authors) presented the intervention thereby reinforcing the credibility of the message. A handout summarising the content of the intervention was distributed after the presentation. When introducing the case-based group assignment to the class, the physiology teacher also stressed the value of peer learning to enhance understanding of the clinical case.

**Instructional approach used with the control cohort**

Students in the control cohort completed exactly the same assignment as the intervention students two years earlier, the only exception being that they were not presented with the metacognitive intervention.

**Data collection and instruments**

Two matched sources of data from intervention and control students were used to evaluate the effectiveness of the metacognitive intervention: questionnaires completed at the beginning and end of the group assignment, and video recordings of two of each group’s informal meetings (student-led, no teacher). The intervention students completed their beginning questionnaire prior to the metacognitive intervention delivery in order to provide comparable baseline data.

**Questionnaires**

The beginning and end questionnaires completed by intervention and control students included measures of Personal Goals and Experiences of the Task. The end questionnaire also included measures of Distribution of Time spent on specific activities during group meetings, and Evaluation of Sources of Learning to achieve the desired learning outcome of the clinical case study group project.

**Personal Goals** - Two statements relevant to establishing students’ motivation to engage in the group assignment were presented to students. They were asked to rate the extent to which these were important goals for them in the group project: “That we all learn from each other” and “To get the highest mark possible”. The rating scale ranged from \(1 = \text{not a priority for me}\) to \(4 = \text{a top priority for me}\).
Experiences of the group assignment - Students’ perceptions of Group challenges and Task challenges related to the assignment (anticipated at the beginning and retrospective in the end) were investigated, using an instrument developed by Järvenoja et al. (under review). Five Group Challenges and five Task Challenges are presented for rating using a scale of 1 = a small challenge to 4 = a big challenge, with the option of selecting 0 = no challenge at all. Examples of Group Challenges include, “Some group members having different work standards” and “Some group members’ goals/ priorities being different”, and examples of Task Challenges include “Case material too difficult to understand, some parts can’t be explained” and “Too much information and difficult to decide what to include and what to omit”. Järvenoja, et al. state that although each item represents a unique type of Group or Task challenge, the two sets of five items represent two coherent underlying constructs and thus form reliable scales, allowing comparison of the extent to which students are experiencing group or task related challenges overall. In the present study, Cronbach alpha coefficients were very high for both scales and on both occasions. Group Challenges was .77 at the beginning and .85 at the end, and Task Challenges was .80 at the beginning and .75 at the end. Difficulty of the clinical case study and Interest in the clinical case study (anticipated at the beginning and retrospective in the end) were also elicited. The rating scale ranged from 1 = not at all to 4 = very.

Self-report of Distribution of Time spent on different types of interactions during group meetings involved students’ providing individual estimates of the percentage of time their group spent on the following four broad types of interactions: Sorting out organisational matters; Discussing and sharing understandings of the case; Listening to the group interactions in frustration; and Engaging in other discussion.

Evaluation of Sources of learning to achieve the desired learning outcomes of the group project involved students rating how much each of the following three activities related to the group assignment helped: “Your own research on aspects of the case”, “Research done by other members of your group” and “Discussions during face-to-face meetings with your group”. All items were rated on a scale of 1 = a little amount to 4 = a huge amount.

It is important to note that this measure was introduced to the research program one year after the control cohort completed their case-based group assignment. Data from the two intermediate cohorts (the years between the control and intervention cohorts, 2007 and 2008) were used as control for this measure. Using data from these
intermediate cohorts \((n = 240)\) was acceptable since these students had completed the same assignment under the same conditions as the earlier control cohort, the only difference being that the intermediate cohorts only completed the beginning and end questionnaires, with no video recordings of their informal sessions. The intermediate cohorts (2007 and 2008) had not been presented with the metacognitive intervention.

*Video-recordings of informal group meetings*

The first round of video recording took place early in the first or second week of the seven-week long assignment, when students met to discuss their clinical case and start generating their learning objectives. The second round took place around the fifth week after the groups had the opportunity to research selected aspects of their case. All video recordings of intervention and control student meetings were scheduled at times convenient to students and made under naturalistic conditions (no instructions from teachers or researchers, only filming students’ informal meetings, and the length of meetings were determined by students). The mean duration of the student-led meetings for the control cohort’s first round of meetings was 44min, 40secs \((SD = 10min 53secs)\), and for the second round of meetings was 25mins 4secs \((SD = 12mins 50secs)\). The intervention cohort’s first round meeting mean duration was 46mins 59secs \((SD = 11min 14secs)\), and the second round mean duration was 43mins 48secs \((SD = 12min 46secs)\).

*Data analysis*

*Questionnaires (self-report data)*

Comparison of the intervention and control students’ questionnaire data was undertaken by carrying out repeated measures multivariate analysis of variance for the data involving beginning and end measures and T-tests for the end measures only.

In regard to the Distribution of Time measure, an index of the relative proportion of time spent on organisational matters versus discussing and understanding the case was created. This was done by subtracting students’ estimated percentage of total meeting time spent on organisational matters from their estimated percentage of meeting time spent on content-related discussion. Positive scores indicate a greater emphasis on content-related discussion during group meetings, and negative scores a greater emphasis on organisational matters.
Video recordings (observation data)

The analysis of the video footage of 40 meetings (9 x 2 from the control cohort and 11 x 2 from the intervention cohort) was based on the theoretical framework and corresponding coding system developed by Volet, Summers & Thurman (2009). Volet et al. distinguish between talk dealing directly with processing the learning content, in this case processing the content of the clinical case, and talk related to other matters, such as task, organisation or off-task.

The theoretical framework proposed by Volet et al. (2009) combines the constructs of social regulation and content-processing for the identification of productive interactions in collaborative learning. Each construct is conceptualised as a continuous dimension. In the present study, the focus is exclusively on the content-processing dimension of the framework. Volet et al. conceptualise content processing of the learning content (clinical case) along a continuum from low-level to high-level, but treat low-level and high-level as broad categories in their coding system, as it is difficult to capture intermediate points along the high-level, low-level continuum. Low-level content processing refers to verbal interactions pertaining to clarification of basic facts, providing definitions, or relaying information verbatim from an information source. High-level content processing refers to engagement in elaborating, reasoning, interpreting or linking ideas, and explaining concepts in one’s own words. Since it is difficult to capture intermediate points along the low to high level continuum, the analysis involved the judges deciding on the best fit of the two categories, depending on the dominant level of content-processing being observed.

Talk related to task and organisational matters refers to discussions related to the completion of the assigned task (e.g. selecting learning objectives, deciding on the scope of the assignment, what to include in the final presentation) to discussions of organisational matters (e.g. scheduling future group meetings, exchanging contact details, delegating sub-tasks within the group). Talk related to matters that are unrelated to the assignment is categorised as off-task. All verbal interactions that did not refer to content processing are reported as other.

For the purpose of this experimental field study aimed at comparing intervention and control students’ extent of engagement with the content of the clinical case during their informal meetings, the following coded data are reported: Time spent processing the content of the clinical case as a percentage of the entire group meeting time overall;
and Time involved in high-level content-processing of the content material as a percentage of the entire group meeting time overall.

**Inter-judge reliability for observation (video) data coding**

Data from the intervention cohort (6/22 or 27%) and the control cohort (7/18 or 38%) student meetings was used to establish the reliability of the coding system for this study. Two judges were used, both blinded to the individual and group performance of the students. One judge, who is one of the authors, coded all the video data. The second judge, a social psychologist, who was not involved in the development of the research project but had extensive experience in discourse analysis and video coding analysis took on the role of independent judge. A third independent person randomly selected the sample of observation data chosen to be double-coded and establish inter-judge reliability. Equal proportions of first and second student group meetings were chosen. The teacher was not involved in any aspects of the research process. Inter-judge reliability was determined by calculating the percentage of time the two judges were in agreement of the total length of the meeting (in seconds). A satisfactory level of agreement in coding was achieved for all groups, with judges being in agreement for 82.7% and 77.3% of the total length of time across all meetings respectively for the intervention and control cohorts.

**Results**

The impact of this intervention was examined by comparing control and intervention students’: Personal goals and experiences of the group assignment (self-report data); distribution of time during group meetings (observation and self-report data); and evaluations of sources of learning to achieve the stated learning outcomes of the group assignment (self-report data).

**Personal Goals and experiences of the group assignment**

Table 1 shows the two cohorts’ mean ratings of personal goals and experiences at the beginning and end of the assignment. The results of the statistical tests comparing the two groups (multivariate analysis of variance with repeated measures) are reported at the bottom of this table.
**Personal goals**

Contrary to expectations and given the nature of the intervention, intervention students did not rate “That we all learn from each other” as a more important goal than their control counterparts by the end of the group assignment. This may indicate that this goal statement was perhaps too general to differentiate between the two cohorts, since a deep level meaning making discussion as well as a simple exchange of information could equally be interpreted as learning from each other. In regard to the second goal “To get the highest mark possible for the group assignment”, while control students had lowered their achievement expectations by the end of the assignment, this was not the case for intervention students. Figure 1 illustrates the different evolution of the two cohorts’ performance goals over the duration of the group assignment.

**Experiences**

The impact of the intervention had a significant impact on students’ accounts of their experiences of the group assignment. The findings are reported in turn for students’ experiences of: Group challenges, Task challenges, Difficulty, and Interest in the clinical case study.

**Group challenges**

As shown in Table 1, the expectation that the intervention students would perceive their group social dynamics as less challenging overall than the control students was supported. The two cohorts’ experiences of two specific group challenges, “Some group members having different work standards” (item C in Table 1) and “Some group members not connecting well” (Item D) evolved differently over the duration of the group assignment. Figure 2 illustrates how handling different work standards within the group became less of a challenge for the intervention students compared to the control students. In regard to group members’ interpersonal connectedness, no change over time was experienced for the control cohorts. In contrast, intervention students
initially expected this aspect to present a moderate challenge but ended up reporting it as being less of a concern at the end of the assignment (See Figure 3).

**INSERT FIGURES 2 AND 3 ABOUT HERE**

*Task challenges*

The expectation that the intervention students would experience the task as less challenging overall than the control cohort two years earlier was also supported (see Table 1). In particular, the two cohorts’ ratings of the specific task challenge “the project required too much time/effort” (Item F in Table 1) evolved in opposite directions from beginning to end of the assignment (See Figure 4). Intervention students reported that time and effort at the end of assignment was less of a concern, in contrast to the control students who reported that this was actually more of a concern. This finding supports the research expectation that intervention students would consider investment of time and effort less of a challenge. Noteworthy is the finding that both cohorts were satisfied with the amount of direction provided by their teachers about how to complete this project (Item I). This highlights the perceived value of the formal structured support that had been provided to both cohorts by their teacher.

**INSERT FIGURE 4 ABOUT HERE**

*Difficulty of and Interest in the clinical case study*

As shown in Table 1, the intervention also had an impact on students’ experience of the difficulty of the clinical case study, with intervention students’ ratings being lower at the end than at the beginning and the opposite for the control students. This finding is consistent with the two cohorts’ experiences of group and task challenges. In contrast, the evolution of the two cohorts’ ratings of their interest in the clinical case study did not differ, supporting the research expectation that all students would value this initial exposure to authentic clinical case files, regardless of the difficulty of the task.

*Distribution of Time during group meetings*

*Observation (video data)*
The video data of control and intervention groups’ actual engagement in the activity was critical to compare with students’ self-reported experiences. Table 2 displays the percentage of overall meeting time spent discussing the clinical case by Cohort and intervention groups in two recorded sessions. For both cohorts, the groups are organised in ascending order of percentage time spent on content related discussion in the second meeting. For clarity, shading was added to highlight any session where the group spent above 30% of their meeting time discussing the content of their clinical case.

INSERT TABLE 2 ABOUT HERE

Comparing the shading across cohorts reveals that in their first meeting, which took place just after students received their clinical case file, six of the nine control (66%) and six of the eleven intervention (54%) groups spent more than 30% of their time discussing the content of their clinical case. In contrast, in the second recorded meeting, which took place after students had completed background research on their case, only three of the nine control (33%) but eight of the eleven intervention (72%) groups spent more than 30% of their meeting time discussing the content. This finding is consistent with the intervention message, which stressed the importance of spending more time during group meetings discussing the clinical case rather than organisational matters.

The opposite trend in the number of groups who spent more than 30% of their meeting time discussing their clinical case from the first to the second session was also reflected in the two cohorts’ mean percentage of meeting time spent discussing the clinical case over the two sessions. The bottom row of the table displays the mean percentages for each session and each cohort. It shows that over the two sessions, the mean percentage of meeting time spent discussing the clinical case decreased from 36.8% to 26.3% for control groups and increased from 39.6% to 44.5% for intervention groups.

The extent to which intervention students spent a greater proportion of their meeting time engaged in high-level content discussion of their clinical case in comparison to their control counterparts two years earlier was also examined. No significant differences were found between cohorts in either session. This indicates that although intervention groups tended to increase the amount of time spent discussing
their clinical case once they had completed background research (Session 2), there was no difference across cohorts in terms of depth of content-processing of the clinical cases overall.

Self-report (questionnaire) data

The two cohorts’ self-reports of the proportion of time spent on organisational matters versus discussing and understanding the case (index analyses) were consistent with the observation data. As expected based on the intervention, the intervention groups reported a greater emphasis on content-related discussion relative to organisational matters during their informal meetings, while the control students had reported the opposite two years earlier. An independent-groups t-test comparing intervention \((N = 88, M = 26.19, SD = 29.07)\) and control \((N = 83, M = -15.81, SD = 42.47)\) cohorts revealed that their reports were significantly different, \(t (169) = -7.583, p < .001\).

Evaluations of Sources of Learning

The research expectation that intervention students would find the group discussions during face-to-face meetings as more useful to achieve the learning outcomes of the clinical case study assignment in comparison to the large control cohort (2007-2008 data) was supported. This provides support for the impact of the intervention. No differences were found for the other two possible sources of learning created by this assignment, namely, learning from the research done by other members of the group, and learning from one’s own research on aspects of the case. Table 3 displays students’ ratings for the three sources of learning and the results of the three separate independent-groups t-tests.

Insert Table 3 about here

Discussion

This semi-experimental study examined the potential of a metacognitive intervention to induce groups of university students to engage in productive learning while working together on a clinical case assignment. Reports of observations of student-led group interactions in natural settings are very scarce in the higher education literature, most studies relying on self-report data. The use of a semi-experimental research design,
combined self-report and observational data, and rigorous methods of analysis, including theory-based coding and inter-judge agreement, were critical to gauge the effectiveness of this intervention.

As expected, differences in content-related discussions between cohorts emerged only in the second recorded session, after students had the opportunity to complete background research on various aspects of the clinical case. The lack of cohort differences in the initial recorded session (36.8% compared to 39.6%) was not unexpected since at that time students were unfamiliar with their case, and thus focused on task delegation and organisational matters for the semester long group activity. Productive content-related collaborative interactions require background knowledge, which these second year students were not expected to have at this early stage.

In the second recorded session, more than double the number of groups from the intervention cohort spent 30% or more of their time in content-related discussions compared to the control cohort, providing support for the effectiveness of the intervention. These findings are consistent with the two cohorts’ own estimates of the time spent on content discussion relative to organisational matters in their group meetings. The research expectation that groups should spend 50-70% of their meeting time discussing the clinical case was not achieved. However, the findings are encouraging in the context of a semi-experimental study, where other influences may have impacted on the intervention. It is possible that intervention students reported a greater amount of time spent in content-related discussions because they knew this was expected of them. This cannot be said about the observation data as these students had nothing to gain in pretending to engage in content-related discussion for they knew there would not be no penalty if they did not use the recommended strategy. This stresses the importance of using multiple data sources in metacognitive intervention research when involving groups.

The metacognitive strategy that formed the main focus of the intervention aimed to increase content-knowledge discussion, and also to encourage deep, high-level content-processing (Volet et al. 2009). The lack of significant differences in high-level content-related discussions between cohorts, indicates that this metacognitive intervention was not powerful enough to achieve this aim. There are multiple explanations. One is that a metacognitive intervention presented in the most convincing, credible, and contextualised way, is not sufficient even for high achieving oriented students. Given these students were keen to follow advice, it is possible that they indeed
tried to implement the two-fold metacognitive strategy within their groups but without meeting the research expectations. This was reflected in more groups reporting and being observed spending time discussing their case, and the overwhelmingly high ratings of learning from group discussions to achieve the learning objectives.

This suggests that students should perhaps be shown a demonstration of effective meaning making interactions. A distinct advantage of demonstrating enacted high-level content processing is that it places the instruction in a “content specific context” and expands content-knowledge (Beishuizen, Stoutjesdijk and Van Putten 1994). Beishuizen et al. argue that metacognitive help should be given in a content specific context and not be limited to general hints alone, therefore expanding students’ content knowledge. Although the two-fold metacognitive strategy presented to students in this study was customised to the specific context of collaborative case-based learning in Veterinary Science, peer modelling of high-level content-processing in this context was not provided. The added value of modelling and scaffolding collaborative learning-enhancing strategies should be examined in future research.

One other explanation for the intervention cohort’s minimal engagement in high-level content-processing could be attributed to the method of assessment. If students perceived that collaborative deep-level content-processing was not necessary to produce a presentation of high standard, and that group members’ background research could simply be collated, then they had no reason to spend additional time and energy discussing reciprocal understandings within the group.

In regard to students’ experiences of the group assignment, the impact of the metacognitive intervention was demonstrated, with intervention students finding the task less difficult overall, and task management and group dynamics less challenging than control students. Interestingly, the findings regarding personal goals were opposite to expectations. Intervention students were keener to get the highest mark possible than control students. This may be a reflection of the general level of confidence the intervention students had about their group assignment, perhaps buoyed by their experience of finding the task less difficult and group dynamics less challenging overall. In turn, the lack of difference in the goal of “learning from each other” could be explained in terms of multiple interpretations of what is meant by “learning from each other”, ranging from exchanging basic facts to complex elaborations of content knowledge.
The findings related to students’ evaluations of sources of learning to achieve stated learning outcomes of the case-based assignment were as expected. The impact of the intervention was highlighted in the significant difference between intervention and Cohort evaluations of their learning from face-to-face group discussions. It may be argued that this finding was influenced directly by what was presented in the intervention, and that intervention students responded accordingly in their self-reports displaying attributes of “good citizens”. However, self-reports were only one of the sources of data collected for this study, and in combination with recorded observations, provide complementary evidence of the value of the intervention. One possible limitation of this study is the absence of objective learning outcome measures to relate the observation and self-report data. Such measures were not available due to alternative forms of assessment for the group presentations.

In sum, this study provided evidence that it is possible to enhance the way groups of students work together: increasing the amount of time students spend discussing and explaining the clinical case, rather than simply managing, organising, and delegating tasks. Examination of the added value of peer modelling high-level content-processing will be a valuable follow-up intervention. In light of less than favourable perceptions of group learning activities among university students, it is imperative to address the paucity of intervention research aimed at promoting effective collaborative learning. Promoting effective peer learning across degree courses may enhance students’ ability to exhibit similar qualities in their professional lives.

Acknowledgement

This research was supported under the Australian Research Council’s Discovery Projects funding scheme (project number DP0986867).

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Figure 1: Interaction effect Cohort by Time for personal goal “Get the highest possible mark”
Figure 2: Interaction effect Cohort by Time for group challenge “Some group members having different work standards”
Figure 3: Interaction effect Cohort by Time for group challenge “Some group members not connecting well”
Figure 4: Interaction effect Cohort by Time for task challenge “Project required too much time/effort”
Table 1: Mean ratings and standard deviations (SD) for self-reports of personal goals and experiences of the group assignment

<table>
<thead>
<tr>
<th>Personal goals</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning Mean (SD)</td>
<td>End Mean (SD)</td>
</tr>
<tr>
<td>That we all learn from each other</td>
<td>3.25 (0.66)</td>
<td>3.16 (0.60)</td>
</tr>
<tr>
<td>To get the highest mark possible¹</td>
<td>3.31 (0.76)</td>
<td>2.95 (0.66)</td>
</tr>
<tr>
<td>Experiences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group challenges²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2.06 (0.87)</td>
<td>1.85 (1.18)</td>
</tr>
<tr>
<td>B</td>
<td>2.10 (1.01)</td>
<td>1.46 (1.27)</td>
</tr>
<tr>
<td>C³</td>
<td>1.91 (1.04)</td>
<td>1.60 (1.45)</td>
</tr>
<tr>
<td>D⁴</td>
<td>1.29 (1.09)</td>
<td>1.29 (1.37)</td>
</tr>
<tr>
<td>E</td>
<td>1.78 (1.05)</td>
<td>1.50 (1.29)</td>
</tr>
<tr>
<td>Task challenges⁵</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F⁶</td>
<td>1.95 (0.92)</td>
<td>2.07 (1.10)</td>
</tr>
<tr>
<td>G</td>
<td>1.89 (1.03)</td>
<td>1.74 (1.19)</td>
</tr>
<tr>
<td>H</td>
<td>2.47 (0.97)</td>
<td>2.77 (1.13)</td>
</tr>
<tr>
<td>I</td>
<td>1.37 (0.96)</td>
<td>1.06 (0.95)</td>
</tr>
<tr>
<td>J</td>
<td>1.64 (0.84)</td>
<td>1.46 (1.03)</td>
</tr>
<tr>
<td>Difficulty of the clinical case study⁷</td>
<td>2.65 (0.59)</td>
<td>2.74 (0.66)</td>
</tr>
<tr>
<td>Interest in the clinical case study</td>
<td>3.33 (0.61)</td>
<td>3.23 (0.67)</td>
</tr>
</tbody>
</table>

**Group Challenges**
- A Different understandings of the task
- B Different priorities e.g. marks, time
- C Different work standards
- D Members not connecting well
- E Different life circumstances

**Task challenges**
- F Project required too much time, effort
- G Case material too hard to understand
- H Too much information
- I Not enough direction from teachers
- J Too hard to get a good mark

**Significant interaction effects Cohort by Time for:**
1 Personal goal Get the highest mark possible, F(1,166)=14.32, p<0.001, See Figure 1
2 Group challenges overall, F(5,162)=2.74, p<0.05
3 Group challenge C, F(1,166)=4.96, p<0.05, See Figure 2
4 Group challenge D, F(1,166)=8.65, p<0.01, See Figure 3
5 Task challenges overall, F(5,161)=2.84, p<0.05
6 Task challenge F, F(1,165)=10.70, p<0.01, See Figure 4
7 Difficulty of the clinical case study, F(1,165)=4.94, p<0.05
Table 2: Percentage of meeting time spent on discussing the clinical case for control and intervention cohorts across two sessions.

