THE EFFECTS OF PROMPTS AND EXPLICIT COACHING ON PEER FEEDBACK QUALITY

Mark Gan Joo Seng

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ABSTRACT

Feedback is seen as both a determinant and consequent of active and meaningful engagement of learners with the learning process. While feedback research on student achievement has predominantly focused on the provision of feedback from the teacher or an external assessment source, less attention has been given to peer feedback and its interactional effects within the classroom context. Using a theoretical framework developed by Hattie and Timperley (2007), this research investigated the impact of instructional support (prompts and coaching) on the nature and quality of peer feedback in three inter-related studies.

The first study explored the characteristics of verbal feedback during a collaborative investigative chemistry task involving New Zealand Year 13 students. Analysis of transcribed verbal data showed that although students adopted a predominantly interactive/authoritative communicative approach (Mortimer & Scott, 2003), with peer feedback as information or evaluation, they are also capable of a more interactive/dialogic exchange, characterised by elaborative peer feedback.

In the second study, the effects of prompting on written peer feedback were examined in New Zealand Year 12 students' chemistry investigation. A quasi-experimental pre-test post-test design was adopted. Students in the experimental group were prompted with questions that asked them to give written feedback to their peers on what they did or did not do well and suggestions for improvement, while students in the control group gave written peer feedback without prompts. The findings showed that prompted peer feedback has a significant effect on the number of comments related to knowledge of errors ($d = .70$), task level ($d = .43$) and process level ($d = .85$) feedback. The use of prompts resulted in a large improvement in the quality of peer feedback in terms of suggestions for improvement ($d = 1.22$) and uptake of comments for revision of report ($d = 1.15$).

The third study extended the use of prompts to include explicit instruction on formulating feedback at task level, process level, and self-regulation levels. Eight classes of students ($n = 332$, 14–15 year olds) from four Singapore secondary schools participated in this study. Students in the experimental group received instruction on feedback levels and practice giving written feedback on crafted laboratory reports with the help of a graphic organiser designed with feedback levels. Students in the control group spent the same amount of lesson time on a lecture about how to carry out an investigation. The results indicated that explicit coaching facilitated the formulation of more task, process, and self-regulation peer feedback compared to the control class.

This research supports the view that helping students to visualise a learning progression involving task, process, and self-regulation levels, facilitates the formulation of differentiated peer feedback. By developing this notion of formulating peer feedback as a progression, this investigation contributes to feedback research by extending the concept of 'quality' from a dualism view (i.e. feedback as positive or negative comments) to one of progression. The main implication for instruction is that peer feedback approaches in the classrooms can be facilitated by the use of question prompts and a graphic organiser with feedback levels. This also implies that learning with peer feedback requires students to recognise the differences in peer feedback discourse as situated within the learning context, perceptions, and practices of the classroom.

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Research on peer feedback has raised concerns about the cognitive demands of generating and interpreting feedback, and the negotiation of feedback for revision (Cho, Chung, King, & Schunn, 2008; Cho & MacArthur, 2010; Gielen, Peeters, Dochy, Onghena, & Struyven, 2010). While there are numerous studies which examine the comparative effects of peer and teacher/expert feedback on performance (e.g., Cho & MacArthur, 2010; Prins, Sluijsmans, & Kirschner, 2006; Yang, Badger, & Yu, 2006), less is known of how peer feedback discourse works within a classroom context and what instructional support is necessary to bring about effective peer feedback for learning (Van Zundert, Sluijsmans, & van Merrienboer, 2010). Drawing from Hattie and Timperley's (2007) feedback model, the notion of peer feedback quality is extended from a dichotomous perspective (e.g., peer feedback information as accurate or inaccurate) to a progressive view. The former is seen as perpetuating a 'terminal view' of feedback for learning, while the latter has the potential to extend learning by engaging learners with peer feedback at the task, process, and self-regulation levels. In particular, this thesis proposes that explicit prompting and coaching promote not only the process of giving and receiving peer feedback, but also the purposeful interaction of the learner with peer feedback, encompassing progressively higher levels of cognitive engagement.

BACKGROUND

Scientific Literacy and Peer Feedback Discourse Practices

One of the main goals of science education is the development of *scientific literacy*. Scientific literacy can be described as the science-related knowledge, practices, and values that science educators hope students will acquire as they learn science. Feasey (1998a) used the terms 'thinking and working scientifically' to describe the process of developing scientifically literate individuals, which is akin to "the ways in which scientists construct and acquire knowledge" (p. 53). The Organisation for Economic Co-

Operation and Development's (OECD) Programme for International Student Assessment (PISA) defined scientific literacy as:

> the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (OECD, 1999, p. 60)

This view is echoed by Goodrum, Rennie, and Hackling (2001), who defined scientific literacy in terms of using science in everyday life, not about knowing a great deal about science as a body of knowledge, but rather knowing science as a way of thinking, finding, organising and using information to make decisions. Although teachers, science educators, and researchers are aware of the importance of science and the need for students to achieve scientific literacy, a key issue is to ensure that such importance is reflected in the teaching of scientific literacy and that it is present in the science curriculum in schools. Goodrum et al. (2001) described scientifically literate students as individuals who are interested in, and understand, the world around them; engage in the discourse of and about science; are able to identify questions, investigate and draw evidence-based conclusions, are sceptical and questioning of claims made by others about scientific matters; and make informed decisions about the environment and their own health and well being. In short, scientific literacy encompasses three knowledge dimensions—the nature of science, interactions of science and society, and representational competence (knowing how, why, and when to interpret and construct models, graphs, tables, and diagrams, and integrate these representations with written language to develop scientific claims, Murcia, 2007; Rennie, 2005).

Central to scientific literacy is the notion of framing science instruction as the enactment of scientific practice. Hodson (2009) emphasised the need for active critical engagement, which he termed “critical scientific literacy” and argued that “the most important function of scientific literacy is to confer a measure of intellectual independence and personal autonomy” (p. 11). Students need to learn the language of science as part of ‘doing science’, and have the opportunity to use this scientific language in meaningful communications and argumentative discourse.

> Indeed, it could be said that learning the language of science is synonymous with learning science, and that *doing* science in any meaningful sense requires a reasonable facility with the language. It is scientific language that shapes our ideas, provides the means for constructing scientific understanding and explanations, enables us to communicate the purposes, procedures, findings, conclusions and implications of our inquiries, and allows us to relate our work to existing knowledge and understanding. (Hodson, 2009, p. 8)

Thus, using the language of science extends beyond recognising the vocabulary or gathering of specific information, it entails learning to think and reason scientifically by engaging in spoken and written discourse practices.

Development of scientific literacy in students is very important and they can best learn science by actively engaging in the discourse practices of science. The term 'discourse' is broadly defined as classroom communication between teacher-student or student-student and involves both verbal and written forms of language. Although discourse practices are seen as avenues for knowledge construction and meaning making in the science classrooms, studies of science discourse have suggested otherwise (Lemke, 1990; Russell, 1983). Teacher-dominated discourses are prevalent in classrooms and in most cases they limit the opportunities for student involvement, access to different modes of communication, and purposeful practice in the use of language (Alexander, 2004; Cazden, 2001; Nystrand, Wu, Gamorgan, Zeiser, & Long, 2003). This notion of authoritative classroom discourse highlights the importance of moving away from a teacher-dominated classroom to focus on choosing and structuring discursive practices that support cognitive and meta-cognitive engagement of the learner when talking and writing science. A more extensive review will be elaborated in Study One.

One significant contribution of classroom discourse studies is the recognition that interactive discourse processes make available to students a wide range of opportunities to learn the *language* of science (i.e., learning science content) as well as learn *about* science (Hodson, 2009). Indeed, the study of discourse practices is increasingly recognised as providing insights into how different views about the use of language in science determine the decisions on pedagogical practices in science classrooms (Kelly, 2007; Saul, 2004). One of the major classroom sources of discourse is between peers, which can play a major part in helping students engage in productive discourse during student-student collaborative learning tasks. In this research, peer feedback is viewed as a discursive practice situated within science classroom discourse and thus, offers *opportunities* for students to engage in talking and writing about science. More specifically, peer feedback allows students access to using scientific language for making informed judgements about their peers' work, identifying learning gaps and formulating revision approaches, interpreting peer feedback responses, and revising their work in light of the comments received. When viewed through this lens of using language and interactivity, peer feedback discourse plays an important role in the collaborative meaning making process of the science classroom. This notion of peer feedback as a resource for learning is a recurring theme throughout the investigation described herein. Despite its potential benefits, there are reservations about the use of peer feedback by teachers, such as the relinquishment of control, and this reluctance may limit the opportunities for students to engage in verbal and written feedback discourse. Thus, a key question is: How can we provide instructional support that helps to promote the use of meaningful peer feedback discourse in the classroom?

Peer Feedback for Learning

A central tenet of 'assessment for learning' and peer assessment is the need for effective feedback (Black & Wiliam, 1998a; Dochy & McDowell, 1997; Topping, 1998). While most researchers and educators recognise the crucial role that feedback plays in learning, there is less consensus on how best to support that role within the classroom. Over the past decade substantial research had examined the impact of assessment practices on students and highlighted the importance of feedback on their learning in the context of the classroom (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Black & Wiliam, 1998a, 1998b; Crooks, 1988; Kluger & DeNisi, 1996; Hattie & Timperley, 2007; Shute, 2008). However, while research had shown that the outcomes of assessment might draw attention to or away from learning, the different types of feedback and their differential effects on learning continue to pose a challenge for educators designing instructional intervention that strives to maximise the potential of feedback for learning (Brookhart, 2004, 2007; Mory, 2004; Narciss, 2008). In addition, recent research had emphasised the need to consider learner characteristics in the feedback process (Shute, 2008), the active engagement of learners themselves with the feedback in self-assessment and self-regulated learning processes (Andrade & Valtcheva, 2009; Dochy, Segers, & Sluijsmans, 1999; Nicol & Macfarlane-Dick, 2006), and the defining role of peers as feedback resources (Falchikov, 2001; Topping, 2005, 2010; Wiliam & Thompson, 2007). While these studies provided fresh insights on feedback, they have created further challenges for researchers and educators keen on untangling the nature of feedback and learning. Given the multi-dimensional nature of feedback and its effect on learning, more research is needed to shed light on conceptualising the *quality* of peer feedback and how it can be meaningfully supported in the classroom learning context.