<table>
<thead>
<tr>
<th>Group</th>
<th>Control Cohort</th>
<th></th>
<th>Intervention Cohort</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Session 1</td>
<td>Session 2</td>
<td>Session 1</td>
<td>Session 2</td>
</tr>
<tr>
<td>cJ</td>
<td>69.20</td>
<td>0.00</td>
<td>iC</td>
<td>52.60</td>
</tr>
<tr>
<td>cE</td>
<td>35.10</td>
<td>1.00</td>
<td>iA</td>
<td>52.00</td>
</tr>
<tr>
<td>cB</td>
<td>17.40</td>
<td>4.70</td>
<td>iJ</td>
<td>61.20</td>
</tr>
<tr>
<td>cI</td>
<td>27.20</td>
<td>10.00</td>
<td>iP</td>
<td>21.30</td>
</tr>
<tr>
<td>cK</td>
<td>42.60</td>
<td>10.60</td>
<td>iL</td>
<td>19.60</td>
</tr>
<tr>
<td>cN</td>
<td>22.60</td>
<td>22.20</td>
<td>iE</td>
<td>28.50</td>
</tr>
<tr>
<td>cG</td>
<td>38.60</td>
<td>48.70</td>
<td>iK</td>
<td>42.60</td>
</tr>
<tr>
<td>cC</td>
<td>46.50</td>
<td>55.00</td>
<td>iO</td>
<td>82.90</td>
</tr>
<tr>
<td>cM</td>
<td>32.10</td>
<td>85.20</td>
<td>iD</td>
<td>20.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>iN</td>
<td>9.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>iI</td>
<td>45.60</td>
</tr>
<tr>
<td>&gt;30%</td>
<td>6/9</td>
<td>3/9</td>
<td>6/11</td>
<td>8/11</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>33%</td>
<td>54%</td>
<td>72%</td>
</tr>
<tr>
<td>Mean</td>
<td>36.8</td>
<td>26.3</td>
<td>39.6</td>
<td>44.5</td>
</tr>
<tr>
<td>(SD)</td>
<td>(15.3)</td>
<td>(29.8)</td>
<td>(22.05)</td>
<td>(21.5)</td>
</tr>
</tbody>
</table>
Table 3: Students’ evaluations of three sources of learning to achieve the learning outcomes of the clinical case group assignment.

<table>
<thead>
<tr>
<th>Source</th>
<th>Control N=240</th>
<th>Intervention N=88</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Research</td>
<td>3.21 (0.67)</td>
<td>3.02 (0.54)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Research by others</td>
<td>2.86 (0.74)</td>
<td>3.02 (0.71)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Group Discussions</td>
<td>2.89 (0.82)</td>
<td>3.26 (0.73)</td>
<td>t(171), 3.90, p&lt;.001</td>
</tr>
</tbody>
</table>
Productive group engagement in cognitive activity and metacognitive regulation during collaborative learning: Can it explain differences in students’ conceptual understanding?

PAPER 3

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Productive group engagement in cognitive activity and metacognitive regulation during collaborative learning: Can it explain differences in students’ conceptual understanding?

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Abstract

This paper addresses the nature and significance of productive engagement in cognitive activity and metacognitive regulation in collaborative learning tasks that involve complex scientific knowledge. A situative framework, combining the constructs of social regulation and content processing, provided the theoretical basis for the development of a comprehensive coding scheme for interactive data analysis. An empirical study was conducted with two groups of university students working on two science-learning tasks. It examined the function of metacognitive regulation to control the flow of cognitive activity, and the extent to which group differences in cognitive and metacognitive regulation processes during collaborative learning could explain differences in the groups’ learning outcomes. The findings provide validation of the framework and its derived coding scheme. An example of a way in which a group engages in socially shared metacognitive regulation is presented to demonstrate how the coding scheme was applied to the data. Theoretical and empirical implications of the findings are discussed. (155 words)

Introduction

The ever-increasing corpus of research on collaborative learning has revealed that while the learning benefits of effective collaboration are well documented (e.g., DeChurch
and Mesmer-Magnus 2010; Springer et al. 1999) and described as an “educational psychology success story” (Johnson and Johnson 2009, p. 365), not all group activities lead to productive collaborative learning (Barron 2003; Summers and Volet 2010). In short, productive collaboration in a group learning activity, although desired, cannot be presumed. This is especially significant given student-led small group collaborative learning is common across most levels of formal education.

A growing body of literature on interpersonal regulation in learning contexts has emerged in recent years (e.g., Allal 2011; Vauras et al. 2013; Hadwin et al. 2011; Volet et al. 2009b; Volet and Vauras 2013), showing empirical evidence of the nature, function and implications of social regulatory processes in collaborative learning. To date, however, little is known about the extent to which group differences in metacognitive regulation during collaborative learning, can explain differences in the group learning outcomes. The present study aimed to address this gap.

**Social regulation in collaborative learning**

Conceptualizations of social or interpersonal regulation of learning vary across perspectives (e.g., socio-cognitive, socio-cultural and situative) and accordingly across bodies of empirical research (Hadwin and Oshige 2011; Molenaar et al. 2012; Rogat and Linnenbrink-Garcia 2011; Iiskala et al. 2011; Volet et al. 2009a; 2013). Based on a SRL perspective, and building on Vauras et al.’s (2003) work on socially shared metacognition, Hadwin and Oshige (2011) defined social regulation as part of the social component of self-regulated learning, making the distinction between co-regulated learning as the “transitional processes in a learner’s acquisition of self-regulated learning” (p. 247) (a socio-cultural perspective of self-regulated learning) and socially shared regulation as the “processes by which multiple others regulate their collective activity” (p. 258) towards the achievement of shared goals (a socio-cognitive perspective).
In contrast, Volet et al.’s (2009b) conceptual grounding for social regulation is in living systems theory, applied to the domain of self and social regulation in learning contexts. A framework, combining the constructs of social regulation and content processing, was developed (Volet et al. 2009a) to examine the nature and emergence of productive co-regulation in collaborative learning. That framework conceptualized social regulation along “a continuum from individual regulation within group to co-regulation as a group” (Volet et al. 2009a, p.131) depending on whether a single person or multiple group members contributed to the regulation of the joint cognitive activity, and it identified high and low levels of engagement in content processing.

More recently, Iiskala et al. (under review) and Volet et al. (2013) adopted the term socially shared metacognitive regulation to make it explicit that the focus is on the regulatory component of socially shared metacognition and is concerned with regulation of cognition (at the exclusion of emotions and motivation). This is consistent with Salonen et al. (2005, italics in original text) reference to the “semantic (or content-related) mode of co-regulation”. The term socially shared metacognitive regulation (hence referred to as SSMR for brevity) is used in instances where metacognitive regulatory processes are genuinely shared among members. We recognize, however, that in collaborative learning situations, one group member may at times display solo attempts to regulate the group cognitive activity (Volet et al. 2009a). We also acknowledge that both individuals and the group as a social entity are self-regulating and co-regulated systems at the same time (Volet et al. 2009b), therefore take it for granted that self-regulation and social regulation occur simultaneously. While evidence of social regulation can be found in verbal and non-verbal interactions, it is mainly recognized when spoken. Instances of verbalized thinking aloud should not be confused with individual attempts at group regulation, the latter being aimed at social regulation.

In the present study, we wanted to explore empirically the theoretical distinction between joint cognitive content processing, which can for example refer to co-construction of knowledge and meaning making, and joint regulation of cognitive content processing, which refers to joint regulation of cognitive activity, or socially shared metacognitive regulation (SSMR). Although the two constructs are conceptually
distinct, they are challenging to distinguish and sometimes confounded in empirical data (e.g., Rogat and Linnenbrink-Garcia 2011; Volet and Summers 2013)

This study also aimed to explore the nature and function of SSMR when applied to respectively, cognitive activity related to joint production of the required task (task production) or to joint construction of knowledge related to the task (knowledge construction). Task production refers to talk orientated at the assigned task, and knowledge construction to talk directed at content related aspects of the task. Identifying qualitative differences in cognitive processing (high or low-level) was also important, in light of empirical evidence that not all students’ interactions in collaborative learning lead to the desired high levels of knowledge construction (e.g., King 2002; Summers and Volet 2010; Rogat and Linnenbrink-Garcia 2011). Exploring these ideas and delving deeper into the “black-box” of collaborative learning (Janssen et al. 2010b, p.139) required further elaboration of our earlier analytical schemes, which was undertaken as a part of this study.

**Analytical approaches for the study of social regulation in collaborative learning**

Research on social regulation in collaborative learning is challenging because it is located at the articulation of individual and social processes, and involves the study of dynamic, interactive and evolving processes. Despite the challenges a range of innovative analytical approaches for examining and interpreting dynamics of interpersonal regulation in real-life contexts have emerged in recent years (see Volet and Vauras 2013). As noted by Volet and Vauras (2013), methods of analysis need to represent key generic theoretical constructs and at the same time be sensitive enough to capture manifestations of social regulation in specific contexts. This is consistent with Efklides (2011), who argued that the regulation of cognitive processing modes is specific to the task at hand. Most importantly, and as emphasized by several authors (Azevedo et al. 2010; Chan 2012; Grau and Whitebread 2012; Volet and Summers 2013), analytical methods must be rigorous enough to generate reliable findings.
Three recent studies of socially shared regulation in collaborative learning used methodological approaches of direct relevance to the present study (i.e., Iiskala et al. 2011; Lajoie and Lu 2011; Rogat and Linnenbrink-Garcia 2011). Drawing from several conceptual perspectives, Rogat and Linnenbrink-Garcia developed an analytical scheme to distinguish sub-processes of socially shared regulation and a ranking system to identify variation in the quality of these sub-processes. They found that differences in sub-processes across groups were related to differences in the quality of the groups’ engagement in socially shared regulation. In contrast, Iiskala et al (2011) explored the nature of fluctuations between cognitive activities and SSMR. Through scrutinizing the focus and function of SSMR, they found how it either facilitated or inhibited cognitive activity.

Lajoie and Lu’s (2011) examination of the value of an external tool to support collaborative, co-regulated medical decision-making, shares similarities with our work. They found that groups using an interactive whiteboard with a structured template engaged in deeper collaborative regulatory discourse and displayed better learning outcomes related to patient management than groups using a traditional whiteboard to visualize and record their arguments. They concluded that the interactive whiteboard “served as a cognitive tool to support the building of a medical argument as well as the sharing of the argument building” (p. 16). The value of external tools to support collaborative learning is well documented in the literature on concept mapping (e.g., Hay et al. 2008) and was examined in the present study.

The present study

The first aim (methodological) was to further articulate and validate a theory-based coding scheme for the analysis of cognitive and metacognitive regulation processes in collaborative learning.

The second aim (empirical) was to examine the extent to which group differences in cognitive activity and metacognitive regulation during a collaborative learning activity
could contribute to explaining differences in the group learning outcomes. It was expected that differences in groups’ cognitive activity and metacognitive regulation would provide valuable insight into the disparate group learning outcomes.

Methodology

Participants and design

The study was embedded within a larger research project conducted with second year undergraduate students in Veterinary Medicine. The clinical case-based group assignment of a physiology unit ‘hosted’ the research. In this assignment, students self-select into groups of five or six members and are randomly assigned a different real-life clinical case, which they progress in their own time over a six to seven week period. The year the research was undertaken, 15 groups were formed, of which 12 volunteered for the research. The teacher was not involved in the research. University ethics approval and consent from participating students were obtained prior to and for all aspects of the study.

The two groups selected for in-depth analysis were: Group A: six students (five female, one male) and Group B: five students (four female, one male). These two groups were selected because their grades in physiology were not significantly different (comparable aggregate marks and within group variation: Group A: \( M = 71.2; \ SD = 4.02 \); Group B: \( M = 74.0; \ SD = 5.6 \)) but they differed markedly in their collective understanding of their clinical case at the end of the group assignment. Group A obtained the lowest score (56%) and Group B the highest score (92%) of the 12 participating groups. The groups’ collective understanding of their case was inferred through assessment of a concept map they constructed at the end of the assignment.

The clinical case-base group assignment

The clinical case-based assignment that ‘hosted’ the research is a regular curriculum feature of the physiology unit. This group based assignment is the students’ first
exposure to real-life case material, its main aim is to encourage students to apply primary preclinical knowledge learnt to date, extracting relevant physiology based clinical concepts, and investigating underlying principles of treatment and management of the various disease processes presented in the cases. All groups are required to set their own learning objectives specific to their assigned case, research selected aspects of the case content and present their findings as a group at the end of semester. The groups are expected to complete this task via group meetings outside of class time. The physiology teacher provides the groups with face-to-face guidance in two scheduled meetings three to four weeks apart. These meetings allow the teacher to guide students into formulating case relevant, concise learning objectives and ensure the groups are progressing satisfactorily. All students are given a group mark based on their class presentation and associated question and answer session at the end. Group marks are based on the teacher’s assessment of the groups having addressed their learning objectives, and constitutes 10% of students’ overall physiology mark for the unit.

Data

Data for the present study consist of video footage of the two groups’ interactions while working on two tasks: Generate learning objectives; and Construct a concept map.

Task 1: Generate learning objectives for the clinical case at the start of the assignment

The first video footage featured each group’s first informal meeting after receiving their clinical case file. The purpose of recording the groups’ initial meetings was to gain access to students’ early cognitive and metacognitive engagement in the collaborative activity. No special instructions were provided and no time limit imposed. Only a technician was present during recording. The total meeting times for Group B and A were respectively 46 min and 50 secs and 33 min 59 secs.

Task 2: Construct a concept map of the clinical case near the end of the assignment
The second video footage featured each group’s joint construction of a concept map of their clinical case after having completed their background research. This task was explicitly designed for research purposes and relevant to students’ study since it took place as they were preparing the presentation of their case. No time limit was imposed for the concept map construction. The purpose of filming students’ construction of a concept map of their case was to gain access to their cognitive engagement and metacognitive regulation processes at an advanced stage of the group assignment. This task had the additional benefit of allowing unique audiovisual access to students’ co-construction process of their collective understanding of the clinical case. The total time taken by Groups B and A to complete their collaborative concept mapping tasks were respectively 18 min 39 secs and 11 mins 55 secs.

To complete this task, each group was given a set of concept cards taken from their specific case. While working on a freestanding, transparent glass work-board (see Figure 1), students were asked to arrange the concepts in a manner that made sense to the entire group, leave aside any cards that did not make sense or deemed irrelevant to the case, and link the concepts with either a unidirectional or bidirectional arrow indicating either a cause-effect relationship or an inter-related relationship. The terms concepts and links refer respectively to the clinical concept cards extracted from the case files and to the arrows connecting the concepts, consistent with Curseu et al.’s. (2010) concept map terminology.

For educational purposes, each group was given feedback on their concept map by an experienced veterinary clinical instructor (one of the authors).
Concept map construction was selected for this study as prior research has shown that the use of concept maps has the distinct benefit of allowing the display of “abstract knowledge and understanding into concrete visual representations that are amenable to comparison and measurement” (Hay et al. 2008, p. 295). Furthermore, the use of concept maps in a collaborative setting enables visualization of the collective knowledge and understanding displayed by the groups, making them an excellent learning and research tool. Medical and veterinary medical education have favored the use of concept maps (e.g., Edmondson and Smith 1998; Schmidt 2006; McGaghie et al. 2004) as complex and often entwined medical and biological knowledge can be clarified when presented in a visual, spatial medium that allows all connections, understandings and explanations to be disentangled and displayed in one integrated map.

The verbal interactions of all video-recordings were fully transcribed and significant non-verbal interactions or body language gestures included in the transcripts. When coding, however, the transcripts were used in conjunction with the video data to enable more fine-tuned coding of the interplay between verbal and non-verbal interactions. In Task 1 (Generation of learning objectives), the total number of coded turns was 814 for Group B and 835 for Group A. In Task 2 (Construction of concept map), it was 290 for Group B and 211 for Group A.

Analysis of the concept maps to assess groups’ collective understanding of their case

A rigorous three-stage assessment procedure was employed to analyze the completed concept maps in a consistent and fair manner. First, the clinical cases were divided based on small animal and large animal content, and two veterinary medical experts in each field were invited to independently construct concept maps of each case using the same clinical case files and concepts as those given to the students. Second, the two experts’ maps for each case were compared. Any discrepancies were discussed and consensus reached regarding appropriate links between concepts. It was not always possible to reach a single agreed answer, as the complex medical knowledge involved could sometimes be linked to theoretical or clinical application. This meant that
alternative links between concepts were sometimes equally acceptable. For example in
one case, one expert took a more theoretical approach to treating a cat in renal failure
while the other adopted a more clinical approach on the grounds that practically, it can
be difficult to orally medicate a cat for prolonged periods of time. Both the theoretical
and clinical applications were considered acceptable, and students’ concept map
assessed accordingly. Third, a final “expert concept map” (combination of the two
expert maps) was produced for each clinical case. This enabled the assessment of each
group’s jointly constructed map, as evidence of that group’s collective understanding of
their case. Each group concept map was given a percentage score, which represented the
proportion of links that were exactly the same between the student concept map and the
expert concept map. The twelve group maps’ scores ranged from 56% to 92% ($M =
78.2\%, SD = 9.5$). As mentioned above, the two groups selected for the present study
were those with the extreme scores (56% and 92%).

Coding scheme for analyzing cognitive activity and metacognitive regulation

The comprehensive coding scheme presented in the present paper was developed over
an extended period of time. The initial scheme, grounded in a situative framework that
combined the constructs of social regulation and content processing, was described in
Volet et al. (2009a), and validated in Summers and Volet (2010). It was elaborated as a
three-stage analytical scheme for the analysis of group cognitive activity and
metacognitive regulation during collaborative learning. The conceptual rationale for the
gradual development of that analytical scheme was outlined in Volet et al. (2013).

As part of the present study, the three-stage coding scheme was further refined, and
empirically tested. The elaborated scheme is grounded in a combination of socio-
cognitive, metacognitive and situative theoretical perspectives, and accordingly
integrates group and individual level analysis. The three stages, illustrated in Figure 2,
focus in turn on: Cognitive activity; Metacognitive activity; and the Social nature and
function of metacognitive activity. Each stage is now presented in turn, with a
description of how the theoretical concepts were contextualized and empirically
examined in the present study.
Stage one – Coding cognitive activity

The first stage focuses on cognitive activity at episode level. It is categorized into one of two orientations, talk orientated at knowledge construction or talk orientated at task production. These orientations are based on the assumption that when students engage in collaborative learning tasks that involve complex scientific knowledge, they shift back and forth between cognitive activity directed at producing the task outcome (required product) and cognitive activity directed at knowledge processing and constructing their understanding of underlying scientific knowledge. Each orientation is further categorized at either low or high-level, which signifies qualitative differences in engagement depth with either task production or knowledge construction.

Knowledge construction refers to talk directed at discussion of clinical case content, for example, laboratory reports, outcomes of diagnostic tests, interpretations of tests and conceptual understanding of the case material. In contrast, task production refers to talk orientated at any aspect of the assigned task, including its expected outcomes, for example, talk about the number and types of required learning objectives or aspects to include in the class presentation.

In turn, low or high levels of cognitive activity refer to the depth of either knowledge construction or task production. Low-level knowledge construction refers to instances where the group discussion is focused on identifying or collating content information relevant to the clinical case e.g., “Yep so sudden onset blindness, noticed on the first of May” (1B81). High-level knowledge construction refers to instances where group talk displays attempts to engage in conceptual understanding, elaboration and justification of the case content material e.g., “And the high Urea and Creatinine basically means that his kidneys aren’t cleaning enough of his blood, yeah?” (1B190). Similarly, low-level task production refers to group talk aimed at discussing task requirements without explicit conceptual case association or content justification e.g., “So do we just pick out
the learning objectives we’re gonna do today?” (1A13). High-level task production refers to talk that attempts to justify or associate task outcomes and expectations with conceptual case file content e.g., “Double arrow from Hepatic fibrosis to Ascites because fibrosis caused the Ascites” (2A149).

The demarcation (boundaries) of the cognitive activity episodes and identification of the orientation of cognitive activity (e.g., knowledge construction or task production at high or low levels) were necessarily determined simultaneously, given episode boundaries could not be established without also demarcating where students’ talk shifted category. In regard to the identification of episodes of high-level depth of cognitive activity it should be noted that such episodes often displayed only “attempts” at in-depth understanding of the case material. This was expected given students were at the early stage of their study in veterinary medicine, with limited prior exposure to clinical material. Two independent judges, one co-author and one external researcher with extensive experience of discourse analysis coded 26% of the data from the two groups. The two judges were in agreement for 74.3% of the coding. Disagreements were resolved by discussion, leading to gradual refinement of the coding scheme to address any ambiguity that contributed to the disagreements.

Stage two - Coding metacognitive activity

The second stage concentrates on the identification of metacognitive activity at the turn level, more specifically, theoretical codes, contextualized sub-codes, and their associated empirical indicators from the data. Table 1 presents an overview of the second stage coding protocol.

| TABLE 1 ABOUT HERE |

The first column presents the theoretical codes of planning, monitoring and evaluation. These executive control processes are assumed to serve the same role whether applied
to task production or knowledge construction. Since the clinical case based assignments involved complex scientific knowledge, they provided an ideal setting to determine if and if so how, these processes regulated transitions between task production and knowledge construction, and whether there were qualitative differences in engagement with content (high or low level).