In this investigation, the notion of peer feedback quality is developed by considering two interconnecting perspectives that underpin feedback research. One view of peer feedback quality suggests that feedback information is useful when it helps learners close the learning gap (Ramaprasad, 1983; Sadler, 1998). Viewing feedback through this lens has helped to identify the shortcomings of feedback interaction, often construed as a passive receptive-transmissive approach (Askew & Lodge, 2000), which is unidirectional and manifested by a teacher-dominated classroom environment. The sole focus on supplying criteria and corrective information results in a narrow view of feedback, and limits the consequential influence of feedback on learning. Although the perspective on closing the learning gap draws attention to the use of feedback information to move towards the learning goal such that the feedback loop is complete, the question remains as to how best this is achieved through the involvement of learners.

Another perspective on peer feedback quality builds on the notion of reducing the ‘discrepancies between current understanding and performance’ by focusing on the learner’s engagement with the feedback information at the task, process, self-regulation, and self levels (Hattie & Timperley, 2007). In Hattie and Timperley’s model, interventions involving feedback are likely to be more effective when the learner’s attention is drawn to cognitive outcomes related to the task, task processing strategies, and the self-regulation strategies adopted, rather than focusing on the self. Incorporating and building on this model of feedback, this investigation develops the notion of peer feedback quality as involving *progressive* feedback information targeted at the task, process and self-regulation levels. A progressive view of feedback such as this posits a shift in focus from one on feedback interaction recognising a learning gap and finding corrective solutions, to one in which the learning gap is seen as an opportunity for the learner to interact with feedback information at different levels of cognitive engagement. In short, instead of the learner asking "What is the correct answer?", a more pertinent question could be "How can I use this peer feedback to develop my answers further?"

Besides providing a theoretical framework for the investigation of peer feedback quality, the model by Hattie and Timperley (2007) allows for the positioning of peers as a resource for feedback interaction. As explicated in the model, effective feedback involves answering three questions—Where am I going? How am I going? Where to next? Instead of teachers providing students with the answers to these questions, students can help each other by formulating feedback related to these questions. In other words, students themselves take on the role of 'reader' and 'reviewer', to be actively engaged with the exchange and negotiation of peer feedback information. Here, the involvement of peers, who are classmates of the same age group, are seen as important for three reasons. First, peers serve as a rich and available resource for giving and receiving feedback. Feedback from peers can be more immediate, timely, and individualised than teacher feedback (Topping, 2010). Second, engendering peer feedback will mean that students have the opportunity for collaborative peer discourse. Students not only learn *with* each other but also *from* each other as well as from the feedback process. Third, the involvement of students suggests that students have the potential to be responsible for their own learning and peer feedback provides an avenue to do so.

PURPOSE OF THIS RESEARCH

The purpose of this research was to address the central question of whether instructional support—in the form of prompts and explicit coaching—could improve the quality of peer feedback during an investigative chemistry task. Hattie and Timperley's (2007) feedback model provides a framework for examining instructional support and its relation to peer feedback quality. Based on this feedback model, the following four assertions were developed:

1. Peer feedback is meaningful when it is integrated into a cycle of learning.

2. Peer feedback is useful when it provides information to identify where the learner is at, direct attention towards the learning outcome, and how best to achieve this outcome.
3. Peer feedback is powerful when it focuses the learner's attention on the learning task, task processing strategies, and self-regulation strategies instead of directing attention on the self.
4. Peer feedback levels are viewed as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.

These four assertions served as a basis for thinking and conceptualising the role of peer feedback in learning and for developing the relation between peer feedback quality and effective instructional interventions.

AN OVERVIEW OF THE CHAPTERS

This series of studies is about the use of instructional support to promote quality peer feedback for learning during chemistry investigations. In Chapter 2, an overview of feedback functions and their relation to learning will be provided. This is followed by a discussion of a model of feedback that provides a framework for investigating the nature and quality of peer feedback for learning. Chapter 2 also provides an overview of the research on the nature and quality of peer feedback, the learning context of science investigations in New Zealand, and the importance of instructional support in peer feedback engagement.

Chapters 3, 4, and 5 report three interrelated empirical studies that examine peer feedback when engaging in a chemistry investigative task. Each chapter builds on the previous chapter to incorporate and develop the key ideas of instructional support for peer feedback information targeted at the task, process, and self-regulation levels. Each chapter includes a literature review, methodology, findings, and discussion section for the empirical study reported therein.

Chapter 3 explores the characteristics of verbal feedback when peers engage in planning and implementing a chemistry investigative task. The focus is on identifying the types and functions of peer feedback within a typical collaborative science learning context, and how these responses shaped the communicative approaches adopted by peers during the investigative task.

Chapter 4 draws on the notion of peer feedback as an opportunity for the discursive use of language for learning science (as developed in Chapter 3). Chapter 4 examines more closely the quality of written peer feedback during a chemistry investigative task. In particular, this intervention study investigated the effects of prompts on helping students to generate peer feedback which identified the learning 'gap' and provides suggestions for improvement. The shift from verbal to written peer feedback was seen as necessary not only to document the process but also to make peer feedback explicit so as to facilitate the use of feedback for discussion and revision of work done by the students. Moreover, making peer feedback explicit through the written discourse allows for a detailed analysis of the students' cognitive engagement at the task, process, and self-regulatory levels, and this idea was developed further in this chapter.

In Chapter 5, the effects of explicit coaching on peer feedback quality were investigated. Students in the intervention classes were taught to use a graphic organiser with prompts to formulate task, process, and self-regulation level feedback to their peers, while students in the control classes spent the same amount of class time listening to lectures about chemistry investigation skills. A more refined coding scheme for differentiating peer feedback at each level, based on Hattie and Timperley's feedback model (2007) is also presented.

Finally, in Chapter 6, the significant contributions of the three empirical studies are elaborated in view of the impact of instructional support on the quality of peer feedback for learning during chemistry investigations. Educational implications are also discussed in this final chapter.

CHAPTER 2
LITERATURE REVIEW

INTRODUCTION

The first part of this review outlines three of the major learning perspectives that frame research in feedback, and it draws on key studies to illustrate how different assumptions about learning and learners can influence the way feedback is construed and incorporated into the teaching and learning process. This first section also addresses the changing conceptions of learning and their relation to an expanded view of feedback for learning. This sets the scene for the second part of the review, which adopts Hattie and Timperley's (2007) feedback model as a theoretical framework to explore and explicate the nature and quality of peer feedback.

The second part of the review addresses research in peer learning, collaborative learning, peer assessment, and peer review, which incorporates elements of peer feedback in educational contexts. Central to this review is the notion that instructional support, which takes into consideration scaffolding through explicit prompting and coaching, may enhance peer feedback quality and effectiveness.

Following this, the literature on students' science learning through investigations is reviewed. This provides the context for the empirical studies in this investigation. Importantly, the feedback model is seen as relevant in this context because students' learning about investigations involves understanding at the task, process, and self-regulation levels, and engaging students in peer feedback discourse at these three levels may influence their learning during investigations.

THEORETICAL PERSPECTIVES ON LEARNING AND THEIR RELATION TO FEEDBACK

Feedback can serve different functions depending on the particular learning perspective under which it is viewed and the underlying assumptions about the learning context on which research in these areas are based. The first section of the review outlines three major philosophical perspectives—objectivism, information processing, and sociocultural theory—that provide the frameworks for describing different views of learning and thus, the nature of feedback (see Table 1).

Table 1. Perspectives on learning and the nature of feedback

Philosophical Perspective	Assumptions	Views of Learning	Nature of Feedback
Objectivism: Reliable knowledge of the world exists.	• All reality consists of entities. • The entities, their properties, and their relations make up our world. • This reality exists outside of the individual. • The mind functions to create representations of these entities and learning involves knowing these correct representations.	• Behaviourist. • Respondent learning, operant conditioning and observational learning. • Social-behavioural	• Feedback is an external response which may contain symbols that match an external entity. • Feedback reinforces current representations or corrects misrepresentations of this external entity (by providing corrective information).
Information-processing: Each learner constructs his or her own reality through processing and interpreting experiences of the external world.	• Reality is an interpretation based on an individual's experiences. • Learning takes place through individual meaning construction or cognitive activity when an individual tries to make sense of the world.	• Information-processing. • Cognitive elaboration. • Self-regulated learning	• Feedback helps learners in meaning construction. • Feedback is used to build internal understanding through connections with learner's prior experiences, mental structures and beliefs.
Socioculturalism: Knowledge is socially constructed rather than an individual experience.	• Reality exists through the individual as well as being shaped by society and an individual's relationship with society. • Learning involves social negotiation of meaning.	• Social constructivist. • Communities of practice	• Feedback is a social negotiation through the meaningful use of language. • Feedback involves a reciprocal and dialogic process of co-construction of meaning. • Feedback quality depends on the interaction process of peers and not just the person providing feedback.

Objectivism

Objectivism takes the view that "reliable knowledge about the world" exists (Jonassen, 1991, p. 8) and instruction based on this assumption is seen as predominantly 'receptive-transmission' (Askew & Lodge, 2000). From an epistemological view, objectivism is a mirror image or reality created by the mind and these representations of the real world constitute the way of knowing (Lakoff, 1987). The paradigm of behaviourism adopts this objectivist perspective and earlier feedback studies have examined feedback within this philosophical viewpoint (Mory, 2004).

From a behaviourist perspective, learning is viewed as conditioning where behaviour that is followed by a reinforcer will increase in frequency or probability (e.g., Skinner's operant conditioning). Learning is seen as a process of reinforcing knowledge acquired in a sequenced and hierarchical fashion, and learning tasks can be preplanned, organized, and programmed with specific outcomes defined. The learning task is analysed to identify the components that must be acquired in order to complete the task and the most appropriate sequence of learning is prescribed based on observable learning outcomes. Feedback is usually seen as reinforcement, helping the learner to progress from a hierarchy of simple to more complex task performance. The objectivist roots are evident, with feedback provided from an external source (usually from the teacher who is viewed as an expert) in order to match an external learning outcome to the learner's current observable performance on the prescribed task. The dominant feedback discourse is one of receptive-transmission (Askew & Lodge, 2000) and a prevalent view of feedback is that it serves as a motivator or incentive for increasing response rate and/or accuracy (Kulhavy & Wager, 1993).

A classical example of this instructional approach is the programmed instruction of the 1960s —depending on the answer to a question the student is directed to remediation or to more difficult questions. Although it can be argued that feedback as reinforcement is beneficial to novice learners on new learning tasks, its effects are limited and at times confusing (Kulhavy & Wager, 1993). The focus on incentives may distract learners from the instructional content of feedback and results in little effort used to interpret feedback for learning (Kulhavy & Wager, 1993). Anderson and his colleagues (1972) found that students usually bypass the feedback if the answer is readily available in the learning task and when feedback is provided prior to completion of the task, students tend to copy their answers from the feedback instead of processing the feedback information meaningfully. This finding points to the importance of feedback as a "consequence" of performance, and not provided before completion of any learning task.