Low-level metacognitive regulation denotes planning the next action without any conceptual justification, or monitoring cognitive activity by simply regulating the gathering of factual information, or evaluating the group activity without any justification. In turn, high-level metacognitive regulation refers to thorough planning or monitoring cognitive activity to achieve conceptual understanding, or providing a meaningful evaluation of the group activity. In the present study, no instances of high level planning and evaluating were found. Thus, contextualized sub-codes for high and low levels were generated only for Monitoring (see center column of Table 1).

The contextualized sub-codes allowed a more precise and fine-grained method of identifying evidence of group monitoring their cognitive activity at high or low level at the turn level. The far right column of Table 1 presents the accompanying empirical indicators that define each theoretical and contextualized sub-code in the context of the data. For example, a student iterates a turn where she adds new factual information to the group’s discussion that sustains discussion about the case content, e.g., “Yeah but we don’t actually have it” (2B90). This would be coded as Monitoring low-level talk - Add Information (AI). Alternatively, a student may seek an explanation, e.g., “Are Ascites and Proteinemia linked in any way?” (2A158) or volunteer an explanation, elaboration or interpretation to enhance the group’s conceptual understanding of the case, e.g., “I would have thought that Azotaemia would link to Isosthenuria or would be interrelated (maybe) not necessary linked to...” (2B189). These would be coded Monitoring high-level talk, respectively, - Seek Meaning (SM) and Volunteer meaning (VM). Another example would be a student exploring an idea while speculating on an explanation, e.g., “Theoretically weight loss can cause Azotaemia” (2B254). This would be coded Monitoring high-level talk – Explore ideas (EI). In terms of assigning a contextualized sub-code, if one turn could be categorized in multiple ways (e.g., a
lengthy turn) then the code that reflected the main regulatory function of that turn in the context of the talk was assigned.

**Stage three - Coding the social nature and function of metacognitive activity**

The third stage of the coding scheme focuses on the social nature and function of metacognitive regulatory talk within the contextual flow of cognitive activity. At this stage a distinction is made between individual solo regulation of the group’s cognitive activity, and multiple students’ contributions to the regulatory efforts, i.e., where more than one student jointly regulate the flow of cognitive activity. It is this latter collective regulation of task completion or knowledge construction that constitutes SSMR.

Both stage two and stage three coding were 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. Deciding on inclusion was dependent on whether it produced a change (regulatory function) in the cognitive flow (e.g., knowledge construction to task production or vice versa, or change in depth of engagement). Evidence of SSMR was when metacognitive regulation was instigated by one student and subsequently taken up and pursued by one or more students. Some instances of isolated metacognitive attempts (no peer follow-up) were found. In rare cases, we found evidence of one student instigating a change in the flow of cognitive activity, and sustaining regulatory input over several turns without others’ contribution (thus evidence of individual regulation).

**Results**

**Task 1- Generate learning objectives for the clinical case**

**Cognitive activity**

The first two columns of Table 2 show the breakdown of cognitive activity in Task 1 by the two groups. As can be seen from the bottom figures, the two groups were comparable in terms of total number of cognitive turns (814 and 835).
The first two rows compare the two groups’ orientation of their cognitive activity, namely, task co-production and knowledge co-construction. Contrasting patterns were found with Group A spending the majority of their time on task co-production (68.7%) compared to only 17.8% by Group B and Group B spending the majority of their time grappling with the clinical case content (82.2%) in comparison to only 31.3% by Group A.

The next two rows show the breakdown of cognitive activity overall (task production and knowledge co-construction combined) by level of engagement (high and low). No significant group differences were found with both groups engaged dominantly at low level. This was expected since students were in the initial stages of their clinical case group assignment, and could only try to make sense of the clinical case content with limited background knowledge.

The last breakdown is by orientation and level. The figures show that Group B’s engagement at high level was three times greater than Group A, for both task co-production (3.5% vs. 0.4%) and knowledge co-construction (16.5% vs. 5%).

These findings highlight similarities as well as differences in the two groups’ cognitive engagement with their clinical case in their first meeting. Group similarities were found regarding level of engagement overall (task co-production and knowledge co-construction combined), which suggests the influence of the task (i.e., an activity undertaken with minimal background knowledge). In contrast, the group differences in terms of orientation (task focus vs. knowledge focus) were consistent with the groups’ respective collective understanding of their clinical case at the end (represented through their concept map). Group B spending the majority of their time focusing on their case content, rather than simply trying to generate their learning objectives was noteworthy. This combined with their effort to engage in at least some amount of high-level
meaning making of their case, and contrasted sharply with Group A’s minimal engagement at that level.

**Metacognitive regulation**

*Frequency and type of metacognitive regulation.* Overall, the two groups were not different in regard to the proportion of metacognitive regulation turns out of all cognitive turns overall (Group B: 183/814; 22.5%; Group A: 148/835; 17.7%). Similarly, the breakdown of metacognitive regulation into types (theoretical codes), namely Planning, Monitoring and Evaluating were not statistically significant (Group B: Planning 31, 16.9%; Monitoring 150, 82%; and Evaluating 2, 1.1%; Group A: Planning 32, 21.6%; Monitoring 115, 77.7%; and Evaluating 1, 0.7%), ($\chi^2 (1) = 1.285, p = .52$). The limited amount of evaluation in both groups was consistent with the fact that students were trying to generate learning objectives and expecting their teacher would decide whether they were suitable.

*Quality of metacognitive regulation.* Further breakdown of monitoring by level of engagement revealed fine-grained differences in the two groups’ metacognitive regulation processes. Table 3 displays the breakdown of monitoring into regulation of low- and high-level talk, and the contextualized sub-codes as empirical indicators of such activity.

**TABLE 3 ABOUT HERE**

A Chi Square test revealed that the distribution of monitoring into high and low levels was significantly different for the two groups ($\chi^2 (1) = 43.49, p < .001$), the most striking difference being Group B spending 39.3% at high level, and Group A only 4.4%.
The finer grain breakdown into sub-codes unveiled the nature of qualitative differences in the two groups’ monitoring processes. In terms of monitoring cognitive activity at low-level (first 4 columns), the two groups differed only minimally. Both groups spent a large proportion of their low-level regulatory activity reflecting on the task, i.e. considering and relating the different pieces of information provided in the case file. It also included adding information to the group discussion, and seeking information from each other.

The breakdown at high-level revealed the specific processes used by Group B to monitor their tentative co-constructed understanding of the case. As can be seen, Group B spent a noticeable amount of time volunteering meaning (12%), exploring ideas (10%), and drawing conclusions from high-level conceptual discussions (8.7%). This contrasted with Group A, who as reported earlier, engaged minimally at high level during their first meeting.

In sum, the findings for Task 1 show that both groups were dominantly discussing their case content at low-level, which reflected both groups’ lack of background knowledge at this early stage. However, and consistent with the group differences in the display of their understanding of their clinical case at the end (concept map), Group B showed consistently more effort to understand their case, in terms of high-level cognitive engagement and associated high-level metacognitive regulation.

**Task 2- Construct a concept map of the clinical case**

*Cognitive activity*

The last two columns of Table 2 show the breakdown of cognitive activity in Task 2 by the two groups. As can be seen from the bottom figures, Group B engaged in more cognitive activity while completing their concept map than Group A (290 vs. 211 turns).
The first two rows compare the groups’ orientation of their cognitive activity while constructing their concept map. Given the nature of the task, it was expected that both groups would concentrate on the production of their map. This was indeed the case for Group A, with all their interactions directed at that activity. In contrast, Group B spent a substantial amount of time co-constructing their understanding of the case (29.3%), alongside co-constructing their map. This was consistent with the orientation of their cognitive activity in Task 1, where most of their time was spent on knowledge construction.

The breakdown by level of engagement (high, low), shown in the next two rows of Table 2, revealed striking group differences. A greater proportion of Group B talk was at high level (58.3% vs. 41.7%), while it was the opposite for Group A (24.6% vs. 75.4%). These findings contrast with Task 1 where both groups’ talk was predominantly at low level. On the other hand, findings in Task 1 were consistent with Group B’s continuous effort to understand their case content, alongside producing the required tasks (whether generating their learning objectives or constructing their concept map).

The breakdown by orientation and level further highlights Group B’s determination to fully understand their case. This was noticeable in the finding that almost all their knowledge co-construction (82/85 turns) and almost half their map co-production activity (87/205 turns) were at high level, with evidence that the group tended to justify their arrangement of concepts and links as they were building their map. In contrast, only 24.6% of Group A’s cognitive activity included some conceptual justifications in producing the task only.

In sum, some marked group differences in level of engagement were found in Task 2. At this advanced stage of the overall group assignment (i.e. after students had undertaken background research and gained familiarity with their case), it was expected that both groups would display some evidence of high-level cognitive activity. The data analysis revealed that Group B spent considerably more time at that level than Group A (58.3% vs. 24.6%), which could contribute to explain the fact that their concept map
was almost a perfect match with the experts’ (92%), while Group A only achieved a 52% match.

Metacognitive activity

**Frequency and type of metacognitive regulation.** Overall and as in Task 1, the two groups were not different in the proportion of metacognitive regulation turns out of all cognitive turns (Group B: 69/290; 23.8%; Group A: 47/211; 22.3%). Similarly, the breakdown of metacognitive regulation into Planning, Monitoring and Evaluating were not statistically significant (Group B: Planning 6, 8.5%; Monitoring 63, 91.3%; and no evidence of Evaluation; Group A: Planning 2, 4.3%; Monitoring 45, 95.7%; and no evidence of Evaluation), ($\chi^2 (1) = 1.307, p = .25$). The limited amount of planning and absence of evaluation could be explained in terms of the highly structured nature of the concept map activity. Planning may not have been necessary, and evaluation may have been bypassed given the anticipated teacher feedback at the end.

**Quality of metacognitive regulation.** Table 4 presents the breakdown of monitoring into regulation of low- and high-level talk, and the contextualized sub-codes as indicators of regulatory activity.

| TABLE 4 ABOUT HERE |

A Chi square test revealed that the distribution of monitoring into high and low levels was significantly different for the two groups ($\chi^2 (1) = 13.41, p < .001$) with Group B spending the greatest proportion (73%) of their monitoring at high-level compared to only 37.8% for Group A.

The nature of qualitative differences between the two groups became further apparent in the further breakdown of monitoring into metacognitive regulation sub-codes. At low-
level (first four columns), the breakdown into sub-codes reveals a comparable distribution within groups. In terms of monitoring at high-level (last eight columns), the importance of Group B’s engagement in Exploring ideas (16 turns) is noteworthy. This finding was particularly striking since the concept map activity took place towards the end of the group assignment. This provides further evidence that Group B appeared to be determined to fully understand their clinical case as a group. In contrast, Group A did engage in monitoring the construction of their map but with less high-level conceptual justifications and rather low-level seeking and adding information.

In sum, the findings for Task 2 revealed some striking group differences, with Group B’s cognitive activity predominantly at high-level for knowledge co-construction, and considerable task co-production. Group A on the other hand engaged predominantly at low-level for task co-production and no engagement in knowledge co-construction. The fine-grained analyses of metacognitive sub-codes for monitoring revealed stark group differences, with Group B noticeable engagement in exploring ideas, volunteering and seeking meaning, in comparison to Group A’s modest engagement at high-level.

Illustration of an episode of high-level cognitive engagement with socially shared metacognitive regulation

This final section provides an example of how the three-stage coding scheme was applied to an episode of productive high-level cognitive engagement and socially shared metacognitive regulation (SSMR). This particular episode was chosen as a good illustration of how a group monitored its cognitive activity, with shifts from high-level co-production to high-level co-construction, and low-level co-production. The coded extract, presented in Figure 3, illustrates a section of Group B’s interactions in constructing their concept map (turns 231-240). It features three students making conflicting regulatory statements about the same content while still progressing towards their common goal.

FIGURE 3 ABOUT HERE
The figure should be read from left to right, starting with the transcript of all verbal interactions, and relevant non-verbal indicators in italics. The next three columns feature the three stages of the coding scheme, namely, cognitive activity at episode level (Stage 1), metacognitive activity at turn level with associated theoretical codes and contextualized sub-codes where evident (Stage 2), and finally a narrative describing the social nature and function of metacognitive activity in the context of the cognitive flow (Stage 3).

The traveling arrow in the cognitive activity column (Stage 1) highlights the continuous flow of the group’s cognitive activity, and therefore the cognitive coding at episode level (low or high, task or knowledge). Adjacent to the traveling arrow are the indicators of metacognitive activity at turn level (Stage 2), with contextualized sub-codes. Pictorial links connect all the metacognitive regulatory statements that are considered as socially shared (SSMR). Typically, SSMR is characterized by a succession of content related turns of a metacognitive regulatory nature that are mostly contiguous in nature and involve more than one student. Most commonly is an individual’s verbal (less commonly non-verbal, for example frowning or nodding) statement that initiates engagement in metacognitive regulation activity. Whether an individual’s metacognitive statement is subsequently followed up by other members’ metacognitive contributions determines if the initial metacognitive regulation turn remains a solo event or develops into an episode of SSMR. Any identified SSMR episode, therefore, displays evidence of more than one student regulating the same cognitive activity and progressing towards a shared learning goal or outcome.

The episode starts by the group discussing the clinical signs of azotaemia (toxins produced from kidney failure), anorexia (not eating), and weight loss, while working on their concept map. Renee draws arrows to link the azotemia, anorexia and weight loss cards, and at the same time ponders over the idea that losing weight could be associated with eating less (turn 231). Her (correct) selection of arrows between the three concepts sparks disagreement by both Blanca and Winnie (turns 232 and 233), uncovering a misconception about the term “anorexia” apparently held by at least these two students.
Their contradiction to Renee, which also reflects monitoring of the cognitive activity, regulates the group’s understanding temporarily away from the correct definition.

After some cognitive exchange (turns 234 to 236) the group shifts temporarily away from high-level coproduction of their concept map, and engages in an episode of high-level co-construction of knowledge (starting at turn 237). At this point (turn 237), Renee displays evidence of self-regulation, as she seems to realize that there are different conceptualizations of the notion of “anorexia” within the group, and that both Blanca and Winnie have misconceptions. By reflecting on the different concepts and correcting her peers’ misunderstandings, Renee displays evidence of concurrent self and social regulation. This episode of SSMR also illustrates that joint monitoring of the flow of cognitive activity is not necessarily contained in a single type of cognitive activity. In this case, the episode of SSMR started during high-level co-production of the concept map and extended into high-level co-construction of knowledge.

Discussion

The theory-based coding scheme presented in this study was conceptually and methodologically useful to determine how group differences in cognitive activity and metacognitive regulation during case-based collaborative learning contributed to explain differences in the groups’ collective understanding. This was made possible through a clear demarcation between group engagement in low or high levels of knowledge construction and task production. In regard to knowledge construction, group discussion involved attempts to engage in high-level conceptual understanding, elaboration and justification of content material or alternatively reflected gathering of factual knowledge. Similarly, in regard to task production, interactions were limited to low-level discussion of task requirements or alternatively included conceptual content association or justification. The systematic coding of these distinctions revealed that when a group’s iterations included a substantial amount of high-level engagement with the case content, this was also associated with evidence of better overall conceptual understanding of the case as evidenced in the end group product (concept map).
Explaining why one of the groups displayed persistent attempts at high-level conceptual understanding throughout the whole group assignment, while the other concentrated on producing the task outcomes is speculative. The possibility of problematic group dynamics was ruled out since there was no visible evidence of interpersonal challenges among members of the less successful group in this study. It is also important to note that this was the very first time that these groups were exposed to real life clinical case material, which inherently presents difficulties in terms of content understanding and grasping the very different format of learning (compared to textbook knowledge). We further speculate that the introduction of learning from case files may somewhat serve as an equaliser for all groups, that is to say, this was a novel experience and at a greater level of difficulty for all of them. Therefore, there were no presumptions that any one group had the benefit of prior knowledge, which would have aided in understanding case file content.

One possible explanation may be differences in the two groups’ implicit or explicit goals for engaging in the clinical case group assignment. It is possible that Group B were aiming at maximizing the learning opportunity provided by the concept mapping exercise while Group A were simply pursuing the goal of completing the task at hand.

Given high-level knowledge co-construction is considered highly desirable in peer learning (King 2002, Volet et al. 2009a), identifying the individual and contextual aspects that might contribute to group engagement in high-level conceptual understanding and knowledge construction is warranted. One further consideration and possible explanation for the group differences in the present study may be whether there was a high level of collective interest in the given task, or a genuine desire to fully understand complex content material within the group. One way to explore this possibility is through the examination of individual and group-level appraisals of the activity, and considering whether high level engagement could be predicted on the basis of the group aggregate profile, or whether such engagement emerges through individual interactions. Previous research by Summers and Volet (2010) reported a relationship between pre-task estimates of motivation (aggregate figure) and amount of time actually
spent on content-related discussions, however these pre-task appraisals were not correlated with groups’ level of engagement in content processing.

Consistent with research by Lajoie and Lu (2011) involving students in medical decision-making, a significant finding from the present study was the clear association of high-level metacognitive regulation (monitoring) with instances of high-level cognitive activity. The interactive whiteboard in the Lajoie and Lu study provided enhanced opportunities for shared metacognitive activity, which led to co-regulatory actions and high-level content knowledge discussion. Similarly, our study revealed episodes of high-level knowledge construction where instances of productive discussion and questioning between multiple group members were also supported by evidence of engagement in high-level monitoring. As predicted, engagement in such high-level activity was associated with a better collective understanding of the content involved. The empirical evidence of a relationship between high-level displays of metacognitive regulation and knowledge construction (process data) and superior conceptual understanding (product data) has educational implications. To date, studies documenting the link between interpersonal regulatory behaviours and learning outcomes are still limited (Winters and Alexander 2011; Janssen et al. 2010a) are some of the exceptions). This represents an important direction for future research.

From a theoretical perspective, evidence of concurrent self and social regulation, as conceptualized by Volet et al. (2009b), was also identified in the study. This psychosocial phenomenon is difficult to distinguish and often confounded in empirical data (e.g., Rogat and Linnenbrink-Garcia 2011). A related concept in social regulation research is “social metacognition” (Chan 2012, p. 68, italicized in the original text) where students are not only self-regulating their own learning, and co-regulating the learning of others in the group, but also becoming more aware of what others in the group do not understand. The present study provided empirical evidence of concurrent self and social regulation in one such instance. This involved a student displaying evidence of emerging awareness of an incorrect understanding about anorexia (see Figure 3 excerpt) and concurrently realising other group members had also
misunderstood. Without this student's cognizance and subsequent highlighting of their collective misunderstanding, it may have persisted.

Social metacognition is an important phenomenon to explore in collaborative learning contexts, and perhaps especially so among students who are highly self-regulated and prepared to grapple with complex scientific concepts, like some of the students in this study. Since it is likely that such students have a sound awareness of their own level of understanding and misconceptions, it would be interesting to scrutinize the level of social metacognition that these students may or may not display. The goal would be to unpack the specific precursors and triggers that make students aware of misunderstandings within a group. Preliminary findings could be used as a basis for design-based research where social metacognition is scaffolded.

From a methodological perspective, the theory based coding system further developed and validated in the present study was found to be sensitive enough to scrutinize and analyze the dynamic and multi-faceted nature of interpersonal regulation. Researchers across a wide range of studies have recognized the importance of rigorous analytical methods capable of generating reliable findings from coded interaction data (Azevedo et al. 2010; Chan 2012; Grau and Whitebread 2012; Volet and Vauras 2013). According to Volet and Vauras (2013), one of the major challenges faced by researchers is the need to accommodate for both general and context specific applications of coding systems. Generalizability is critical as it enables reliable comparisons of interpersonal regulation across age groups, tasks and different activities. Specificity or granularity (Azevedo 2009; Chan 2012) on the other hand, allows for closer, contextualized inspection of the activity or task under scrutiny, which is necessary to explore task-related differences within groups. The operationalization of a coding system that is too general may mean that group or task differences are only captured at a 'macro' level, and therefore produce minimally useful information from an educational perspective. The differences between groups or tasks may well lie at a 'micro' level of contextualized, fine-grained coding. As an illustration of the issue of granularity, differences in the metacognitive regulation of the two groups' second task were only uncovered when the contextualized sub-codes in the second stage of the coding system was applied. Analyzing the data solely at the
macro level of frequency and type of metacognitive regulation revealed no significant difference between the two groups.

The present study advanced research on interpersonal regulation by articulating and validating a comprehensive theory-based coding scheme for the analysis of cognitive and metacognitive regulatory processes in real-life, time-framed collaborative learning. Group differences in collective content understanding at the end of the activity could be linked to qualitative differences in group cognitive activity and metacognitive regulation processes during the collaborative task. There are however still many issues to unravel in the intricate inner workings of productive group engagement and social regulation. The fast development of innovative analytic methodologies that can capture, examine and interpret dynamic real-life collaborative regulation processes is one way forward. Another is continued theoretical developments into the significance of concurrent self and social regulatory processes. In light of the increasing use of small-group collaborative learning from school to university, studying the nature of productive collaborative learning is likely to dominate the research agenda for years to come.

Acknowledgment

This research was supported under the Australian Research Council’s Discovery Projects funding scheme (project number DP0986867).