The view that feedback serves as a motivator or incentive for learning is still prevalent in the classrooms of today and there remains a perpetual confusion by teachers between praise and content-related feedback (Hattie & Timperley, 2007). Deci, Koestner, and Ryan (2001) found that when teachers provide tangible rewards as a form of feedback, intrinsic motivation is significantly undermined and students are less inclined to take responsibility for motivating or regulating themselves. Feedback in the form of extrinsic rewards often led students to place more emphasis on incentives, which result in greater surveillance, evaluation and competition, rather than enhanced engagement of learning. Kulhavy and Wager (1993) suggested that motivational variables be separated from feedback messages, in order to focus on the instructional content of feedback.

Information Processing Perspective

The information-processing perspective of learning may be seen as a transition phase from behaviourism to socioculturalism and represents a shift in emphasis from an external view towards an internal view. An important feature of information-processing theories is that they recognize the cognitive ability of individuals to use information actively when engaging with the learning task. This suggests that feedback functions not only to reinforce correct answers but also as corrective information to help learners to correct their errors. The feedback-as-information position asserts that correction and analysis of errors is a crucial component of learning and feedback acts as verification of a learner's response certitude or level of certainty (Kulhavy & Stock, 1989).

Kulhavy and Stock's (1989) response certitude model, for example, suggested that instructional feedback messages contain two important components: verification and elaboration. Verification is a *dichotomous judgment* to indicate that a response is right or wrong. Elaboration is the component of the feedback message which contains relevant information to help the learner in error correction. Feedback elaboration can be classified based on the type of information included: (a) task specific, (b) instruction-based, or (c) extra-instructional. Task-specific elaborations include restatement of the correct answer, or inclusion of multiple-choice alternatives as part of item feedback. Instruction-based elaborations provide explanations of why a certain response is correct, or re-present the instructional text in which the right answer was contained. Extra-instructional elaboration refers to the provision of new examples or analogies not found in the instructional text.

In this model, the feedback process is composed of three cycles, where each cycle involves an external stimulus, learner comparison of the input to a reference standard, followed by a resultant response. The first cycle describes the learner as comparing the perceived task demand against previous experience and evaluation of various response possibilities. The second cycle involves feedback processing by the learner. Here the learner's level of certainty (response certitude) is related to the discrepancy between perceived stimulus and reference standard results. According to Kulhavy and Stock (1989), when learners are certain their answer is correct (high certitude correct, with low discrepancy), they will spend little time analysing feedback, and verification feedback is sufficient. When learners are certain their answer is correct but it was in reality an incorrect response (high certitude correct, with high discrepancy), elaborate information in feedback is useful to the learner, who will spend more time reviewing feedback. For learners with low certitude responses, they would more likely to benefit from feedback that acts as new instruction. Cycle three involves the learner responding to the same task after processing the feedback, and the corrective feedback now leads to a correct response. Although this model is built around experimental testing environments that are unlike the typical classroom learning situation, it supports the notion of learner involvement in the feedback process and highlights the need for adaptive use of feedback information with consideration to learner characteristics, in this case, high or low confidence in responding to questions.

Taking things a step further, Bangert-Drowns et al. (1991) proposed the five-stage model of mindful feedback. This model suggests that feedback which encourages learners' mindful reflection is beneficial to learning. Although the model explicates the need for reflection on the part of the learner, the main focus of the text-based feedback is to change the current behavioural and cognitive state of the learner. For feedback to promote learning, it has to be designed to *bring about mindfulness* and to *minimize* *mindlessness*, such as providing feedback before learners begin their memory search for an answer.

Another feedback framework with an information processing perspective is the feedback intervention theory by Kluger and DeNisi (1996). This theory suggests that feedback intervention that focuses the learner on the learning task results in a larger learning gain than feedback that draws attention to the self, which can be detrimental to learning. Norm-referenced feedback comparing the individual's performance to lower achieving learners may, for example, encourage them to attribute poor performance to a lack of ability, leading to lower expectations in future performance and decreased motivation on future tasks. Kluger and DeNisi (1996) argued that there were three classes of variables which determined the effect of feedback on performance: the cues of the feedback message, the nature of the task performed, and situational and personality variables. Feedback can provide cues that capture a person's attention: the central assumption being that feedback information gets a person's attention, and that *attention* is hierarchical in nature.

Of the many goals of feedback, it certainly can direct attention to the processes to accomplish the task, provide information about erroneous hypotheses, and it can be intentionally be motivational so that students invest more effort or skill in the task. Feedback effectiveness decreases as attention moves up the hierarchy closer to the self and away from the task. Therefore, feedback that directs its attention to the meta-task goals may lead to disengagement from the task even when the feedback is positive. A major key to unlocking the power of feedback is to ensure cues are responsive to the task performed and concerned about the situational and personality attributes of the receiver.

Butler and Winne (1995) proposed an examination of feedback that takes into account how internal and external feedback affects self-regulated cognitive engagement with tasks and how different forms of engagement relate to achievement. They argued that feedback serves a multidimensional role in knowledge construction, which translates into a model involving self-regulation. This helps to extend the traditional view of feedback as predominantly seeking a set of correct responses, or as error-correction, to one in which feedback is a function of regulative cognitive processes of the learner and is both dependent on the outcome of self-regulated learning. Internal feedback is generated when self-regulated learners monitor the processes of task engagement (e.g., setting goals, applying strategies, or reviewing products of learning). This internal feedback provides information for the learner to regulate their task engagement and may be further influenced by external feedback, motivational beliefs, and affective reactions. When there is a perceived discrepancy between a current state and the desired goals, internal feedback allows the learner to decide whether to invest further effort, modify their plan, or abandon the task completely. The result of this cognitive monitoring and processing is the possible change in knowledge and beliefs, which in turn, might further influence subsequent self-regulation (Butler & Winne, 1995).

Feedback as self-regulation recognizes the importance of interaction between feedback information and the receiver, as well as the active engagement of the learner in cue-seeking, monitoring, and evaluating their own performance. For example, Butler and Winne (1995) postulated that the study of cue-seeking behaviour in learners may lead to "several elaborated forms of feedback that may support self-regulated engagement in tasks by enhancing the learner's calibration" (p. 251). *Calibration* describes the "accurate associations between cues and achievement" by the learner, and the learner is said to be *well calibrated* when he or she is able to "self-regulate by recursively adjusting approaches based on perceived task cues in relation to achievement" (p. 251). Citing the study by Balzer, Doherty, and O'Connor (1989), Butler and Winne argued that cognitive feedback may enhance learners' calibration by monitoring cues such as task features or cognitive activities, which is a necessary part of self-regulation.

Butler and Winne (1995, p. 250) also asserted that learners' "beliefs about learning affect self-regulation by influencing the nature of and interpretation of feedback". They quoted evidence from two lines of research—Schommer and her colleagues' (1992) research on learners' epistemological views about learning and Chinn and Brewer's (1993) review that identified seven ways that learners respond to anomalous information—to acknowledge that feedback should be interpreted in light of the learners' beliefs and knowledge domains. In summary, Butler and Winne (1995) concluded that the learner's prior knowledge, beliefs, and thinking act as a filter to mediate the effects of externally provided feedback as well as internal feedback. This mediation, in turn, influences the learner's monitoring of task engagement and progress, which is an inherent part of self-regulated learning. The explicit emphasis on the role of monitoring and feedback within a self-regulated learning framework broadens the objectivist conception of feedback to include the viewpoint of information processing, and hence, "integrates instruction, self-regulation, feedback, and knowledge construction" (p. 275). What is also evident from this synthesis is the acknowledgement that learners are not passive receivers of feedback but actively interpret feedback information through self-regulatory processes and have the capacity to be responsible for their own learning.

Narciss and Huth (2004) suggested a content-related classification of feedback in terms of the instructional context that is addressed by simple or elaborated information. In general, they claimed that designing and developing effective formative feedback needs to take into consideration the instructional factor or context (e.g., instructional objectives, tasks, and errors), learner characteristics (e.g., learning objectives and goals, prior knowledge, skills, abilities, and academic motivation), as well as feedback elements (e.g., content of feedback, function, and presentation). The informative value of the feedback can be enhanced by combining elaborated feedback, tutoring, and mastery learning strategies. Narciss (2008) used the term *informative tutoring feedback* to refer to feedback strategies that provide elaborated feedback components to guide learners towards successful task completion. The elaborated feedback information may take the form of: (1) task rules, task constraints, and task requirements; (2) conceptual knowledge; (3) errors or mistakes; (4) procedural knowledge; and (5) metacognitive knowledge. Feedback as tutoring is focused on guiding students in error detection, overcoming obstacles, and applying more efficient strategies for completing the learning tasks (Narciss, 2008).

Socioculturalism

Feedback may be seen as performing a wider function in helping learners when viewed from a sociocultural perspective. The sociocultural view derives from the work of Lev Vygotsky (1978, 1986). Vygotsky advanced a view that knowledge and understanding are socially constructed through interactions with others. For Vygotsky, the learner's interactions with other people, preferably a more competent member of the society in which the learner is growing up, initiates the learner into the social, linguistic practices and artefacts of the society. Through participating in the cultural life of the community, the learner is seen as engaging in a kind of cognitive apprenticeship, which helps them to acquire the ‘cultural tools’ that develop more advanced levels of thinking and greater conscious control over their mental processes. According to Vygotsky, the processes of interaction between the learner and others become internalized as the basis for *intramental* reflection and logical reasoning. Thus, learning and development are seen as mediated by the dialectical relationship between interpersonal and intrapersonal processes (Mercer & Littleton, 2007).

Research by Villamil and de Guerrero (2006) provided some insight into situating feedback within a sociocultural framework. Through a long-term study of peer feedback and revision, the researchers found that individual development in a second language could be enhanced by the social experience of talking about writing, as well as writing and revising with a partner. Five classes were taught on how students could revise their writing. The first drafts were collected and then students were randomly paired. Next, in pairs they were asked to revise these drafts with one working as the writer and the other as the reader. Villamil and de Guerrero analysed the interactions and found that the peers needed to be at similar stages of self-regulation and shared control, as well as having high levels of empathy when listening to the partner’s comments. Then they could discuss textual problems, acquire strategic competence in revising a text, acquire a sense of audience, and develop a sense of regulation about their own writing. Although the study recognized the beneficial effect of peer interaction in learning, the authors noted the necessity of preparing and instructing learners on desirable behaviours such as maintaining mutual cognitive engagement and minimize negative behaviours that would impede collaborative learning. The authors recommended the need for educators to be aware of the learners’ strategic behaviours that influence the success of scaffolding during peer feedback and to explicitly address the learners’ sociocultural contexts and learning backgrounds to enhance collaborative learning in the classroom. They concluded that the exchange of ideas amongst peers resulted in consolidating, reorganizing, and making knowledge explicit for the development of writing skills and discourse strategies. An important implication for feedback is the need to address the sociocultural differences between learners, which may take the form of social relationships, cultural norms, and behavioural expectations (see Pryor & Crossouard, 2008). For example, the nature of the teacher-student/student-student relationships may influence the level of acceptance of feedback by students as well as their involvement in seeking feedback (Bell & Cowie, 2001).