References


Figure 1: Freestanding, transparent glass work-board used for filming students’ construction of their concept map
Figure 2: Three stage coding protocol for the analysis of cognitive and metacognitive activity
<table>
<thead>
<tr>
<th>Transcript from Group B’s meeting to construct their concept map (Task 2, turns 231 to 240)</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-level co-production</td>
<td>Cognitive activity</td>
<td>Metacognitive activity</td>
<td>Social nature and function of metacognitive activity</td>
</tr>
<tr>
<td>231 Renee: But then the more weight you lose the less you eat. ... Interrupted by Blanca who is frowning as Renee draws arrows from Azotaemia to Anorexia to Weight loss</td>
<td>231 EI</td>
<td>This episode of SSMR begins with Renee drawing arrows on the board to link the Azotaemia, Anorexia and Weight loss cards. Renee also starts to explore the idea that more weight loss also means eating less.</td>
<td></td>
</tr>
<tr>
<td>232 Blanca: No. Isn’t that the other way around? Frowning</td>
<td>232 SM</td>
<td>Renee’s arrow placement is instantly met with Blanca’s disagreement and trying to seek meaning in the arrow placement</td>
<td></td>
</tr>
<tr>
<td>233 Winnie: Gesturing with hand No, other way around.</td>
<td>233 VM</td>
<td>Winnie also volunteers that the arrows should be the other way around because “Anorexia is extreme weight loss”.</td>
<td></td>
</tr>
<tr>
<td>234 Blanca: Other way round.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>235 Winnie: Anorexia is extreme weight loss.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>236 Blanca: Yeah weight loss has to lead to Anorexia. Thea and Renee are talking at the same time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>237 Thea: Anor, Anorexia is the…looking at Winnie</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>238 Renee: But that tapping Azotaemia card you’re not feeling well, so you don’t want to eat, therefore he loses weight Matt tries to say something but Renee continues to speak as she has now turned to look at the group and specifically at Winnie. Anorexia is not eating, it has nothing to do with weight. See he’s not feeling well so he stops eating therefore he loses weight. Referring to the Azotaemia, Anorexia and Weight loss cards in turn</td>
<td>238 CD</td>
<td>The transition to high-level co-construction begins with Thea starting to make sense of what is being said when Renee volunteers explicit meaning for the direction and placement of the arrows and concludes from her own explanation that the order of her arrow placement is correct and that anorexia means “not eating” rather than “weight loss”</td>
<td></td>
</tr>
<tr>
<td>239 Winnie: Okay Nodding. Blanca and Thea also nod.</td>
<td></td>
<td>Winnie openly accepts this explanation with Blanca and Thea also nodding in agreement, bringing this episode to an end and to the start of the next episode.</td>
<td></td>
</tr>
<tr>
<td>240 Matt: You could put those here, and then draw…</td>
<td>Low-level co-production</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: EI: Explore ideas, SM: Seek meaning, VM: Volunteer meaning, CD: Conclude from discussion, SSMR: Socially Shared Metacognitive Regulation

Figure 3: Example of a coded extract featuring high-level co-production and high-level co-construction and three students engaged in SSMR of the group cognitive activity
Table 1: Second stage coding protocol: Theoretical codes, contextualized sub-codes and empirical indicators

<table>
<thead>
<tr>
<th>Theoretical codes</th>
<th>Contextualized sub-codes</th>
<th>Empirical Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Low level would involve putting forward a proposal on how the group should approach the task at hand. High level would involve conceptual justification.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring</td>
<td>Regulatory processes that shift the cognitive flow from high- to low-level talk or maintain low level talk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seek information (SI)</td>
<td>Asking for more factual information to assist with the group’s current understanding of the task or content, often a tentative enquiry.</td>
</tr>
<tr>
<td></td>
<td>Add information (AI)</td>
<td>Injecting new factual information to bring the group back into gathering facts or pursuing content discussion. This may also include adding information that was previously discussed.</td>
</tr>
<tr>
<td></td>
<td>Reflect on task (RT)</td>
<td>Reflecting on what is required to complete the task or what has been done so far. In the concept map activity, it may also involve reflections on what cards to select or links to draw without any discussion of meaning.</td>
</tr>
<tr>
<td></td>
<td>Stop discussion (SD)</td>
<td>Stopping the flow of discussion to bring the group to a decision or action point. It could trigger the end of an episode of high-level talk.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Regulatory processes that shift the cognitive flow from low- to high-level talk or sustain high level talk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seek meaning (SM)</td>
<td>Asking questions that would enhance the group’s conceptual understanding of the case.</td>
</tr>
<tr>
<td></td>
<td>Volunteer meaning (VM)</td>
<td>Proposing an explanation, elaboration, or interpretation that enhance the group’s conceptual understanding of the case. It could be based on knowledge and understandings from readings or experience.</td>
</tr>
<tr>
<td></td>
<td>Explore ideas (EI)</td>
<td>Engaging in tentative explanations, interpretations or speculations to enhance the group’s conceptual understanding of the case.</td>
</tr>
<tr>
<td></td>
<td>Question meaning (QM)</td>
<td>Questioning the group’s current conceptual understanding of aspects of the case with a view to clarify or rectify that understanding.</td>
</tr>
<tr>
<td></td>
<td>Conclude from discussion (CD)</td>
<td>Concluding from the group’s tentative conceptual understanding of aspects of the case to make a decision about the task or the group’s conceptual understanding of the case.</td>
</tr>
<tr>
<td></td>
<td>Justify decision (JD)</td>
<td>Justifying a task-related decision on the basis of the group’s conceptual understanding of the case.</td>
</tr>
<tr>
<td></td>
<td>Reflect on meaning (RM)</td>
<td>Reflecting on the group’s current understanding of the content or case and what is needed to further enhance understanding.</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Low level would involve checking that all task requirements or all aspects of the content or case have been considered. Can refer to favourable or unfavourable evaluation. High level would involve conceptual justification.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Table 2: Breakdown of cognitive activity by orientation and level, for the two groups in Tasks 1 and 2

<table>
<thead>
<tr>
<th>Cognitive activity</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group B</td>
<td>Group A</td>
<td>Group B</td>
</tr>
<tr>
<td>By orientation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task co-production</td>
<td>145 17.8%</td>
<td>574 68.7%</td>
<td>205 70.7%</td>
</tr>
<tr>
<td>Knowledge co-</td>
<td>669 82.2%</td>
<td>261 31.3%</td>
<td>85 29.3%</td>
</tr>
<tr>
<td>By level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>163 20.0%</td>
<td>44 5.3%</td>
<td>169 58.3%</td>
</tr>
<tr>
<td>Low</td>
<td>651 80.0%</td>
<td>791 94.7%</td>
<td>121 41.7%</td>
</tr>
<tr>
<td>By orientation and level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task co-production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>29 3.5%</td>
<td>3 0.4%</td>
<td>87 30.0%</td>
</tr>
<tr>
<td>Low level</td>
<td>116 14.3%</td>
<td>571 68.3%</td>
<td>118 40.7%</td>
</tr>
<tr>
<td>Knowledge co-construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>134 16.5%</td>
<td>41 5.0%</td>
<td>82 28.3%</td>
</tr>
<tr>
<td>Low level</td>
<td>535 65.7%</td>
<td>220 26.3%</td>
<td>3 1.0%</td>
</tr>
<tr>
<td>Total</td>
<td>814 100%</td>
<td>835 100%</td>
<td>290 100%</td>
</tr>
</tbody>
</table>
Table 3: Breakdown of metacognitive regulation, by level of monitoring, and further into contextualized sub-codes for each group in Task 1 (Generating learning objectives)

<table>
<thead>
<tr>
<th>Grp</th>
<th>Monitoring low-level</th>
<th>Monitoring high-level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SI</td>
<td>AI</td>
</tr>
<tr>
<td>B</td>
<td>15 10.0%</td>
<td>23 15.3%</td>
</tr>
<tr>
<td></td>
<td><strong>Total low-level: 91; 60.7%</strong></td>
<td><strong>Total high-level: 59; 39.3%</strong></td>
</tr>
<tr>
<td>A</td>
<td>22 19.1%</td>
<td>16 13.9%</td>
</tr>
<tr>
<td></td>
<td><strong>Total low-level: 110; 95.6%</strong></td>
<td><strong>Total high-level: 5; 4.4%</strong></td>
</tr>
</tbody>
</table>

**KEY:** Monitoring low level: SI: Seek information; AI: Add information; RT: Reflect on task; SD: Stop discussion; Monitoring high level: VM: Volunteer meaning; EI: Explore ideas; SM: Seek meaning; QM: Question meaning; RM: Reflect on meaning; CD: Conclude from discussion; JD: Justify decision.
Table 4: Breakdown of metacognitive regulation theoretical code for Monitoring low- and high-level talk, and further into contextualized sub-codes, for each group in Task 2 (Constructing concept map)

<table>
<thead>
<tr>
<th>Grp</th>
<th>Monitoring low-level</th>
<th>Monitoring high-level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SI</td>
<td>AI</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4.8%</td>
<td>7.9%</td>
</tr>
<tr>
<td>Total low-level: 17; 27.0%</td>
<td>Total high-level: 46; 73.0%</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>24.4%</td>
<td>15.6%</td>
</tr>
<tr>
<td>Total low-level: 28; 52.2%</td>
<td>Total high-level: 17; 37.8%</td>
<td></td>
</tr>
</tbody>
</table>

**KEY**: Monitoring low level: SI: Seek information; AI: Add information; RT: Reflect on task; SD: Stop discussion; Monitoring high level: VM: Volunteer meaning; EI: Explore ideas; SM: Seek meaning; QM: Question meaning; RM: Reflect on meaning; CD: Conclude from discussion; JD: Justify decision.
Making clinical case-based learning in health sciences visible: Analysis of collaborative concept mapping processes and reflections.

PAPER 4

The following version of this paper is the most recent submission for the journal review process.
Making clinical case-based learning in veterinary medicine visible: Analysis of collaborative concept mapping processes and reflections

Abstract

The value of collaborative concept mapping in assisting students develop an understanding of complex concepts across a broad range of basic and applied science subjects is well documented. Less is known about students’ learning processes that occur during the construction of a concept map, especially in the context of clinical cases in veterinary medicine. The aims of this study were to investigate the unfolding collaborative learning processes that took place in real-time concept mapping of a clinical case by veterinary medical students, and to explore students’ and their teacher’s reflections on the value of this activity. This study was in two parts. The first part investigated the cognitive and metacognitive learning processes of two groups of students that displayed divergent learning outcomes in a concept mapping task. Meaningful group differences were found in their level of learning engagement in terms of the extent to which they spent time understanding and co-constructing knowledge, alongside completing the task at hand. The second part explored students’ and their teacher’s views on the value of concept mapping, as a learning and teaching tool. Students’ and their teacher’s perceptions revealed congruent as well as contrasting notions about the usefulness of concept mapping. The relevance of concept mapping to clinical case-based learning in veterinary medicine is discussed, alongside directions for future research.

Introduction

Central to effective learning in science is the development of a deep understanding of the basic core scientific concepts upon which further knowledge can be built. A number of researchers in science education have argued that scientific knowledge is more web-like rather than linear in its organisation, which has led to the view that scientific concepts should be learnt as inter-related knowledge networks and not as listed facts. In the context of tertiary science education, it has been claimed that many students see science as an accumulation of disconnected facts and ideas, rather than an integrated
network of knowledge where scientific concepts are both situated and related in a way that makes sense to the learner\textsuperscript{3,4,5}.

Recognising the interconnected nature of scientific knowledge has led to numerous investigations of the usefulness of concept mapping both as a learning tool, to facilitate the construction of inter-related concepts, and as a research tool to explore the interconnectedness of students’ knowledge representations. Less studied is the extent to which students’ engagement in cognitive and metacognitive processes while co-constructing a concept map in real time is related to the quality of their completed map. Also under-examined are students’ own accounts and reflections of engaging in such an activity, and how this relates to their teacher’s perspective. The two studies presented in this paper addressed these issues.

**Concept mapping as a learning tool**

Novak and Gowin\textsuperscript{6} are widely recognised as being the first to propose the technique of concept mapping to observe and record changes in children’s understanding of scientific concepts. The authors developed a two-dimensional knowledge representation tool, showing concepts that identified specific ideas, and the links between them to explain how the concepts are related to make meaning. The combination of a pair of concepts and their respective link makes up a single proposition. Later in the evolution of concept mapping, Novak\textsuperscript{7} defined a concept map as being made of any number of propositions to display an overall understanding of a particular idea or phenomenon. Since initial development, concept mapping has been applied to the teaching of complex scientific concepts in physics, biology, physiology, as well as veterinary and medical education\textsuperscript{8-15}.

The benefits of concept mapping to students’ learning have been extensively explored. Perhaps the best aspect of concept mapping in enhancing science learning is its capacity to provide a visual and spatial display of intertwined and often abstract knowledge\textsuperscript{11,16}. Another important benefit is to foster structural learning and conceptual organisation, thus facilitating learning that is meaningful\textsuperscript{4}, This is consistent with the notion that meaningful learning is the means and ability to structure complex, intertwined material, not just the ability to assimilate large volumes of information\textsuperscript{17}. It follows that concept
maps may enable the expression of meaningful learning through their construction, that is, the presentation and organisation of relevant contextualised concepts, coupled with links to explain inter-relatedness. Finally, as complex material is conceptually organised and therefore simplified, commitment to memory and its subsequent recall becomes automatic as the cognitive workload is reduced.

Concept mapping has also been conceptualised as a way of organising fragmented knowledge. It may assist in the identification of connections between concepts previously unrecognised by learners. It has been shown that concept mapping can also serve as a metacognitive tool, where new material converges with existing cognitive structures, and as a valuable summary and revision tool when copious volumes of material need to be condensed.

As widely documented in the literature, the benefits of concept mapping are directly applicable to students’ learning in science from schools to university contexts. In research involving nursing students; medical students; and medical and veterinary students, where learning material involves voluminous and complex concepts with multi-interwoven connections whose relations may not be initially apparent, the value of concept mapping as a learning tool has been shown.

Another reported benefit of concept mapping, as a learning tool for high-school chemistry; science; and physics students, is that it facilitates teachers’ identification of gaps in students’ understanding of concepts and their links. It also helps learners identify deficiencies in their knowledge, assisting them in monitoring their own learning.

**Concept mapping in collaborative learning**

It is well established in the literature on collaborative learning that when peers work on a shared task, mutual understandings must be created and sustained continuously. Collaborative concept mapping provides a communal learning site where participants’ co-constructed meanings and knowledge are made visible, thereby facilitating collaboration. Some empirical studies have shown concept mapping to be a highly productive way of increasing students’ engagement in collaborative knowledge.
construction and reciprocal scaffolding. Roth and Roychoudhury’s analysis of students’ discourse during a high school physics collaborative concept mapping task shed light on the process of meaning construction. The authors concluded that concept maps, “as a metacognitive tool may provide an ideal context for overt negotiations of meaning and construction of knowledge because they require individuals to externalize their propositional frameworks … particularly when students collaboratively construct these maps” (p. 505). Similarly, van Boxtel et al. argued that concept mapping “is a powerful task because it stimulates and supports the articulation, elaboration, and co-construction of meaning and sense” (p. 45). Roth and Roychoudhury also noted the value of concept mapping as a research tool in observing students’ processes of making meaning from a learning task.

**Collaborative concept mapping as a research tool**

A large body of empirical research has used collaborative concept mapping as a research tool to investigate collaborative development of knowledge. For example, recent research demonstrated concept mapping to be a stable and powerful tool in understanding and evaluating groups’ representation of group cognition. In that study, group cognition referred to the combined knowledge representations emerging from peer interactions and their transformations during group discussions and learning. The authors argued that collaborative concept mapping was a more reliable research tool to investigate group level cognition as a holistic group level phenomenon, than was the use of aggregation methods. This is an important distinction in light of the observation that concept map research in small group contexts tends to examine the aggregation of individually constructed maps rather than how groups of students jointly construct a single map to represent their collective understanding.

Overall, three areas have received limited attention in research on collaborative concept mapping. The first, highlighted in a meta-analysis by Nesbit and Adesope, is the identification of the learning processes involved in concept map construction as it unfolds in real time. The second is the use of authentic clinical case material in science-based collaborative concept mapping, whereas most previous studies were conducted mainly in the context of lectures and textbook knowledge. A third area is the need to
elicit both students’ and teachers’ perceptions of the value of collaborative concept mapping in a real-life learning environment.

The studies presented in this paper addressed two research aims:

- To determine the extent to which students’ engagement in cognitive and metacognitive processes while collaboratively completing a concept map of a clinical case can explain differences in their collective understanding of that case (Study 1).

- To explore students’ accounts and reflections on the value of collaborative concept mapping to enhance their understanding of a clinical case, and their teacher’s views of the potential of concept mapping as an instructional tool to facilitate students’ understanding of clinical cases (Study 2).

Both studies aimed to provide an ecologically valid and relevant insight into concept map collaborative learning processes in the context of veterinary physiology.

**Study 1**

As highlighted by Nesbit and Adesope, there are few detailed analyses of concept mapping in the literature. One study examined high school aged physics students constructing concept maps in dyads to demonstrate their understanding of electrical concepts. Students’ interactions were coded in terms of question episodes, conflict episodes and reasoning episodes. Another study explored how educational psychology students solved a case problem through constructing a concept map. Students’ speech acts were coded in terms of externalisation, elicitation, integration-oriented consensus building and conflict-oriented consensus building. Though valuable contributions to micro-level analysis of concept mapping, neither of these studies explored how groups regulated their collaborative cognitive and metacognitive activity to complete the task. Given the importance and considerable research attention directed at research into social regulation in collaborative learning, the first study addressed this gap.
Methodology

The research site for the concept mapping activity was the real-life clinical case-based group assignment of a second year physiology unit in veterinary medicine. The assignment was the same each year, which enabled follow-up research on the same task with different cohorts. This group assignment required groups of five or six students (self-selected membership) to work on a real-life, complete clinical case file (containing unedited clinical records) in their own time over a six to seven week period. The instructional aim was to offer students an opportunity to apply primary preclinical knowledge attained thus far in their degree program to investigate various disease processes and related treatments, presented in each case file. Cases were randomly allocated. After reading though the record for the case that had been assigned, each group of students was required to identify the main features of the case and to generate a set of 4 to 5 learning objectives specific to their case. These learning objectives were used by groups to guide their background research, and a mandatory ten-minute oral presentation to the rest of the class at the end of the semester. The teacher met with each group twice over the duration of the assignment. The main purpose of the first meeting was to guide the writing of the learning objectives, ensuring that they were relevant to the case and achievable within the time available for the assignment. The main purpose of the second meeting was to ensure that groups were progressing satisfactorily. Students received a group mark based on their performance in the class presentation and subsequent question and answer session, making up 10% of the overall physiology mark.

Groups were invited to complete the concept mapping activity after they had completed background research on their case. Video recordings, subsequently transcribed for coding purposes, were made of each group as they completed their maps. The year this study was undertaken, there were 15 groups in the class, and 12 consented to participation in the research. The non-participating groups were given the option of completing the case mapping exercise. University ethics approval was granted for all aspects of this research.

Students were provided a set of concept cards extracted from their specific case and based upon the learning objectives generated by each group. Students arranged the cards
on a freestanding, transparent glass work-board in a manner that made sense to the entire group, and then connected the cards with either unidirectional or bidirectional arrows indicating either a cause-effect relationship or an inter-related relationship. There was no time limit imposed. Once completed, and for educational purposes, one of the researchers (an experienced veterinary clinical instructor) provided feedback on the arrangement of cards and their links, and answered questions about case content. The aim of the exercise was to facilitate and measure students’ overall understanding of the case rather than to explore specific, individual concepts.

**Scoring students’ concept maps.** This was done as a three-stage process. Firstly, two veterinary medical experts independently constructed a concept map for each case using the same cards provided to students. Secondly, the experts met and decided on a final map for each case. Some mutually agreed-upon alternatives were included for each case to take into account the possibility of acceptable alternatives in, for example, methods of diagnosis or treatment plans. Thirdly, the final expert maps were used as a benchmark against which students’ maps were assessed. Each group map was given a percentage score, which represented the proportion of links that were exactly the same between student and expert maps. This assessment revealed scores that ranged from 56% to 92%, with a mean of 78.2% and a standard deviation of 9.5.

**Coding students’ learning processes during concept mapping.** Two groups with extreme scores of 56% (Group A) and 92% (Group B) were selected for this study. The complex, comprehensive coding system, detailed in Khosa and Volet was used to compare the two groups’ engagement in cognitive and metacognitive processes as they jointly constructed the concept map of their clinical case. This coding system captured the orientation of students’ cognitive talk, whether focusing on task production (the map) or knowledge construction (scientific understanding), and whether at high or low level of depth. It also captured how students regulated the progress of their cognitive activity, in terms of planning, monitoring and evaluation. Coders were blind to how the two groups’ concept maps related to the expert maps.

**Results**
The findings of the two groups’ engagement in cognitive activity and metacognitive regulation, as they constructed their concept map in real-time, are summarised in Table 1.

**INSERT TABLE 1 ABOUT HERE**

The top part of Table 1 compares the two groups’ engagement in cognitive activity, divided up into engagement in task co-production or knowledge co-construction. Task co-production refers to talk focusing on producing the concept map (i.e. the task to be completed), and knowledge co-construction to talk relating to the clinical case content. Both task co-production and knowledge co-construction talk were further divided into high- and low-levels, to capture the depth of cognitive engagement while constructing knowledge or producing the map. Low-level refers to students either identifying and highlighting content knowledge or discussing concept cards and link organisation. High-level refers to talk aimed at understanding the clinical case, elaborating on case material, or adding conceptual justifications when selecting concepts and their links.

The two groups’ engagement in cognitive activity differed significantly. Group A did not engage in any knowledge co-construction. All of Group A’s talk was directed at task co-production, of which 75.4% was at low-level. In contrast, Group B spent a third of their engagement on co-constructing knowledge with 28.3% at the high level. Moreover, 30% of Group B’s task co-production included conceptual justifications (high-level).

Further contrasting patterns emerged when metacognitive regulation of cognitive activity was examined (see bottom part of Table 1). It should be noted that metacognitive regulation (planning, monitoring and evaluation) was coded as low or high depending on the level of the cognitive activity being regulated.

Planning at high level was not evident in either group. Minimal planning at low level was present in both groups with Group B (8.7%) exceeding Group A (4.2%). Furthermore, neither group displayed any evidence of evaluation. Group B spent most of their efforts (69.6%) monitoring their cognitive activity at the high-level, while Group A spent just 36.2% at this level and over half (59.6%) at the low-level. This
suggested that the marked group differences in knowledge co-construction and task co-production (cognitive activity), and associated monitoring of these activities (metacognitive regulation) may have contributed in explaining the quality difference of their concept maps (Group A: 56%; Group B: 92%).