A FRAMEWORK FOR PEER FEEDBACK QUALITY

The above perspectives suggest that there is a need to understand the underlying assumptions that educators have about learning, and how such assumptions impact on the way feedback is delivered and used. In classrooms, there may be a need to shift from seeing the teacher as giver and learner as receiver of feedback, to also accounting for the social context of learning—particularly the ways peers provide feedback. Thus, feedback needs to move from a predominantly transmissive and verifying process to a dialogic and elaborative one that occurs in a social context. Then feedback can be seen in a context of collaborative student learning, actively interacting with differing levels of regulation (by others, with others, self), and with differing levels of information and focus with respect to the feedback information. It follows that the studies which comprise this investigation are situated in a sociocultural perspective, involving peers in feedback exchange and investigating not just the feedback information, but also recognising that peer discourse is part of the peer feedback process. Hattie and Timperley's (2007) feedback model lends itself to framing peer feedback within a sociocultural perspective because it allows for the development of an interactive and progressive view of peer feedback engagement as situated in a social context (i.e., collaborative peer learning in the classroom).

According to Hattie and Timperley (2007), feedback is information provided by an agent (e.g., teacher, peer, book, or one's own experience) about aspects of one's performance or understanding. The feedback can take the form of corrective information, suggestions for alternative strategies, clarifying of ideas, or evaluation of the correctness of a response. Hattie and Timperley pointed to Sadler's (1989) comments about feedback being part of an instructional process whereby it must provide information specifically about the task or process of learning; filling a gap between what is currently understood and what needs to be understood'. The focus is on task-based feedback that is a 'consequence' of student performance, i.e., building on previous work done by the learner and targeted at learning goals. From a synthesis of over 800 meta-analyses, 146,000 effect sizes, involving over 52,000 studies, and consisting of about 240 million students, Hattie (2009) found that the average effect of schooling on achievement was d = .40. Using this effect size as a benchmark figure, the influence of feedback on achievement was found to be almost twice the average effect d = .73 (1,287 studies and 2,050 effect sizes) (Hattie, 2009, p. 173). This finding points to the importance of feedback in classroom learning situations and suggests the need to look beyond whether feedback works and its effects to engender quality feedback that brings about meaningful learning outcomes in the classroom.

Hattie and Timperley (2007) indicated that feedback may help learners to 'reduce discrepancies between current understandings and performance and a learning intention or goal' (p. 86) by engaging learners to focus on three major questions and four different levels in which feedback operates (see Figure 1).

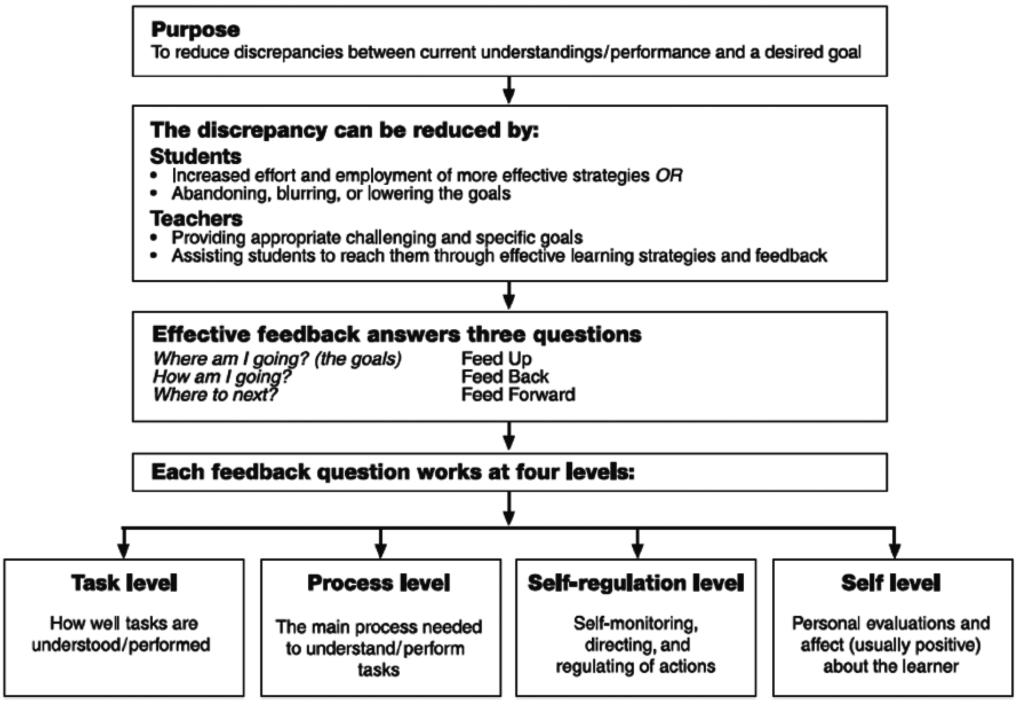

Figure 1. A model of feedback (Hattie & Timperley, 2007)