Group differences in cognitive activity and metacognitive regulation, as they jointly constructed a concept map of their clinical case, were largely consistent with the qualitative differences found in their final map. This finding supports the use of concept mapping as a research tool to uncover the nature of productive collaborative learning, specifically, the nature of productive engagement in cognitive activity and metacognitive regulation. How students and their teacher perceived the value of concept mapping as a learning tool or as a teaching tool, respectively, was addressed in Study 2.

**Study 2**

With some exceptions\(^{28,10,34,13,35}\), research on students’ views of concept mapping is under-represented in both the general science and veterinary medical education literature. Roth\(^{13}\) stated that eliciting students’ reflections on concept mapping in physics is important since “As teachers, we have often implemented teaching-learning strategies without asking students whether these strategies make sense to them, whether they find them helpful as they try to learn in our subject areas, or whether and what they learn about learning as they engage in constructing new knowledge” (p. 25). The present study was undertaken to gain insight into how students learn and what students themselves think of the learning process. This information is paramount if concept mapping is to be used successfully in science and veterinary medical education.

Similarly, little is known about teachers’ perspectives of how students learn from concept maps. Some studies have explored teachers’ perspectives on using concept maps in classrooms\(^{12}\), or have observed the role of teachers in concept mapping\(^{36}\), but little empirical attention has been given to teachers’ understandings about how students learn from participating in collaborative concept mapping.

*Methodology*
Study 2 involved the same case-based group assignment as Study 1, with a new student cohort, embedded into regular teaching, with no filming, research observations, or assessment of the produced maps. The concept map exercise was undertaken during the second meeting with the teacher, and presented as a useful learning exercise to consolidate understanding of the case and prepare for the class presentation. The concept map construction procedure was the same as for Study 1, including teacher feedback to address any content misunderstandings.

**Students - data collection and analysis.** Students’ views on the value of learning from the concept mapping exercise were elicited in a guided written reflection exercise embedded within the case-based assignment. This exercise contained ten questions, and formed 5% of the unit mark. One question addressed the concept mapping exercise, “In regard to the concept mapping activity (during the second meeting with your teacher), how useful do you consider such an activity was, to gain a better understanding of the case as a whole? Also, how useful is it for students to bring their thoughts together at the time they are putting their presentation together? Please explain your answer.” This question was designed to elicit reflections on two aspects of the concept mapping exercise: completion of the required activity (task production), and the opportunity to learn case content with and from each other while completing the activity (knowledge construction). The cohort of 87 students completed the exercise and 80 consented for their reflections to be used for research purposes.

To gain a comprehensive overview of all responses, a direct, thematic content analysis was undertaken, followed by magnitude coding to indicate frequencies of the categories. To gain familiarity with the data, all 80 responses were read multiple times by two coders and initial codes were produced. Themes were then generated, refined, defined, and named for coding purposes. Inter judge reliability was established through double coding of 10/80 or 12.5% responses, achieving a satisfactory 80% agreement. The teacher was not involved in any aspect of the coding and the teaching evaluation of the reflection exercise was undertaken separately to the research.

**Teacher - data collection and analysis.** A conversational-style interview was used to elicit the teacher’s perceptions of the instructional value in asking students to
collaboratively construct a concept map of their clinical case file. The (70 minute) interview was audio recorded and fully transcribed for analysis.

**Results**

*Students - perceptions of the usefulness of concept mapping.* Five thematic categories emerged from the data: three learning-related themes of big picture of knowledge, focus and flow of knowledge, and management of understanding; and two task-related themes of completion of concept map and/or assignment, and completion of class presentation. These five themes, with examples, are presented in Table 2.

The process of categorisation of data into themes was relatively straightforward, although occasional overlap emerged. For example, in a single statement a student could reflect on the development of a big picture of their knowledge but also mention focus and flow of knowledge. Where it was not possible to clearly demarcate themes at the statement level, the predominant theme was given precedence for coding.

One third (32.5%: 26/80) of students’ responses primarily focused on learning case content and understanding related concepts, mentioning at least two learning-related themes. In contrast, 13.7% (11/80) of students made comments that were exclusively focused on task-related aspects, with no reference to learning-related themes. These students appeared to be mainly focused on meeting the instructional requirements.

To gain further insight into students’ perceptions of the usefulness of the concept mapping exercise, the five themes are outlined and illustrated with examples.

*Big picture of knowledge (learning-related theme).* The theme “big picture of knowledge” captured students’ views that the mapping task was helpful in seeing their clinical case as a whole, integrating complex and sometimes confusing case content, and highlighting any missing information.
Thirty-five percent (28/80) mentioned the usefulness of concept mapping to develop an overview of their clinical case. Some students saw the opportunity of collectively viewing the case in its entirety for the first time, for example, it was the first time the case could be projected as a whole instead of just fragments (S56) and It also helped us to link various parts together and to take a step back to look at the case as a larger picture since we were only looking at our individual chunks of information prior to that (S1).

Some students pointed to how individual research efforts were integrated, unveiling research gaps and overlooked information, for example how the concept map made us think of the other sections of the case that the other group members were researching and how they relate to our own section we individually researched (S12). One student reflected that it reminded us to look at the bigger picture and the other effects of our disorder, which we had previously ignored (S18).

Flow and focus of knowledge (learning-related theme). This theme refers to students’ views that the concept map exercise helped them visualise connections and relationships of key concepts involved in the clinical case. 42.5% of students (34/80) mentioned such views. Some saw the exercise as simplify[ing] the whole case into a few main points, and by connecting these points, the case could be understood in a simple way (S8). One student thought it made it possible to see clearly which parts related to what and that, of course, some were related to many factors (S11).

A few students mentioned that the visual representation of the main case components and their connections gave a focus to their research think about the causes and effects logically ... gave us a guided structure of how the disease occurred and what factors to focus on (S25). Similarly, the mapping session did us good by marking the focus of this clinical case our group struggled quite a bit to find all the focus points of this case... (S59).

The opportunity of discussing the order, flow and direction of the clinical case with the aid of the arrows linking concepts was a related area of reflection. Some students claimed that understanding the flow of the case helped them understand the underlying physiology concepts made us question which aspects of the case could work in more...
than one direction, and how different aspects could have an effect on one another ... was useful in trying to understand the physiology behind the case (S28), also ... discussing the order of the cards amongst ourselves certainly ensured that we had a similar understanding of the case (S33).

Management of understanding (learning-related theme). The most frequently mentioned theme related to the usefulness of concept mapping for content-related reasons was management of understanding. 48.8% (39/80) of students mentioned concept mapping to be a useful tool for the group to assess their progress and collective understanding of the material. For some, completing the concept map contributed to building their confidence ... a great tool for bringing information to the table ... some had different views of how the case was put together and this gave an opportunity for discussion ... allowed those who knew the case better to share their opinions (S15). I feel that the mind map gave us confidence that we had a pretty good idea what we were talking about (S29).

Comments were also made about the mapping activity providing an opportunity for questioning each other, identifying errors, and allowing different opinions relating to the case material to be shared ... a quick test of the information we’ve been reading and learning about... questioning this allows for discussion and broader thought processes (S27) and ... allows for the potential of errors to be rectified, and for members to discern the clinical significance and importance of the different areas (S26).

Completion of concept map and/or assignment (task-related theme). This theme captured students’ reflections related to the completion of the concept map or the case based assignment as a whole. Students often declared that completing the concept map was part of completing the assignment with fifty percent (40/80) making statements that fitted within this theme. Some reflected on the approach used by their group to construct their concept map, and how useful or challenging they found the activity ... we were undecided on where a particular card should go... at the end we just made a decision and left it as it is, but we all went back to do more research on it, and came up with a conclusion (S54). Another student commented ... everybody in the group knew the basic relationships and links between the ‘words’ that were given. Once we got the basic relationship sorted, our group went into detail and talked to each other about how
one relates to another ... although we didn’t agree with all the links, we compromised and made sure that the final map was all agreed upon (S57).

A few students suggested it would have been useful for groups to create their own cards, as in their opinion, the set that was provided had concepts missing, ... I feel there were a few vital keywords missing from our mapping activity that would have been good to have in order to fully map our case study and gain a better understanding (S70).

Students’ reflections on the usefulness of the concept map exercise were often accompanied with reflections on how easy or challenging they found the activity. It was perceived as easy when placing the cards and drawing the arrows was decided quickly within the group. It was reported as a challenge when students were unsure about card placement and added they would need to do further research to help better understand the concepts.

Completion of class presentation (task-related theme). This theme was expected to predominate in students’ responses, since the class presentation determined to a large extent the assessment of the groups’ clinical case based assignments. Unsurprisingly, 63.8% (51/80) students referred to the usefulness of the concept map exercise for the preparation of their class presentation. Some pointed to its value for developing a coherent and flowing presentation that aided their audience and their own overall understanding of the case at the same time, ... helps to ensure flow throughout the presentation instead of having chunks of ‘unrelated’ information ... it improves the quality of the presentation and helps the audience understand the ‘bigger picture’ of the case (S1).

Another student stated … In order for an intelligible, smooth flowing speech the presentation must have a degree of unity, which is made easier if people’s thoughts are in harmony. The final presentation should sound like a single speech that is broken up into a number of parts, rather than several speeches brought together with only a somewhat tenable connection ... the mapping exercise was useful in bringing our thoughts together, which is of great importance to the proper presentation of the case as a whole (S73).
As mentioned previously, not all statements fell into a single theme, with some intertwining of learning-related and task-related themes. For example, references to developing a big picture and a better understanding of the flow of knowledge related to the clinical case were evident in some students’ reflections on the value of concept mapping to prepare their class presentation. These students displayed an awareness of how constructing a meaningful, coherent presentation was beneficial not only to them (given the presentation was assessable) but also to the audience. A few students observed the value of concept mapping to organise complex information in a meaningful way, and that it potentially enabled a systematic, quick recall of information to answer questions following their presentation.

Overall, the thematic analysis of students’ responses showed that most students perceived concept mapping as a useful tool to gain a clear visual overview of their case, helping to organise and connect key concepts, providing order to the complex, entwined case material, and as a means for the group to assess their progress in collectively understanding the case. An additional benefit of concept mapping was that it provided students with the opportunity to question each other, identify errors and to exchange differing opinions about case understanding.

**Teacher - perceptions of the usefulness of concept mapping.** The teacher commenced with reflection on the overall case-based assignment and the use of concept mapping during his formal meeting with student groups, primarily focusing on the learning issues. He articulated the challenging complexity of the assignment and the value of concept mapping to address some of the learning challenges experienced by students, ... these are case records, basically records out of the clinic ... they are expected to pull out the normal and the abnormal physiology and sometimes they have difficulties ... the biggest problem is knowing what is important ... I think the concept maps help them do that...

The teacher observed that most groups had managed to construct their map with relative ease, citing group preparedness and organisation as key factors in expediting the construction of maps. For the groups that may not have been well prepared, he reported providing guidance in how to construct the map, advising that his suggestions were directed at a method of map construction rather than the arrangement of cards and
arrows ... if they couldn’t draw the arrows properly then I said to them maybe pick a main point ... make that the centre ... have everything else radiating from that ... but that’s not telling them how to arrange it ... just suggesting maybe have a central point.

He stressed the importance of providing feedback on the final product, and addressing any error so that students did not leave the meeting with erroneous information ... if there are any factual errors ... there might have been relationships between various points on the cards that I might have asked them about ... you can’t let them have incorrect information.

The opportunity to listen to students’ interactions as they constructed their concept map enabled the teacher to gauge each group’s collective level of understanding of their clinical case. He reported observing how some groups benefited from paying attention to the links between concepts ... revealing relationships that they hadn’t thought about before between various facts of the case ... probably could have given a bit more understanding out of the case...

In regard to performance, the teacher mentioned that although some students were seeking feedback about the content material to include in their class presentations, in most cases they just wanted confirmation that they were on the right track with the information they planned to present. When prompted to comment on whether the concept mapping exercise may have helped students prepare for their class presentation, ... my perception was that it didn’t help their presentation ... just looking at the marks, and the general quality of talks, I can’t see that they have really changed over the years...

Finally, the teacher was asked to speculate on what he thought students would say about the value of constructing a concept map of their clinical case. He believed that students would have similar views to his own emphasis on the learning aspects of the group concept mapping exercise, based on his observations of students’ interactions while constructing their map.

The teacher’s reflections stressed the value of concept mapping for both student learning and instructional purposes, while playing down its usefulness for performance
purposes. The teacher made several references to his observations of students’ discussions while constructing their maps, and how these helped him to improve his feedback. The decision to incorporate concept mapping as a regular feature of the case-based clinical group assignment indicates that the teacher found concept mapping to be useful in clinical case-based learning.

Discussion

The unfolding learning processes that took place as veterinary medical students constructed a collaborative concept map of a clinical case, and the students’ and their teacher’s reflections on the value of this activity as a learning and teaching tool were explored.

The detailed, coding system used toanalyse cognitive and metacognitive learning processes was effective in highlighting differences in two groups with divergent learning outcomes in a collaborative concept mapping task. This is consistent with the claim that the investigation of learning processes used by students use in concept mapping should also be related to higher-level learning goals such as problem solving and application of knowledge.

In the present study, high-level engagement in cognitive and metacognitive learning processes was evident as students attempted to understand the clinical case, to elaborate and discuss case material, and to add conceptual justifications when selecting concepts and their links. Analysing the levels (or quality) of cognitive engagement in collaborative learning is important given that high-level knowledge co-construction is considered to be the most effective type of learning process in peer learning. Previous research provided evidence that analysing the quality of cognitive and metacognitive regulatory activity in students’ collaborative interactions is especially useful in elucidating differences in the way students engage in effective and less effective peer learning.

Consistent with these previous studies, the findings suggested that some students engage in high-level collaborative learning processes and meaning making. In particular, the present study showed that it was possible for some students to do this when they used concept mapping to negotiate complex case-based learning. This
suggests that the development of an instructional intervention to facilitate and scaffold the use of cognitive and metacognitive learning processes in concept mapping, particularly to construct knowledge at the high-level in case-based learning, may be a useful future study.

The differences in quantity and quality of cognitive and metacognitive activity are one reason the two groups in Study 1 displayed divergent learning outcomes. Speculatively there may be other reasons, such as varying learning goals and levels of interest. The better performing group may have pursued the goal of maximising the learning opportunity from the concept mapping task, with the desire to gain a more complete understanding of the case material. In contrast, the lower performing group may have had the intention of simply completing the task in the most efficient way. Since learning from clinical case files was a new experience for most students and the two groups did not differ significantly in their aggregate marks in physiology, the group differences in engaging in the activity could not be explained in relation to prior knowledge or previous experience.

The challenging nature of learning from clinical case files as compared to more traditional textbook or lecture-based learning would have served as an equaliser for all groups, with all students finding this assignment quite demanding. Even if there were differences in the complexity of cases, students were required to set four of five learning objectives on which they based their research and addressed in their presentation. To some extent, the use of this set of learning objectives would have tended to negate differences in the complexity of cases. One limitation in this study was that students were limited in the choice of concepts provided to them. A few students mentioned that creating their own set of concept cards may have provided a more complete picture of the case, as they felt there might have been concepts “missing”. Even if students had been allowed to create all their own concept cards, they would still have been constrained within the learning objectives generated by the group. Giving students the freedom to create their own concept cards also assumes that second year students are able to identify the concepts that are important in constructing an understanding of their clinical case. Future iterations of this same concept mapping task will likely involve students been given a set of concepts based upon their learning objectives, and additional blank cards to add concepts they feel are also relevant for their case.
Exploring students’ perceptions of using concept mapping to learn from clinical case files revealed thematic responses that were generally consistent with past research. Consistent with previous observations ⁴ that concept mapping is beneficial to structure learning and conceptual organisation, in our study, students reported that the concept mapping exercise allowed them to see connections and relationships of key concepts in the clinical cases, and provided an opportunity to discuss the flow, direction and order of the clinical concepts. Their reflections on the use of concept mapping to manage their understanding of the case material were also consistent with conceptualisations of concept mapping as a way of organising fragmented knowledge ⁵,⁴, and serving as a metacognitive tool where new material and prior knowledge converge to enhance understanding ¹⁸,¹⁴. Students’ accounts also revealed how they used concept mapping to assess their collective understanding of the case, identify errors, question each other’s understanding and increase their levels of confidence if they felt all group members were contributing to complex discussions. Surprisingly (given the hint in the guided reflection question), and contrary to the literature that has stressed the best benefit of concept mapping as an excellent means of providing a visual and spatial ‘big picture’ display of knowledge ¹⁶,¹¹, in our study, this aspect was less represented when compared with other thematic categories. One possible explanation is that since this was the students' first exposure to real-life clinical information, the opportunity offered by the concept mapping exercise to better understand the complex and detailed case file content, was perceived as being of greater importance than gaining a overall view of their case.

Consistent with students’ reflections, the teacher stressed how case content understanding could potentially be enhanced using concept mapping. The teacher’s opinion that the concept maps would not necessarily help students in their preparation for the class presentation was in contrast to students’ views that the maps were very helpful in preparing their presentations. The teacher’s comments about providing feedback to correct factual errors after listening to interactions as students constructed their maps, provided evidence that the teacher placed more emphasis on concept map for understanding of content rather than for preparing the presentations. Providing feedback and monitoring students’ understanding as they constructed their maps, may have been a key method for the teacher to help students better understand their cases, rather than simply as a means for improving assignment marks.
The extant literature suggests concept mapping is more effective for knowledge retention and recall than textbook- or lecture-based learning\textsuperscript{27}, particularly useful when deep-level conceptual understanding and application are required\textsuperscript{15}, or course objectives require students to link concepts\textsuperscript{28,10}. The present study provided evidence that concept mapping may be extended to situations in which students are required to learn from case files or clinical case-based material. To complement textbook- and lecture-based learning, the very nature of complex, entangled medical case based material might be best disentangled and made sense of when displayed as a concept map. Connections, understandings and even misunderstandings can be made clearer, potentially facilitating students’ overall understanding of the case, particularly at a deep or high-level. The favourable perceptions of students and their teacher to concept mapping attests to the value of concept maps in facilitating understanding of complex clinical case material. This low cost, accessible teaching methodology has the potential to make complex scientific content apparent and help reveal its interrelated nature. Future research in using concepts maps for students’ learning is warranted, as concept maps may be an under utilised yet effective way to enhance the quality of learning and research in the health sciences, especially in clinical case-based instruction.

Acknowledgement

This research was supported under the Australian Research Council’s \textit{Discovery Projects} funding scheme (project number DP0986867).

References


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Table 1 Cognitive activity and metacognitive regulation for Groups A and B in the concept map construction activity

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th></th>
<th>Group B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Cognitive activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge co-construction</td>
<td>0%</td>
<td>0%</td>
<td>28.3%</td>
<td>1%</td>
</tr>
<tr>
<td>Task co-production</td>
<td>24.6%</td>
<td>75.4%</td>
<td>30%</td>
<td>40.7%</td>
</tr>
<tr>
<td>Metacognitive regulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>0</td>
<td>2 (4.2%)</td>
<td>0</td>
<td>6 (8.7%)</td>
</tr>
<tr>
<td>Monitoring</td>
<td>17 (36.2%)</td>
<td>28 (59.6%)</td>
<td>48 (69.6%)</td>
<td>15 (21.7%)</td>
</tr>
<tr>
<td>Evaluation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Themes</td>
<td>Description</td>
<td>Example</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Learning related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big picture of knowledge</td>
<td>Statements about the various parts of the case coming together to understand the case as a whole</td>
<td>... understanding the case as a whole because it made us think of the other sections...other group members were researching and how they related to our own section we individually researched</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus and flow of knowledge</td>
<td>Statements related to discussing events and progression of case content, cause and effects, contextualising understanding into the case overall</td>
<td>... good to see which parts of your topic are most important and connect each of the points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of understanding</td>
<td>Statements about consolidating knowledge, confidence in understanding, questions raised in discussions</td>
<td>... drawing links to the clinical signs and theories we learnt ... seeing we had come that far into the research provided a motivational boost as well</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Task related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completion of concept map and/or assignment</td>
<td>Statements about how the concept maps and research were completed, reflections on task progress</td>
<td>... the activity helped us work together to decide which information to throw out and which ones would put our learning objectives into focus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completion of class presentation</td>
<td>Statements about preparation and completion of class presentation (not content aspects of presentation)</td>
<td>... cards served as tools for us to communicate our views on how the case presentation should flow... provide constructive and tactful feedback to each other on our respective parts of the presentation so that we can make changes to improve it</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Metacognitive regulation in collaborative learning. Conceptual developments and methodological contextualisations.

BOOK CHAPTER

To comply with copyright laws, the following version of the above book chapter is the accepted version and not the published version.
INTRODUCTION

This chapter examines and illustrates new ways of conceptualizing, capturing, analyzing and representing evidence of metacognitive regulation in collaborative learning in different contexts at school and university. In recent decades, there has been a massive expansion of the use of student-led group projects and collaborative problem- and case-based learning activities at almost all levels of formal education. The degree to which these forms of instruction are effective in enhancing learning and understanding has been debated in scholarly exchange (e.g., Hmelo-Silver, Duncan & Chinn, 2007; Kirschner, Sweller & Clark, 2006). Emerging from this vast body of literature has been a recognition that the benefits of group learning activities depend on effective regulation and scaffolding of student learning. As collaborative learning groups are composed of multiple self-regulating agents with distributed skills and knowledge, who may initially have incompatible goals, it is important that we understand how group members jointly negotiate, coordinate and regulate their collaborative pursuits to reach a shared understanding of the task and shared goals, adopt effective strategies, co-construct knowledge and work productively to complete the task.

The construct of regulation has been used to explain individual and social processes of adaptation, engagement, participation, learning, and development (discussed in Volet, Vauras & Salonen, 2009a), and is central to two often overlooked aspects of human adaptive behavior: social dynamics (i.e., the continuous situational and developmental adjustments of an individual’s behavior to environmental changes) and relationality (i.e., the functional relatedness of an individual’s behavior to the behavior of others and to the characteristics of environmental objects; Fogel, 1993; Hinde & Stevenson-Hinde, 1987). The interpersonal coordination required for collaboration not only involves the regulation of cognition (or metacognitive regulation according to Brown, 1987), but
also the regulation of social, affective and motivational processes that relate to, for example, group dynamics, power relations and interpersonal problems (see, Reis, Collins & Berscheid, 2000; Salonen, Vauras & Efklides, 2005; Thompson & Fine, 1999; Vauras, Salonen & Kinnunen, 2008). In this chapter, we focus on the regulation of joint cognitive activity to achieve shared learning goals, and delineate metacognitive regulation and cognitive content processing, a useful distinction for facilitating analysis of shared regulation in high-level collaborative learning (Volet, Summers & Thurman, 2009b).

Our position is that in real time collaborative learning, individuals and social entities must be simultaneously conceptualized as self- and socially regulated systems (Volet et al., 2009a). Self-regulation refers to the cognitive and metacognitive regulatory processes that individuals use to plan, enact, and sustain their desired courses of action. Social regulation refers to individuals’ joint regulation of each other’s cognitive processes, sometimes involving engagement in genuinely shared modes of metacognitive regulation of ongoing cognitive processes. Educational psychologists’ interest in social regulatory processes in real-time, student-led collaborative learning activities has gained momentum in recent years (Iiskala, Vauras, Lehtinen & Salonen, 2011; Järvelä, Volet & Järvenoja, 2010; Rogat & Linnenbrinck-Garcia, 2011; Volet, et al., 2009b). The latest conceptual developments in the social nature of metacognitive regulation of learning (Hadwin, Järvelä & Miller, 2011; Iiskala et al, 2011; Volet et al., 2009a), high-level metacognitive processing of learning content (Rogat & Linnenbrinck-Garcia, 2011; Volet et al., 2009b), emotion and motivation (Järvelä et al., 2010; Järvenoja & Järvelä, 2009) and situative perspectives on learning in activity (Greeno, 2006; Nolen & Ward 2008) provide useful perspectives from which to explore the nature and trajectories of participation in collaborative learning and knowledge co-construction.

Despite growing agreement that regulation is best understood as both an individual and a social process (see, e.g., Hadwin et al., 2011; McCaslin, 2009; Nolen & Ward, 2008; Volet et al., 2009a), empirical evidence on social regulatory processes pertaining to higher order learning is scarce compared to the extensive body of conceptual and
empirical work on individual metacognition that has accumulated since John Flavell and Ann Brown’s seminal work in the 1970s and 1980s (Brown, 1978; Flavell, 1979). In contrast to the vast array of sophisticated means of studying individual metacognition and self-regulation, the study of metacognitive regulation as a social phenomenon has been characterized by a lack of clear operationalization and methods of data analysis until rather recently. In this chapter, we aim to contribute to addressing this shortage of research methods for improving our understanding of social regulatory processes in dynamic, changing interactive situations.

This chapter presents in-depth analyses of the nature and function of metacognitive regulation in group learning contexts, to illustrate methodologies that are theory-grounded, empirically contextualized and useful in revealing group and task-related differences. First, we briefly outline the conceptual and methodological underpinnings of our own work on metacognitive regulation, to locate it within this emerging field. Second, we present two distinct research programs that illustrate our approaches to the study of metacognitive regulation in student-led, challenging collaborative learning activities. Finally, we discuss the opportunities and challenges we have experienced in interactive data collection and analysis.

CONCEPTUAL AND METHODOLOGICAL UNDERPINNINGS OF OUR RESEARCH ON METACOGNITIVE REGULATION IN COLLABORATIVE LEARNING

Our chapter illustrates rigorous analysis methods for capturing the social nature of metacognitive regulation in time-framed student-led collaborative learning in ways that accommodate differences in group composition (dyadic and small group interactions), context (face-to-face, virtual), task and content (mathematical word problems, ill defined science problems, and veterinary science case-based tasks) and educational level (school and university). These methods have been developed in two distinct research programs. One examines school student-led collaborative problem solving and inquiry learning. The other examines university student-led collaborative learning activities involving complex scientific knowledge. Although our empirical work has
been carried out at different sites and has involved different age groups and tasks, the theoretical assumptions and key constructs underpinning our research are shared and have been developed in collaboration (Volet et al., 2009a).

We have argued (Vauras et al., 2008) that a group is a social system, a qualitatively different entity from individuals working side by side (Hinde & Stevenson-Hinde, 1987; Salomon & Globerson, 1987) and that the motivational and interrelational characteristics and functioning of groups are best understood as involving a complex situational interplay across different systemic levels (Volet et al., 2009a). The core idea in our thinking is that in all real-time learning activities, from solo to collaborative, the opportunities and constraints created in social interactions have to be recognized alongside the role of agency, without reductionism to either the individual or the social level of analysis. We believe that a balanced, integrated consideration of self- and social regulatory processes would assist the development of more powerful explanatory and predictive models of regulation in real-life learning activities (Volet et al., 2009a).

Some ten years ago we started to elaborate the idea of the consensual monitoring and regulation of joint cognitive processes in demanding collaborative situations. We proposed the concept of socially-shared metacognition (Iiskala, Vauras & Lethinen, 2004; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003), which has since been used by other researchers (Hadwin & Oshige, 2011; Hurme, Merenluoto & Järvelä, 2009; Molenaar, van Boxtel & Slegers, 2011; Rogat & Linnenbrink-Garcia, 2011; Whitebread, Bingham, Grau, Pino-Pasternak & Sangster, 2007) to refer to the regulation of joint cognitive processes in demanding collaborative learning situations. We have argued that in genuine collaborative learning, participants’ regulatory activities are shared and interdependent, with ‘collaboration’ conceptualized as involving symmetry, shared goals, and low division of labor in the interaction (see, Dillenbourg, 1999).

Later, Kimmel and Volet (2010) adopted the term (meta)cognitive regulation to stress its specific reference to the regulation of cognitive activity (thus meta in parenthesis). This formulation is consistent with that of other researchers in the field (e.g., Hadwin et
al., 2011; Rogat & Linnenbrink-Garcia, 2011), in that it leaves aside other forms of regulation, which Salonen et al. (2005; cf. Vauras et al., 2008) coined ‘pragmatic’ (e.g., regulation of motivation, emotions, social dynamics). Here, we also keep our original term \textit{socially shared} to denote joint regulation, for instance, in episodes where the group effort is focused on jointly regulating cognitive activity towards the same goal. This is in line with the work of Rogat and Linnenbrink-Garcia (2011), who did not use the term ‘co-regulation’, which is more typically used in research from a sociocultural perspective to refer to a transitional process towards self-regulation (e.g., Hadwin & Oshige, 2011). The term socially shared regulation is well-suited to capture instances of genuine, consensual forms of social regulation. We would still argue, though, that the term co-regulation may be more appropriate for other instances of social regulation in which individuals’ contributions to the collective regulatory effort are not necessarily consensual or do not progress in the same direction. However, in the interest of conceptual consistency across related research (Hadwin et al., 2011; Rogat & Linnenbrink-Garcia, 2011), we have chosen to use the term socially shared regulation to identify all instances of non-individual, joint regulation of content processing or task completion. To stress its metacognitive nature, we use the term \textit{socially shared metacognitive regulation} (SSMR; for the sake of clarity without parenthesis) throughout the description of the methodologies from our two research programs. The term \textit{metacognitive regulation} is used as a more generic term without implications about regulating agents (self-, other, co- or shared).

Based on this common conceptual ground, there are important common features across the two programs regarding analysis of metacognitive regulation:

- First, common to both programs is the search for reliable indicators of metacognitive regulation in student-led collaborative learning interactions, with a particular focus on traces of socially shared regulation. We have aimed to scrutinize what to take as evidence of metacognitive regulation as distinct from collaborative cognitive processes, and of socially shared as opposed to individual regulation.
- Second, we have sought to identify the functions and foci of metacognitive regulation of the cognitive activity, and examined the extent to which group
engagement in socially shared regulation may be sensitive to task and situational characteristics.

- Third, we have attempted to develop effective ways of capturing, analyzing and reporting evidence of metacognitive regulation as an interactive and dynamic psychosocial phenomenon. For this purpose, we have collected micro-level interactive data of students’ communications as they work together on complex tasks without a teacher, in face-to-face, computer-supported or virtual learning environments.

EMPIRICAL ILLUSTRATIONS: METACOGNITIVE REGULATION IN STUDENTS’ COLLABORATIVE PROBLEM SOLVING AND INQUIRY LEARNING IN SCHOOL

We now present the first of two sets of empirical illustrations from our aforementioned research programs. This first set of illustrations is taken from Vauras and colleagues’ (Iiskala et al., 2004, 2011; Salonen et al., 2005; Vauras et al., 2003) initial exploration of whether episodes of SSMR could be reliably identified in collaborative problem-solving interactions, and Iiskala and colleagues’ (Iiskala, Lehtinen & Vauras, 2012) follow-up work on collaborative inquiry learning. These studies exemplify computer-supported collaborative processes, the first in synchronous, dyadic face-to-face interactions between high-achieving elementary school students and the second in asynchronous, small-group virtual interactions between high school students.

Early case studies by Iiskala et al. (2004) and Vauras et al. (2003) demonstrated that it is possible and even conceptually preferable to distinguish social from individual regulation processes in collaborative learning and problem-solving contexts. Most interestingly, they showed that these high-order metacognitive processes already play a crucial role in very young students’ learning. They also pointed out that reliable methods of identifying and analyzing SSMR within large data sets of interactions were urgently needed to understand the functions and fluctuations of self- and social regulation in collaborative contexts. Iiskala et al. (2011) then investigated whether and how this could be done, and presented a detailed episode-based analysis of the occurrence, functions and foci of socially shared metacognition, which was also

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analysed as a function of task difficulty. Material from this study provides our first illustration, presented below, of a systematic approach to operationalizing and analyzing SSMR.

**Metacognitive regulation in the high-level collaborative processes of young students**

Iiskala et al. (2011; see also related studies by Iiskala et al., 2004 and Vauras et al., 2003) examined face-to-face dyadic interactions in eight high-achieving 10-year-old students. The eight students, comprising four dyads, were all in the top 11% of their schoolmates (n = 393) in mathematical word-problem solving and reading comprehension. The dyads worked face-to-face in a computer-supported, game-format learning environment. Across the four dyads, 251 problems of three difficulty levels were solved over 56 (30-45 minute) lessons.

Iiskala et al. (2011) aimed to identify socially shared metacognitive regulation episodes, determine their frequency relative to cognitive activity, and capture their role in the collaborative problem-solving process in terms of function and foci. We were also interested in whether metacognitive experiences (see Efklides, 2006) trigger socially shared regulation. Indeed, this appeared to be the case in more than 54 % of SSMR episodes.

The detailed analyses of SSMR processes started with careful word for word transcriptions, including nonverbal communications (e.g., eye contact, a pupil’s pointing his/her finger at the computer screen). Communication was denoted in terms of *turns*. A turn was defined as a student’s verbal comment or concrete action on the computer screen (e.g., writing or clicking the buttons) until another student took the turn or joined the other (e.g., counting in unison). A total of 14 675 turns were numbered and the nonverbal communication was attached in parenthesis to the numbered turns. Nonverbal communication was used to confirm specific actions (e.g., eye contact to confirm attention given to the peer). Finally, in order to study SSMR, turns within the
dyad were analyzed as set of turns, that is, as episodes. Each episode had to involve a minimum of two turns but there was no specific upper limit to the number of turns included in the episode. In an episode of SSMR, the students had to jointly regulate cognitive processes towards a common goal, thus requiring reciprocal turns.

Figure 4.1 illustrates a short extract from the transcriptions, with arrows indicating reciprocal turns within the SSMR episode. The method of marking the turns with arrows in a flowchart was adapted from Sfard and Kieran (2001), and well suited to our purposes of identifying reciprocal turns and determining the starting and cut points of SSMR episodes. In this example, Joel and Oiva work on a difficult problem (turns 4518–4533). In this problem, the boys had to count a square of a remaining area when a courtyard has been separated from a bigger area. Before the extract in Figure 4.1, the boys had assessed the nature of the task and then made an incorrect calculation, but soon monitored and regulated their actions. After some rethinking, the boys’ shared regulation focused on what was really meant by length and width in the problem, that is, they built-up their consensual understanding through symmetrical reciprocating (see Figure 4.1, turns 4518-4533). Their regulatory acts were centered on regulating cognition. Although not all individual comments may appear metacognitive (no arrow drawn) when considered in isolation, they gain their metacognitive nature in combination with other comments. This highlights the importance of considering the preceding and ensuing turns when identifying instances of social regulation. The extract also demonstrates that nonverbal communication (e.g., gesturing and looking) can play a role in SSMR, suggesting importance of considering nonverbal information when coding and analyzing instances of SSMR. It also shows that the SSMR episode led to continued cognitive processing (from turn 4533 onwards), and eventual success in solving the problem.

<INSERT FIGURE 4.1 ABOUT HERE>

Figure 4.2 illustrates typical fluctuations between cognitive activity and socially shared (metacognitive) regulation within two tasks, easy and difficult. The graphs illustrate the
effect of task difficulty on the need for metacognitive regulation in high-level collaboration. The easiest tasks were swiftly solved, usually correctly, with hardly any need for visible metacognitive regulation, either individual or shared. In difficult problems the pattern of collaboration was rather different. Much more time was needed to solve these problems (see the number of turns in the two examples), and the students regularly engaged in SSMR. At times, self-regulation was also apparent. Overall, the results showed significantly more SSMR for difficult problems, whereas no significant effects were found between the easy and the moderately difficult problems (Iiskala et al., 2011).

Allocation of resources as a function of task demands signifies high-level collaboration, which was very nicely reflected in this study where SSMR emerged when task difficulty increased and routines failed, necessitating joint effort to successfully carry out the task. Thus, task difficulty may influence metacognitive activity by determining the point at which it is necessary to regulate cognitive activities. In word problem solving, the construction of a situation model, which integrates existing world knowledge with mathematical information in the task, prevents using straightforward formulation of mathematical operations. Thus, in studying SSMR in math word-problem solving, it is not only essential to consider the impact of task difficulty in general, but also the focus of metacognitive processes, that is, whether these refer to the formation of the situation model, to specific operations or to incidental matters. To further specify social regulation in collaborative learning, the function of SSMR has to be identified. This involves determining the direction in which the cognitive processes and related interactions shift during collaborative problem solving. A major function of SSMR is to facilitate continuation of a group’s cognitive activity in its current direction, for example, through building a shared representation of the problem, reaching consensus, and activating new lines of thinking. At other times, inhibitory control processes are called for to prevent incorrect lines of thinking or other inappropriate actions, and the need to slow down, change or stop ongoing processes emerges.
Table 4.1 depicts the key features and subcategories of these two functions, as found by Iiskala et al. (2011). Each SSMR episode was analyzed in terms of function and focus. The function of the episode was classified according to whether it facilitated (activated, confirmed) or inhibited (slowed, changed, stopped) the continuation of the dyad’s previous activity. The focus of the episode was classified into one of the following three categories, namely the situation model, the operation, or the incidental matter. The detailed function categories were data-driven and the focus categories originated from the models by Cummins, Kintsch, Reusser and Weimer (1988) and van Dijk and Kintsch (1983).

The analyses showed that facilitative and inhibitory functions and foci of SSMR could be reliably identified and coded in high-level, task-oriented collaboration. SSMR episodes primarily focused on the situation model or operations, and rarely on incidental matters. Joint confirmation of operations was the most frequently observed episodes (50 % of all SSMR episodes), perhaps indicating the necessity of a social feedback process in cognitive task which demands definite solutions. Confirmation aided not only in deciding the correctness of the solution, but also in implementing a possible operation; that is, passing from planning to execution. Confirmation was prevalent in easy problems, indicating that relatively easy tasks seem to trigger rather narrow and simple forms of SSMR. Although confirmation was the most typical function at all difficulty levels, the percentage of facilitative activation and inhibitory slow and stop functions increased in more difficult problems indicating that these problems trigger a more variable array of SSMR. There was also a significant relationship between the problem difficulty level and the focus of regulation. Focusing on operations was the most typical episode at all problem levels (64 % of all SSMR episodes), and served the important function of preventing students from reaching solutions too hastily. In difficult problems, particularly, some operations were complex or even novel to the students, and therefore demanded keen focus. The need to construct a situation model increased as a function of problem difficulty. In difficult problems 37 % of SSMR episodes were
focused at this level, whereas in easy problems the students had practically no reason to regulate the construction of situation model (Iiskala et al., 2011).

Our analyses confirmed the prediction that the function of socially shared metacognitive regulation is to facilitate a shared representation of the problem or inhibit activities that are not conducive to reaching a shared solution to the problem. The frequency, function and foci of SSMR varied according to task difficulty. In challenging problems, SSMR was more prevalent, served more diverse functions and focused more on formulating a general situation model beyond the given word problem than in easy or moderate problems. Socially shared regulation seemed to be crucial when there was an individual failure to formulate the situation model, particularly in difficult mathematical problems. However, it must be kept in mind that the study participants were top-achieving students, possessing high-level cognitive competence. Our observations of students in the same age group indicate totally different patterns of regulation, with other-regulation dominating (e.g., Salonen et al., 2005). Thus, the analysis tools described above may be less well-suited to trace metacognitive regulation in their learning.

**Metacognitive regulation in school student-led group activities in virtual inquiry learning**

The next illustration comes from current work by Iiskala et al. (2012) that examines whether socially shared metacognitive regulation can also be found in small groups working in an asynchronous computer-supported, collaborative inquiry learning environment. In this illustration, a complex and demanding learning project in science was based on the idea of the learning process as collaborative of inquiry (see, Hakkarainen, 2003; Muukkonen, Lakkala, & Hakkarainen, 2005; cf., Brown & Campione, 1994; Scardamalia & Bereiter, 1994) and highlights the traceability of socially shared metacognitive regulation, even in asynchronous interaction without face-to-face contact. Volet et al. (2009a) have pointed out how virtual collaborative learning environments create unique challenges for individual and social regulation. These can be due to the limited social and emotional cues available or insufficient human scaffolding. In any case, collaboration between participants is expected, and it is
not well understood how learners actually regulate each other’s contributions in the absence of visible emotional cues and a limited sense of social presence or to what extent metacognitive regulation is facilitated, maintained, or alternatively inhibited in such contexts.

A recent study by Iiskala et al. (2012) on computer-supported, collaborative inquiry learning, involved six small groups consisting of four to five (6th grade, 12-year-old) students (n = 25). Unlike Illustration 1, the students did not represent any specific achievement group. The small groups worked in an asynchronous CSCL environment during 22 (45 min) lessons, participating in research-like processes of inquiry (see, Hakkarainen, 2003; Scardamalia & Bereiter, 1994), and solving complex ill defined problems concerning the universe, which is a part of the 6th grade formal curriculum in science. The students had no extensive prior experience of CSCL in school. The inquiry CSCL process was partly scripted and divided into overlapping phases as follows: setting up research questions; constructing hypotheses; making a plan for working; searching and processing knowledge; and summarizing findings and concluding. The students generated 4771 written productions (i.e., notes).

The nature of interaction (asynchronous with variable time lags between notes, varying combinations of students involved in interactions) and sole reliance on written productions (e.g., without confirming nonverbal communication) posed new challenges due to the need for a measurement approach suited to the dynamic, interdependent nature of student interactions, that could capture the metacognitive focus of these interactions. Initially, we considered the episode, a set of adjacent notes, as the primary unit of analysis. The underlying idea was that, as in Illustration 1, socially shared metacognitive regulation cannot be coded via individuals’ single actions, and the small group must be treated as a system, in which individuals’ regulatory actions are inseparably interrelated, i.e., socially shared. In our evolving thinking, though, the episode concept did not seem to capture the true nature of an asynchronous interaction, which could also contain overlapping discussions. Thus, to emphasize the different character of communication in an asynchronous learning environment, we started to talk about threads, composed of a set of notes. This terminological variation did not change our underlying conceptual ideas of the socially shared metacognitive regulation but influenced the analytical tools to trace it within the flows of notes.
Since our analysis of asynchronous small group learning is still in progress, here we illustrate only the identification of SSMR threads. Each thread had to involve a minimum of two notes and two students but there was no specific upper limit to the number of turns included in the thread (cf., Iiskala et al., 2011). Furthermore, although not illustrated here, each SSMR thread was analyzed in terms of its function. The function of a thread was classified according to whether it facilitated (activated, confirmed) or inhibited (slowed, changed, stopped) the small group’s learning process. Due to time lags and the nature of a long-term inquiry project, the interactions among the students evolved over several days. Figure 4.3 illustrates the different patterns of SSMR threads in asynchronous inquiry CSCL compared to dyadic face-to-face collaboration.

Our analyses revealed that SSMR also occurs in virtual collaboration. According to the analyses so far, SSMR threads were more prevalent when the students constructed hypotheses, summarized findings and set conclusions. In contrast, SSMR threads were typically absent during the phase of making a plan for working.

Table 4.2 contains a short extract from transactions via notes in a small group of four girls, Mona, Iida, Heidi and Irene. At this point, three girls were involved in the process. The task was to draw conclusions from their inquiry. The extract shows how the girls stopped to monitor and regulate their process and how they shared awareness that, in fact, they lacked reliable knowledge and unsolved questions existed. Before the extract in Table 4.2, Iida’s note had acted as a starting point for SSMR by bringing up the problem of insufficient reliable knowledge, and received reciprocating reactions from Heidi. The next day, Iida continued the SSMR thread by initiating discussion about their problematic situation (see Table 4.2, 2nd day, 10:33). Within two minutes (10:35), Heidi and Irene simultaneously reacted to Iida’s note and continued the SSMR thread, both summing up the consensual thinking of the problem that had been reached. Iida (2nd day, 10:36) and Heidi (10:39) then assessed the knowledge obtained from an expert, and finally, Iida (2nd day, 10:40) and Irene (10:43) ended the SSMR thread with conclusions based on the girls’ preceding notes. Throughout this interaction, the girls monitored and regulated not only their own cognitive processes, but to an important extent also those of the group. After this SSMR thread, the group started to write the findings, thus moving to cognitive activities.
Figure 4.3 depicts the entirety of the group’s interactions, spanning two days (thread 2). The time gaps of different durations between the notes do not represent halts in the interactions, but periods in which the girls discussed other topics, before returning to the topic of the SSMR thread. In an asynchronous CSCL environment, SSMR may not manifest as unbroken turns within an episode but instead may consist of intermittent turns that form a thread over time (thread 2). Multiple threads can be in progress almost simultaneously, perhaps with different composition of participants and/or on different topics (threads 1 and 3).

EMPIRICAL ILLUSTRATIONS: METACOGNITIVE REGULATION IN UNIVERSITY STUDENT-LED ACTIVITIES THAT INVOLVED COMPLEX SCIENTIFIC KNOWLEDGE

The second set of illustrations draws from Volet and colleagues’ (Khosa & Volet, 2012; in press; Summers & Volet, 2010; Volet et al., 2009b) on-going research on social regulation in university student-led collaborative learning activities that involve complex scientific knowledge. This research has led to the development, refinement and validation of a situative framework and derived methodological approaches for studying metacognitive regulation during collaborative learning. We illustrate in turn our methodological approach to: trace high-level co-regulation of content knowledge in collaborative learning activity; capture the orientation and function of metacognitive regulation when the activity involves complex scientific knowledge; and identify group differences and task-related differences in metacognitive regulation.

The three empirical illustrations are taken from a series of studies focusing on collaborative learning within the naturalistic setting of a veterinary science course. A
complex and demanding collaborative case-based learning task was used as the ‘host activity’ for the development of this program of research over several years.

The collaborative case-based learning task used as the ‘host activity’ for the research is a regular curriculum component of a pre-clinical physiology unit within the veterinary science degree program. Students are required to self-form into groups and investigate an authentic clinical case file for the first time in their undergraduate course. Each group is provided with a different case to work on in their own time over a 7-week period. Their initial task is to produce a set of learning objectives, which provide a direction for their research into the clinical case. Guidance is provided from the teacher in the form of two mandatory meetings conducted at the beginning and towards the end of the group task period. The overall objective of this student-led collaborative learning task is to encourage students to extract relevant physiological principles and explore underlying concepts that make up treatment and management of a specific disease process presented in a case. Each group is required to demonstrate adequate research and understanding of the case through their self-generated learning objectives, and is assessed based on a class presentation and a follow-up question and answer session. Video footage was collected from the informal, out of class, student-led group meetings.

The first illustration comes from our initial examination of the process of collaborative learning in the naturalistic setting of student-led group activities at university. The second and third are taken from our follow-up research aimed at capturing the focus, depth, nature and function of regulation of cognition, and examining how group and task-related differences in metacognitive regulation could be identified.

**Tracing high-level co-regulation of content knowledge in collaborative learning**

Identifying the nature and process of productive collaborative learning in student-led group activities called for a theoretical perspective and derived methodology that would combine the dynamic, interdependent nature of student interactions and the metacognitive focus of these interactions. This approach resonates well with Greeno’s...
(2006) proposal to merge the strengths of cognitive science and interactional studies into a situative perspective to explore ‘learning in activity’. Consistent with Greeno (2006) and Nolen and Ward (2008), we endorsed the idea that to understand the nature and emergence of productive interactions in student-led collaborative learning activities, the focus had to be on intact activity systems. Our unit of analysis, therefore, was the group activity as it unfolds, rather than individuals’ contributions to the activity. This was deemed appropriate since student-led activities at university are by nature unstructured, thus allowing emerging and varied forms of participation and regulation as well as evolving levels of engagement in content discussion, mediated through social interactions.

Our initial investigation also aimed to develop a theoretical approach and associated methodology for the reliable identification of productive forms of group collaborative learning. Since the ‘host activity’ consisted of veterinary students’ grappling with complex clinical cases, we concentrated first on the identification of episodes showing evidence of social regulation of content-related cognitive talk. By content-related, we meant any discussion focusing on knowledge related to the case. This could include clinical information extracted from the case file or underlying biomedical knowledge brought in to make sense of the case. Since students were exposed to authentic clinical material for the first time and they had limited scientific knowledge, a substantial amount of content-related talk was expected to take place during the groups’ informal meetings, for example, deciphering and distilling information from the case file, identifying relevant physiological principles and integrating the information with biomedical knowledge from pre-clinical disciplines. Based on the features of effective collaborative learning identified in the literature, (e.g., Cohen, 1994; King, 2002; Vauras et al., 2003) it was expected that evidence of a group productive engagement with the clinical case would include high-level reciprocal questioning, collective elaborations and joint meaning making.

On the assumption that groups afford various forms of participation, regulation and engagement with the learning content, it was reasonable to expect that in-depth analyses of the socially regulated processes and content related talk in combination would
provide insight into the emergence and maintenance of group engagement in high-level cognitive processing (King, 2002) or high-level discourse (Cohen, 1994). Furthermore, by conceptualizing the constructs of content processing and social regulation as two continuous dimensions, it was possible to derive a coding scheme that distinguished between individual and co-regulation, and simultaneously between low and high levels of cognitive engagement with the content (Volet et al., 2009b for details). The key features of the two continuous dimensions are described in Table 4.3. The most effective form of collaborative learning based on the theoretical perspective, namely, high-level co-regulation of content processing, often confounded with knowledge co-construction, is described at the bottom of the table.

<TABLE 4.3 ABOUT HERE>

Talk related to other matters was categorized as either task-related (e.g., negotiating the selection of learning objectives and what to include in the final presentation), organizational (e.g., scheduling group meetings, delegating sub-tasks) or off task. All coding was done directly from the video footage. Verbal interactions were the main data source, body language being used as complementary information only to assist in confirming or discounting coding in grey areas.

Coding was challenging since demarcating distinct episodes and identifying the type of content-related interaction had to be done simultaneously. This is because the episodic boundaries could not be determined without categorizing when group talk changed from one category into another. Inter-judge reliability, therefore, was not calculated based on episodic coding but on the percentage of the total length of the group meeting that the independent judges were in agreement. Having conceptualized level of content processing (predominantly low or high) and dominant form of social regulation (individual or group) as two continuous dimensions made the coding process a challenge since there was the potential of many equivocal coding instances between categories. Indeed, it was reasonable to expect that intermediate points may be present along each dimension, especially between low and high levels of content processing.
The identification of dominant equivocal areas was discussed extensively, and categorical descriptors continuously refined. In the end, the analytical scheme proved satisfactory to code the video footage of eighteen meetings, with 77.3% perfect agreement between two judges for the independent coding of seven meetings (Summers & Volet, 2010).

Based on the coded video data, group differences emerged in the overall amount of time dedicated to content-related talk during meetings, and most importantly in the proportion of time spent on high-level co-regulation of the content knowledge related to the case. Figure 4.4 illustrates these group differences.

As shown in Figure 4.4, large variations in patterns of content-related talk across groups were detected, ranging from 64% to 14% (all categories included). Particularly striking was the widespread minimal engagement in high-level content processing across groups (high-level individual and co-regulated content-processing combined). A major benefit of demarcating the precise start and end of episodes of high-level co-regulation of content processing (from low-level content-related talk) was the possibility to explore how such episodes emerged and how they were sustained over a period of time (Volet et al., 2009b). This provided valuable insight on the emergence of productive collaborative learning in a naturalistic setting, which was capitalized upon for the subsequent development of an intervention study (Khosa & Volet, in press). This methodology also revealed the missed opportunities for engaging in productive collaborative learning discussed in the literature (e.g., Barron, 2003; King, 2002; Visschers-Pleijers et al., 2006).

The validation of the methodology was explored further through examining the extent to which group members’ self-reports of how they interacted as a group and how much they learned from each other during their group meetings. Their reports were consistent
with the coded observations of group engagement in co-regulation of content-related processing, as reported in Summers and Volet (2010). Additionally, individual engagement in high-level processing (whether part of individual or co-regulated episode) was significantly related to higher marks in the physiology unit where the ‘host activity’ was located.

In sum, our initial theoretical perspective and related methodology enabled the identification of instances of social regulation of content knowledge processing during student-led group collaborative activities, and the extent of such engagement across groups. However, as previously discussed, at the empirical level high-level co-regulation episodes may be confounded with instances of co-construction of knowledge, given these processes are likely to take place concurrently. The focus of this study on content-related talk excluded the analysis of other types of cognitive talk, such as how groups planned and monitored their completion of the set task. On the assumption that productive co-regulation of content knowledge benefits completion of the task – in this instance, the generation of a set of learning objectives, subsequent research to achieve those objectives and preparation of a class presentation of the group findings - the next step of our research endeavored to refine the theoretical approach and related methodology in order to explore the articulation of social regulation of content processing and social regulation of task completion in real time interactions.

**Capturing the focus and function of metacognitive regulation**

The insight that student groups who engage in high-level content-related talk recognize the learning value of such experience (Thurman, Volet & Bolton, 2009) lead us to investigate how groups navigate between cognitive activity focusing on task outcome or product (the instructional requirement), and cognitive activity focusing on content knowledge-processing during a collaborative learning task. More specifically, we wanted to explore if regulatory activity could be detected when the focus of cognitive activity changed. In other words, we became interested in the articulation of regulation of content-related talk (as defined in our earlier research) and regulation of task production, on the expectation that this may provide valuable insight into how groups
monitor the quality of their task production especially when the task calls for an understanding of complex scientific knowledge.

To date, this issue has attracted limited attention in the literature. In their study of socially shared regulation among upper-elementary school children working on three collaborative math tasks, Rogat and Linnenbrink-Garcia (2011) point in this direction by distinguishing between monitoring content (similar to our conceptualization of co-regulation of content-processing), and monitoring the plan or the task progress (focus of regulation not examined in our initial work). Gresalfi’s (2009) work with upper-elementary school children working on algebra problems also makes a distinction between ‘working on content by focusing solely on working accurately’ (idea close to our definition of task production) and ‘working on content by making connections between ideas’, which she conceptualizes as working one step further to ‘understanding why the answer is correct’. This is close to our view that while groups are completing their set task, they can suddenly engage in temporary episodes of knowledge construction. In research with younger students (e.g., Whitebread & Pino-Pasternak, 2012), such distinctions may not be made since the task at hand and related knowledge are more tightly intertwined.

To address this question, we developed a conceptual framework that distinguishes between two orientations of cognitive engagement during collaborative learning tasks, namely, task production and knowledge construction. Consistent with our earlier work (Volet et al., 2009b) we also distinguished between two levels in the depth of cognitive engagement (low, high) in knowledge construction, and we extended this distinction to task production. Table 4.4 presents a description of the key terms (task, knowledge) and categories of cognitive engagement during a collaborative learning activity.

<INSERT TABLE 4.4 ABOUT HERE>
Task co-production refers to group effort to produce the tangible outcome of the collaborative task, and as with knowledge co-construction it is expected that group effort can reflect a low or high-level of cognitive engagement.

As discussed earlier, the term socially shared metacognitive regulation (SSMR) is used to identify all instances of non-individual, social regulation of content processing or task completion in the context of this study. Identifying how SSMR steers groups’ engagement in either task production or knowledge construction also makes the conceptual distinction between co-regulation of cognitive processes and co-construction of knowledge more explicit, although as mentioned earlier, these processes have been found to partially overlap and are often difficult to distinguish empirically (Rogat and Linnenbrink-Garcia, 2011; Volet et al., 2009b).

Figure 4.5 presents our conceptual framework for the analysis of group cognitive engagement and metacognitive regulation during a collaborative learning task that involves complex scientific knowledge.

On the left hand side of the framework is the flow of cognitive activity (travelling arrow from top to bottom) with task co-production at center stage. The flow of cognitive activity leads to the tangible outcome of the assigned collaborative task. Task co-production is central in the framework because it provides direction for the group effort to complete the set task and achieve the expected outcome. In our framework, the flow of cognitive activity features a number of incursions into knowledge co-construction. These incursions capture the group’s temporary suspension of task co-production to either gather additional information (low-level knowledge co-construction) or clarify conceptual understanding of the scientific knowledge underpinning the task (high-level knowledge co-construction) before resuming task production. Task co-production is
considered high-level when conceptual justifications are provided to support task-related decisions.

On the right hand side is the metacognitive activity, more specifically the function of metacognitive regulatory processes that steer the flow of cognitive activity. Based on our earlier findings of how high-level shared regulation emerges and is sustained (Volet et al., 2009b), we assumed that metacognitive activity would be found at transition points between task production and knowledge construction (A & B in the Figure) or between shifts from high to low levels of cognitive engagement (D & E). This assumption is consistent with the view that regulatory processes are activated when an individual or the group experience a cognitive challenge (Järvelä & Volet & Järvenoja, 2009), following a metacognitive experience (Efklides, 2006) or as the result of evaluating and monitoring current cognitive engagement (Flavell, 1979). We also assumed that productive episodes of knowledge co-construction and task co-production within either low or high levels might display evidence of metacognitive regulation aimed at effective planning and monitoring to sustain these episodes. This is illustrated as C in Figure 4.5.

The overall function of the metacognitive regulation, therefore, is to produce a change in the flow of cognitive activity or alternatively to sustain a productive episode of cognitive activity. Engagement in metacognitive regulation activity is typically initiated by one individual’s verbal statement, although facial expressions can provide indicators of non-verbalized metacognitive experiences, for example, shaking head, frowning, looking puzzled. The extent to which one individual’s engagement in metacognitive activity is a solo event, or whether it leads to collective engagement in shared metacognitive regulation depends on whether the initial metacognitive trigger is followed by further metacognitive contributions of other group members, which would be evidence that the group is monitoring and regulating their activity towards a shared goal. These theoretical ideas lead to a three-stage analytical scheme, which is presented in Figure 4.6.
Data analysis proceeds as follows: First, a distinction is made between two orientations and two levels of depth of cognitive engagement at the episode level; second, the indicators and foci of metacognitive regulation are identified at the individual turn level; and third, the social nature and function of metacognitive regulation in the development of the cognitive activity are examined at the context level. The comprehensive nature of this analysis requires full transcripts of groups’ interactions to use in conjunction with video data, since the coding relies on some non-verbal behaviors to complement the verbal interactions.

Critical to the first stage of the analysis at the episode level, is whether talk orientated at content processing and talk focusing on task related matters (low or high-level of depth) can be distinguished empirically in a meaningful and reliable way. This method of analysis is similar to the approach used in Volet et al. (2009b), in that the demarcation of distinct episodes and the identification of type of cognitive foci are undertaken simultaneously. Inter-judge agreement of 74.3% for the independent coding of 26% of the data supported our assumption that these two orientations of cognitive activity at low or high-level of engagement can be distinguished conceptually at the episode level.

The second stage of the analysis involved identifying indicators of metacognitive regulation and their respective focus at the individual turn level. The early metacognitive literature (e.g., Flavell, 1979; Brown, 1987) conceptualized metacognitive regulation as individual engagement in regulation of cognition through executive management processes, with a focus on planning, monitoring and evaluation. In the context of collaborative learning, it is assumed that metacognitive regulatory processes serve the same role, whether focused on task production or knowledge construction. Since the ‘host activity’, in our research, involved complex scientific knowledge (physiology, biochemistry, anatomy, histology) this provided an ideal situation to determine if and if so how, indicators of metacognitive regulation triggered
transitions between task co-production and knowledge co-construction, and from low to high levels in particular, and if some also served to sustain productive cognitive activity.

The third stage of the analysis addressed these issues by examining the function of metacognitive regulation within the flow of cognitive activity (context level) and also its social nature. We noted metacognitive indicators that captured individuals’ solo attempts to regulate the group process, without other members contributing to the regulation effort, a phenomenon reported elsewhere in the literature on social regulation in collaborative learning (e.g., Iiskala et al., 2011, 2012; Volet et al., 2009). In the majority of instances, however, we found evidence of several individuals jointly regulating their cognitive engagement in task co-production or knowledge co-construction. These episodes illustrate what has been labeled as socially shared metacognition (Iiskala et al., 2011) or socially shared regulation (Hadwin et al, 2011; Rogat & Linnenbrink-Garcia, 2011). It is important to stress at this point that metacognitive regulation represents regulation of cognition or semantic mode of regulation and it excludes “pragmatic” forms of regulation, such as regulation of motivation, emotions or social dynamics (Salonen, Vauras & Efklides, 2005).

Two coded excerpts from Group B’s initial meeting to generate their learning objectives are presented in Figure 4.7 to illustrate how our three-stage analytical scheme works.

<INSERT FIGURE 4.7 ABOUT HERE>

This figure should be ‘read’ from left to right, starting with the transcribed protocol, then the cognitive coding at the episodic level, then the metacognitive indicators where evident at the turn level, and finally a pictorial illustration with accompanying narrative describing the social nature and function of metacognitive regulation in the evolving context of the cognitive activity. The ‘travelling arrow’ illustrates the continuous cognitive flow, with the cognitive coding done at the episodic level (episodes of low or high, task or knowledge). Adjacent to the arrow are the metacognitive regulation
analyses that reveal the focus and function of regulation in the flow of cognitive activity. First are the metacognitive indicators identified at the turn level, and their focus in the cognitive flow (e.g., planning, or monitoring at low or high level of engagement). Next are the single or interlocking circles that depict the social nature of metacognitive regulation. A single circle represents a single student engaged in metacognitive regulation, and two or more interlocking circles illustrate two or more students involved in shared metacognitive regulation. SSMR is characterized by a succession of related metacognitive regulatory statements, which are mostly contiguous in nature and address the same cognitive development.

The top half of Figure 4.7 exemplifies one episode of individual metacognitive regulation. The excerpt reveals evidence of a solo regulatory attempt to shift the cognitive flow orientated at knowledge co-construction towards a focus on task co-production and therefore on the generation of learning objectives. Given no other student picks up this shift in direction, aside from a brief acknowledgement and accompanied hesitation, the preceding cognitive talk on knowledge co-construction is resumed almost immediately. In contrast, the bottom half of Figure 4.7 illustrates one episode of SSMR involving three students. In this episode, the contiguous metacognitive regulation statements serve to propel and sustain the cognitive talk on task co-production. It is the successive up-take of ideas and most importantly the related metacognitive regulatory statements from multiple students that seamlessly sustain this productive episode of task production. Further detailed functions of the successive metacognitive regulation statements are presented in the narrative on the right hand side of Figure 4.7.

Identifying group differences and task-related differences in metacognitive regulation

To validate the conceptual usefulness of our methodological approach, we examined the extent to which meaningful group differences as well as task-related differences could be identified, using our framework and its associated analytical scheme.
For this illustration, we selected two groups that were similar in academic performance in physiology (comparable aggregate marks) and in terms of within-group variance in performance (comparable, low standard deviations), but contrasted sharply in terms of their understanding of their clinical case at the end of the semester (Group A: 56%, lowest of all groups in the class; Group B: 92%, highest). This was important to rule out the possibility that group differences could be interpreted in relation to academic performance in general, and reciprocally to maximize the likelihood that differences could be traced to how each group engaged, cognitively and metacognitively, in their student-led collaborative learning tasks.

First and most importantly, we wanted to examine whether, using our analytical scheme, meaningful group differences would emerge in cognitive engagement and metacognitive regulation, and whether differences could already be identified in the groups’ first meeting. Second, we wanted to establish the extent to which the characteristics of the two tasks may interact with group differences. In other words, we were interested in the conceptual usefulness of our methodological approach to reveal possible interaction effects between groups and tasks.

This investigation was undertaken by comparing the two groups cognitive and metacognitive regulation while they completed two tasks related to their clinical case, each leading to a distinct outcome. The first task, completed by the groups immediately after receiving their clinical case file, involved the generation of a set of learning objectives related to their case. The second task, completed by the groups after having completed their background research, involved the construction of a concept map of their clinical case. This second task involved the groups being presented with a set of clinical concept cards extracted from their clinical case file. Students were asked to arrange the concepts in a manner that made sense to the entire group based on their collective understanding of their clinical case, leaving out any concepts deemed not relevant to their case. Once the students had decided on card relevance and placement order, they had to link the cards using either a single directional or a bi-directional arrow, indicating either a cause-effect relationship or an inter-related relationship between concepts. This task was completed on a freestanding, transparent glass, work
board that allowed filming through the glass as the students were constructing their concept maps.

Based on theoretical assumptions about the benefits of metacognitive regulation on individual cognitive activity (Flavell, 1979; Brown, 1987), and research reporting differences in metacognitive regulation between more and less successful groups in mathematics problem-solving (Rogat & Linnenbrink-Garcia, 2011), it was expected that the two groups would differ in depth of cognitive engagement (low or high-level) and that differences might also be found at the metacognitive regulation level. More specifically, we expected that the highest performing group would display evidence of metacognitive regulation focused at high-level co-production of the task, with incursions into high-level co-construction of knowledge. Because of the lack of previous research using the proposed framework, no predictions could be formulated in regard to possible differences related to task co-production and knowledge co-construction.

In regard to the impact of the tasks, it was speculated that group differences in cognitive engagement and metacognitive regulation would be greater in the final concept mapping exercise than in the initial generation of learning objectives, on the grounds that at the first meeting both groups were new to their clinical case and needed to decipher novel material and gather factual information before they could engage in high-level meaning making.

Figure 4.8 presents an overview of the two groups’ cognitive engagement and related metacognitive regulation during two tasks. The first task was to generate learning objectives and the second was to construct a concept map.
Looking vertically, the two boxes on the left hand side refer to Group A (lowest performing group) and those on the right hand side to Group B (highest performing group). Looking horizontally, the top two boxes refer to Task 1 and the bottom two boxes to Task 2. Looking inside the boxes, the pie charts represent each group’s percentage of time spent on four different types of cognitive engagement. Below each pie chart is some information on the group’s patterns of engagement in metacognitive regulation.

Comparing the two groups at Task 1, it can be seen that both groups’ depth of cognitive engagement was predominantly low-level. This would reflect the characteristics of the task. Low-level engagement was expected, since students’ background knowledge was insufficient at that stage to engage in conceptual understanding and meaning making. However, the breakdown of cognitive engagement into task production and knowledge construction unveiled major group differences in the focus of their engagement. Group A spent over twice as much time working on task production (generating learning objectives) than on knowledge construction (gathering information and making sense of it), while it was the opposite for Group B. Moreover, Group B’s greater engagement in tentative meaning making (high-level co-construction) was noteworthy compared to Group A’s more modest engagement at that level. Finally, Group A spent a substantial amount of meeting time on miscellaneous talk (social chat and organizational matters) in comparison to Group B. These differences reflect the unstructured characteristics of the task and informal nature of the meeting, which allowed for wide variation of engagement in knowledge gathering to assist with the generation of learning objectives.

Despite differences in cognitive engagement, the two groups’ patterns of metacognitive regulation activity were quite similar, with 19% of Group A’s and 21% of Group B’s cognitive turns displaying metacognitive regulation and over 70% of both groups’ metacognitive regulation embedded in SSMR episodes. Metacognitive regulation, however, reflected each group’s cognitive orientation. Group A’s metacognitive regulation simply served to steer the generation of learning objectives, while Group B’s controlled the shift back and forth between knowledge gathering from the clinical case file and the generation of learning objectives.
The group differences in cognitive engagement were further highlighted in the concept map activity (Task 2). By breaking down cognitive activity into task co-production and knowledge co-construction we detected opposite patterns of engagement. Group A’s talk was almost exclusively concerned with task production, mainly at the low-level, and contained no episodes of knowledge construction. In sharp contrast, Group B not only provided conceptual justifications for its developing map, reflected in task production mainly at the high-level, but also made numerous incursions into high-level co-construction of knowledge. Interestingly, the two groups’ overall engagement in metacognitive regulation was remarkably similar (21% for both groups, with over 60% being embedded in SSMR episodes). However, Group A’s metacognitive regulation was essentially applied to low-level co-production of the task with minimal conceptual justification, while Group B’s metacognitive activity was primarily focused on regulating high-level episodes of task production and knowledge construction.

The expectation of greater group-related differences in the concept mapping exercise than the initial generation of learning objectives was however not supported, since group A’s limited engagement in co-construction of knowledge, and group B’s commitment to high-level co-construction of knowledge were consistent across tasks. Task-related differences in depth of cognitive engagement and corresponding focus of metacognitive regulation were particularly striking for Group B.

Finally and as expected, metacognitive regulation activity was overwhelmingly taking place at transition points between task co-production and knowledge co-construction, and when talk shifted from low to high-level of engagement.

CONCLUDING REMARKS

The major aim of this chapter was to examine and illustrate rigorous methodologies for capturing, analyzing and representing metacognitive regulation in time-framed collaborative learning. A major advantage of drawing on two programs of research was the opportunity to strengthen the common theoretical position while representing a
range of methodologies that can be derived from the common conceptual grounding. By including illustrations from a number of empirical studies that involved different applied settings, age groups, tasks and modes of communication, the value of methodologies that combine theoretical coherence and empirical contextualization was highlighted.

Developing methodologies that can capture social regulation of content processing in naturalistic settings is a challenge, due to the interactive and dynamic nature of unfolding data. Furthermore, such methodologies need to accommodate the unique characteristics of each target situation. As argued by Hmelo-Silver and Bromme (2007), “understanding inter-subjective meaning making is possible only when we are sensitive to the embeddedness of learning processes in context and content structures” (p.463). It is therefore imperative to contextualize methodologies, while maintaining theoretical consistency. In combination, the two programs of research present an array of context-specific methodologies that were developed from a common theoretical perspective.

One major feature of the research reported in this chapter is that the empirical studies at both research sites were carried out over several years. This created opportunities to retrace and explain how methodological approaches were modified over time to either refine an analytical scheme (e.g., distinction between metacognitive regulation of task production or content construction), address new research questions (e.g., impact of task difficulty and focus of cognitive activity) or extend the research to new modes of interactions (e.g., face-to-face synchronous, virtual asynchronous). The rationale behind methodology development is not always unpacked and publicized in the current research literature, yet this is important in an emerging field, where suitable research methods are still in short supply.

Several examples of methodological contextualizations can be found in the present research. Some reflect the educational context or level, others the mode of interaction, group composition, or nature and content of the task. One example is discussed below. It comes from Vauras and colleagues’ research, when they extended their investigations
from dyads’ face-to-face interactions to small groups’ virtual collaborations. In face-to-face dyadic interactions, socially shared metacognitive regulation was identified from consecutive turns that formed meaningful episodes within a limited time frame. In such situations, participants react to each other relatively immediately; they keep focused and typically have one joint discussion at a time, particularly in task-oriented, engaged dyads. Face-to-face interaction in itself does not guarantee these features, though, and evidence from small groups often display parallel interactions within the group.

Multiple cognitive and social metacognitive transactions can be tracked concurrently as in virtual transactions, making the analysis of different transaction episodes more challenging. In virtual, computer-supported learning interactions, socially shared metacognitive regulation is traced in students’ written notes over longer time periods. These notes are often scattered and receive fewer reactions from others. Parallel and intertwined discussions with intermissions also characterize these interactions. The unit of analysis for delineating manifestations of socially shared metacognitive regulation, therefore, has to reflect the characteristics of these different modes of communication. This was done by focusing on the notion of threads, composed of sets of notes, rather than episodes composed of consecutive turns, but the underlying conceptualization of socially shared metacognitive regulation was consistent.

One major methodological issue in empirical research on metacognitive regulation is to decide on the basic unit of analysis, basically the individual or the group. This issue is linked to the underpinning theoretical perspective that is adopted, although a combination of perspectives can be adopted. At the theoretical level, the simultaneous nature of self and social processes is well established (Järvelä et al., 2010; Volet et al., 2009a). The criticality of a situative approach, focusing on ‘learning in activity’, has been stressed (Greeno, 2006; Nolen & Ward, 2008) but at the empirical level it remains unclear how both levels can be integrated. This chapter documents the value of both alternatives.

In Vauras and colleagues’ research, the analysis is turn-based and sets of turns identified as episodes or threads of socially shared metacognitive regulation. A clear distinction is also made between cognitive and metacognitive regulation talk, which was
neatly illustrated in Figures 4.1 to 4.3. In contrast, Volet and colleagues’ analysis starts at the episode level, with the identification of the focus of the group cognitive talk, i.e., task production or knowledge construction. Attention to the individual, turn level comes next, but is used only to identify indicators of metacognitive regulation activity, which is confirmed in the context of the group discussion. This means that metacognitive regulation talk is not separated from but represented as part of the cognitive flow in the graphical illustrations (e.g., Figure 4.7), regulating the cognitive flow from within. We do not believe that these alternative approaches represent inconsistency in theoretical grounding. Rather, we posit the possibility of alternative manifestations of metacognitive regulation. For example, conversations in which students plan how they will work on a task could be considered metacognitive regulation talk that is distinct from content-related cognitive talk in which they do the work that they planned. In contrast, other talk may be part of the content-related cognitive flow, while also serving a metacognitive regulatory function. For example, the injection of new, contradictory information in an episode of knowledge construction, followed by peers’ acknowledgement of the significance of that input, may influence the subsequent direction of their talk. Future research may establish the extent to which these alternative operationalizations of metacognitive talk may be artifacts of the tasks or learners’ characteristics, or whether they capture different manifestations of metacognitive regulation.

Finally, in regard to data analysis, research at both sites involved the development of detailed coding systems and established the reliability of the coding through inter-judge agreement. Furthermore, most of the coding was based on full transcriptions of the verbal interactions, with substantial, complementary descriptions of non-verbal communication. While full transcriptions are highly desirable at the developmental stage of new analytical tools, and facilitate close review and comparison of interactions, they are extremely time-consuming to produce. With increasing understanding and well-tested methods of analysis, this may not always be necessary. Coding can sometimes be more economically done using qualitative data and research analysis software such as Observer XT (Noldus Information Technology) or Atlas.ti. Future research will determine how methodological approaches to the study of metacognitive
regulation in student-led collaborative learning could be made more efficient without compromising on scientific rigor.

Acknowledgements

This research was supported by grant No DP0986867 from the Australian Research Council, awarded to the first author, and grants Nos 201782, 114048 and 130307 from the Council for Cultural and Social Science Research, the Academy of Finland, awarded to the second author. We also thank graphic designer Katja Kontu for the preparation of Figures 4.1 and 4.2.

REFERENCES


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Table 4.1. Coding categories of function and focus of socially shared metacognitive regulation

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitate</td>
<td>The direction of the activity continues the same as previously and strengthens during the episode</td>
<td>Drawing the understanding of the problem on paper to inspect and to progress towards the goal</td>
</tr>
<tr>
<td>Activate</td>
<td>Activating a new construct in line with previous direction</td>
<td>Deciding to check the correctness of what is previously done</td>
</tr>
<tr>
<td>Confirm</td>
<td>Confirming that the previous direction is correct</td>
<td></td>
</tr>
<tr>
<td>Inhibit</td>
<td>The direction of the previous activity is interrupted during the episode</td>
<td></td>
</tr>
<tr>
<td>Slow</td>
<td>Slowing down a continuation of the previous direction</td>
<td>Questioning reasoning, e.g., what’s been done previously and hesitantly continuing</td>
</tr>
<tr>
<td>Change</td>
<td>Changing the direction of previous activity</td>
<td>Rejecting on-going activity and taking another course of action</td>
</tr>
<tr>
<td>Stop</td>
<td>Stopping the direction of previous activity but a new direction does not appear</td>
<td>Reaching the dead end and not deciding how to continue</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Focus</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situation model</td>
<td>Attempt to regulate a situation model, cognitive representation of the events, actions, persons, or an analysis of the problem or different circumstances of the problem</td>
<td>Discussion on a real or fictitious world situation outside the problem, drawing the givens of the problem, combining different conditions to represent the whole problem</td>
</tr>
<tr>
<td>Operation</td>
<td>Attempt to regulate merely strategies or a local matter (e.g., of that moment) without considering the whole problem</td>
<td>Discussion merely on the mathematical operations without considering the situation model, e.g. decision to check calculations</td>
</tr>
<tr>
<td>Incidental matter</td>
<td>Attempt to regulate incidental/detail/issues</td>
<td>Discussion on details, e.g. should whole numbers or decimals be used</td>
</tr>
</tbody>
</table>
### Table 4.2. Example of socially shared metacognitive regulation in asynchronous collaboration

<table>
<thead>
<tr>
<th>Time</th>
<th>Heini</th>
<th>lida</th>
<th>Heidi</th>
<th>Irene</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:33</td>
<td></td>
<td>... there is no evidence of our hypothesis nor our problem. We have to present different hypotheses and it comes from it then...</td>
<td>Initially our hypothesis was that ... Our hypothesis has not changed very much. Our ground is still same but more views and thoughts have been gathered.</td>
<td>It has not been found out in the universe yet ... Still we think that ...</td>
</tr>
<tr>
<td>10:35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:36</td>
<td></td>
<td>... Heidi has consulted a specialist as well but from him we did not get facts because he ended up the same conclusion. (That demonstrates that we got a reasonable conclusion.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:39</td>
<td></td>
<td></td>
<td>... I went ... to the Web page ... where an expert replied to the thoughts of visitors. From him I got an idea which nevertheless was not more than one of many other theories. (so it gave us new reflections but not more.)</td>
<td></td>
</tr>
<tr>
<td>10:40</td>
<td></td>
<td>As it has been noted ... we have not got much knowledge ... There are various hypotheses that will come up in our project. I think of ... that ... we have possibility to explain rather much of them. We may get ... a project...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:43</td>
<td></td>
<td></td>
<td>yes, that's right, and because the issue had not been able to solve by the professional researchers yet so it would not have been possible to us either to solve it. Would we try to write a draft of our whole project here ...??</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.3. Categories of talk dealing with the learning content

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content-processing</td>
<td><strong>Low level</strong></td>
</tr>
<tr>
<td></td>
<td>Reading verbatim, clarifying basic facts, describing, defining, questioning</td>
</tr>
<tr>
<td></td>
<td>for details</td>
</tr>
<tr>
<td></td>
<td><strong>High level</strong></td>
</tr>
<tr>
<td></td>
<td>Elaborating, interpreting, inferencing, speculating, relating, questioning</td>
</tr>
<tr>
<td></td>
<td>for understanding, meaning-making</td>
</tr>
<tr>
<td>Social regulation</td>
<td><strong>Individual regulation</strong></td>
</tr>
<tr>
<td></td>
<td>Predominantly verbal contribution</td>
</tr>
<tr>
<td></td>
<td>from a single speaker</td>
</tr>
<tr>
<td></td>
<td><strong>Co-regulation (group)</strong></td>
</tr>
<tr>
<td></td>
<td>Verbal contributions from multiple group members</td>
</tr>
</tbody>
</table>

*High-level co-regulation of content-processing*

In this study, it was coded as multiple parties’ involvement in elaborating, interpreting and meaning making, questioning each other for understanding, explaining to others in own words. At the empirical level many episodes of high-level coregulation were confounded with high-level coconstruction of knowledge since injections of, for example, questioning for understanding, inferencing or speculating played a regulatory role in the flow of cognitive activity.
Table 4.4. Key terms and orientation of cognitive engagement during collaborative learning

<table>
<thead>
<tr>
<th>Key terms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task</td>
<td>The learning activity and expected tangible task outcome, as set up by instruction</td>
</tr>
<tr>
<td>Knowledge</td>
<td>The information [about the clinical case, facts, reports], interpretations, and conceptual understandings [related to the clinical case]</td>
</tr>
<tr>
<td>Cognitive engagement</td>
<td></td>
</tr>
<tr>
<td>Task co-production</td>
<td></td>
</tr>
<tr>
<td>Low level</td>
<td>Group effort to produce the task outcome without explicit conceptual justification</td>
</tr>
<tr>
<td>High level</td>
<td>Group effort to produce the task outcome with explicit conceptual justification</td>
</tr>
<tr>
<td>Knowledge co-construction</td>
<td></td>
</tr>
<tr>
<td>Low level</td>
<td>Group effort to gather all the information [relevant to the clinical case]</td>
</tr>
<tr>
<td>High level</td>
<td>Group effort to enhance their conceptual understanding [of the clinical case]</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 4.1. Example of socially shared metacognitive regulation in dyadic problem solving

Figure 4.2. Examples of regulation patterns in easy and difficult mathematical word problems

Figure 4.3. Example of regulation patterns in asynchronous collaboration

Figure 4.4. Distribution of time spent on content processing, high-level, and high-level co-regulated

Figure 4.5. Function of regulatory processes in the flow of cognitive activity

Figure 4.6. Three-stage analytical scheme for the analysis of metacognitive regulation in collaborative learning

Figure 4.7. Example of coded metacognitive regulation in a collaborative learning task

Figure 4.8. Comparing cognitive engagement and metacognitive regulation across groups and tasks
<table>
<thead>
<tr>
<th>No.</th>
<th>Joel</th>
<th>Social level metacogn.</th>
<th>Oiva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4518</td>
<td>... look... isn't this a length <em>(shows with his hands in the air)</em></td>
<td></td>
<td>If four meters, hang on, lem... <em>(unassuredly)</em>, what was a length here</td>
</tr>
<tr>
<td>4519</td>
<td>And this is a width <em>(glances at Oiva at the same time when shows with hands in the air)</em></td>
<td></td>
<td>No, this was</td>
</tr>
<tr>
<td>4520</td>
<td></td>
<td></td>
<td>Wait a bit <em>(glances at Joel)</em></td>
</tr>
<tr>
<td>4521</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td>So this is a length, this is a width <em>(points to the notebook)</em></td>
</tr>
<tr>
<td>4522</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td><em>(points to the notebook)</em></td>
</tr>
<tr>
<td>4523</td>
<td>Look, I'm so tall <em>(shows with hands to himself lengthwise)</em> and so broad <em>(shows with hands to himself across)</em> <em>(glances at Oiva)</em></td>
<td></td>
<td>No this is, this is a length <em>(with emphasis)</em>, no, this <em>(with emphasis)</em> in length <em>(points to the notebook)</em></td>
</tr>
<tr>
<td>4524</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td><em>(points to the notebook)</em></td>
</tr>
<tr>
<td>4525</td>
<td>It's not <em>(looks at Oiva's showing)</em></td>
<td></td>
<td>And this is a width <em>(points to the notebook)</em></td>
</tr>
<tr>
<td>4526</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4527</td>
<td>It's not <em>(looks at Oiva's showing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4528</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4529</td>
<td>Look <em>(looks at Oiva's showing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4530</td>
<td><em>(looks at Oiva's showing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4531</td>
<td>Yes so because it's nine meters shorter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4532</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4533</td>
<td>Look, let's put it here, a length, here <em>(draws on the notebook)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Easy Word Problem

START

END

time

Difficult Word Problem

START

END

time

○ = Joel's turn
○ = Olva's turn
◉ = Olva and Joel in unison
T = Teacher's comment
○○ = Socially shared metacognitive regulation
○○ = Individual's metacognitive regulation
○○ = Cognitive activity
<table>
<thead>
<tr>
<th>Knowledge co-construction</th>
<th>Task co-production</th>
<th>Function of metacognitive regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>A. Triggers engagement in Knowledge co-construction (e.g. by asking for more information)</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>B. Returns to Task co-production (e.g. by stopping the discussion)</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>C. Sustains productive Task co-production at low-level (e.g. through collective effort to monitor task progress)</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>D. Produces change to high-level task co-production (e.g. by starting to explore ideas)</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>E. Moves to high-level knowledge co-construction (e.g. by volunteering an explanation or questioning meaning)</td>
</tr>
</tbody>
</table>

Task outcome

Flow of cognitive activity

Metacognitive activity
Cognitive engagement
At episode level

Metacognitive regulation
At turn level

Metacognitive regulation
At context level

Orientation and depth

Indicator and focus

Social nature and function in context
<table>
<thead>
<tr>
<th>Two coded extracts from Group B’s initial meeting to generate their learning objectives</th>
<th>Cognitive flow</th>
<th>Metacognitive regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Orientation &amp; depth</td>
<td>Indicator &amp; focus</td>
</tr>
<tr>
<td>641. Adrianna: Diagnosis, blind. Hypertensive retinal disease. (Reading from case file)</td>
<td>K co-con Low</td>
<td>Adrianna and Chelsea are in the process of trying to decipher the contents of the case file (Knowledge co-construction) when Claudia attempts to shift the discussion to learning objectives (Task co-production). Her attempt is unsuccessful as her suggestion is not followed-up (thus evidence of individual MR). Adrianna continues to decipher the case (which reflects the return to Knowledge co-construction).</td>
</tr>
<tr>
<td>642. Chelsea: I’ll put BP200 mmHg (writing) all right.</td>
<td>T co-pro Low</td>
<td>644 Plan</td>
</tr>
<tr>
<td>643. Jack: OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>644. Claudia: So just like, to wrap up, do you wanna just go through the learning objectives we came up with the other day and see if we’re still happy with them?</td>
<td>K co-con Low</td>
<td></td>
</tr>
<tr>
<td>646. Adrianna: Diagnosis. What does that word say? (Speaking to Isabelle and pointing at her notes, as Isabelle has been trying to decipher the same section of notes as Adrianna).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>750. Chelsea: Um, describe pathophysiology of retinal detachment, which obviously hypertension plays a role in. And then, I hadn’t written a learning objective that encompasses hypertension but I do have a note to make one.</td>
<td>T co-pro Low</td>
<td>750 Plan &amp; Monitor</td>
</tr>
<tr>
<td>751. Claudia: Mm.</td>
<td></td>
<td>752 Monitor</td>
</tr>
<tr>
<td>752. Chelsea: If anyone’s got something off the top of their head.</td>
<td></td>
<td>754 Plan &amp; Monitor</td>
</tr>
<tr>
<td>753. Adrianna: Would that be involved in the mechanisms of channel blockers to treat hypertension? That learning objective?</td>
<td></td>
<td>756 Monitor</td>
</tr>
<tr>
<td>754. Claudia: I think it is involved (Chelsea nods) Like I think out of, out of logical order. Cos I think, the channel blocker would be the last objective we’d look at (laughs).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>756. Isabelle: Well if you think about, this was a couple of John’s lectures and the learning objectives after that, it might be— (Chelsea interjects, below).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: K co-con = Knowledge co-construction; T co-pro = Task co-production; Low = Low-level; High = High-level; MR = Metacognitive Regulation; SSMR = Socially Shared Metacognitive Regulation
Task 1: Generate Learning Objectives

Group A

Cognitive engagement: % time orientation & depth
- 19% of cognitive turns display MR
- 78% of MR is embedded in SSMR episodes
- Session contains 36 SSMR episodes

Group B

Cognitive engagement: % time orientation & depth
- 21% of cognitive turns display MR
- 71% of MR is embedded in SSMR episodes
- Session contains 27 SSMR episodes

Task 2: Construct Concept Map

Group A

Cognitive engagement: % time orientation & depth
- 21% of cognitive turns display MR
- 60% of MR is embedded in SSMR episodes
- Session contains 9 SSMR episodes

Group B

Cognitive engagement: % time orientation & depth
- 21% of cognitive turns display MR
- 69% of MR is embedded in SSMR episodes
- Session contains 16 SSMR episodes

Key
- High Level
- Low Level
- Knowledge co-construction
- Task co-production
- MR Metacognitive Regulation
- SSMR Socially Shared Metacognitive Regulation
- Miscellaneous