Effective feedback needs to address three major questions asked by the teacher and/or by the student: Where am I going? (What are the goals?), How am I going? (What progress is being made toward the goal?), Where to next? (What activities need to be undertaken to make better progress?). The first question relates to goals or "Where am I going?" When students understand their goals and what success at those goals looks like, then the feedback provided is more powerful. Without such an understanding (and even better, a commitment to attaining these goals), feedback is often confusing, disorienting, and interpreted as something about the student not their tasks/work; or worse, seen as irrelevant, not understood, and ignored. The second question is more related to progress feedback "How am I going?" This entails feedback (about past, present or how to progress) relative to the starting or finishing point and is often expressed in relation to some expected standard, to prior performance, and/or to success or failure on a specific part of the task. The third question is more consequential, "Where to next?" Such feedback can assist in choosing the next most appropriate challenges, more self-regulation over the learning process, greater fluency and automaticity, different strategies and processes to work on the tasks, deeper understanding, and more information about what is and what is not understood. Thus, the three questions in this model are seen as central to providing direction and scope for conceptualizing a notion of quality peer feedback that has a consequential impact on learning.

While the three questions focus attention on the processes of receiving and interpreting feedback (i.e., *consequential-orientation*), the four different levels consider the cognitive and meta-cognitive engagement of feedback with learners as well as the learning task (i.e., *cognitive/meta-cognitive-orientation*). First, Hattie and Timperley (2007) postulated that feedback can engage learners at the task level, such as providing information on correct response. Second, feedback can be aimed at the process level, such as providing task processing strategies and cues for information searching. The third level of feedback is focused on self-regulation, including the skills of self-evaluation, expanding effort in task engagement or seeking further feedback information. The fourth level of feedback is seen as directed to the "self", usually involving praise. Examples of such feedback include, "You have done well!", "Keep up the good work!" In nearly all learning situations, praise does not provide information on how to improve performance on the task (Kluger & DeNisi, 1996).

Feedback in the form of praise can actually have negative consequences, such as distracting the learner from the task, and encouraging effort avoidance behaviour in order to minimise the risk to the self (Hyland & Hyland, 2006; Kluger & DeNisi, 1996). It follows that the feedback message needs to differentiate between the four levels, with minimal use of the fourth level. An important key to the effectiveness of feedback is that it must be received, interpreted meaningfully, and acted upon by the learner. In contrast, extrinsic rewards or praise are found to undermine motivation and are mostly ineffective, as they lack learning-related information to help learners improve their performance. Hattie and Timperley (2007) claim feedback is powerful when it engages the learner with the learning task or goal at, or just above, the level where the learner is currently functioning. Thus, the challenge for educators is to provide ‘calibrated’ feedback which is designed to function at the appropriate operational level for the learner.

In this investigation, Hattie and Timperley’s feedback levels (2007) provide a learner-centred framework to examine the quality concept of peer feedback and how best to support peer feedback in the context of carrying out a science investigative task. Building from Hattie and Timperley’s feedback model, four assertions are proposed:

1. Peer feedback is meaningful when it is integrated into a cycle of learning.

This assertion draws on the consequential orientation of the model, as explicated through the three major questions. Instead of peer feedback as a ‘terminal’ activity, such as to summarise or provide closure after the whole learning task, peer feedback can be seen as recurring and dialogic, with the exchange and negotiation of meaning that much characterise the discursive talk or discourse in the investigative practices of learning science. Here, it is also argued that learning opportunities may be created whereby students can use the comments from their peers for review and revision of their work, and thus, adding value and meaning to the peer feedback process.

2. Peer feedback is useful when it provides information to identify where the learner is at, directs attention towards the learning outcome and indicates how best to achieve this outcome.

This assertion, which also incorporates the consequential orientation of the model, proposes the need to identify a learning gap and the use of feedback to close this gap. In particular, this assertion could be used to design feedback prompts that cue learners to identifying the learning gap and making suggestions for improvement. There is also emphasis on the use of criteria in formulating peer feedback, which allows students to see their performance against those learning goals.

3. Peer feedback is powerful when it cues the attention of the learner to the learning task, task processing strategies and self-regulation strategies instead of directing attention to the self.

In this investigation the feedback levels are conceptualised as hierarchical information provided by a peer during learning that engages the learner at different levels of understanding. Learning using *task level feedback* involves giving, receiving and interpreting declarative knowledge on one's performance. Learners who engage with *process level feedback* make use of procedural knowledge for task processing or completion; while those who engage in s*elf-regulatory feedback* utilise conditional knowledge to select and employ task and process level strategies and knowledge. If learners are to become proficient in giving and receiving useful peer feedback, they need to develop the capacity to evaluate quality learning in a given context and challenge their own and others' understandings by explicitly seeking, interpreting, and applying task level to self-regulatory level feedback. This assertion suggests the influence of cognitive and meta-cognitive peer feedback, and could be used to conceptualise and design a coding scheme to analyse peer feedback statements.

4. Peer feedback levels are viewed as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.

This assertion emphasises the importance of the learner focusing on the link between feedback, and cognitive and meta-cognitive engagement with the learning task. It means that for feedback to be effective, it must match the learner's current level of understanding and provide sufficient challenge so that the learner will put in effort to engage with the peer feedback at task, process, and self-regulation levels, and progressively move towards the learning goals. It also implies an expanded feedback discourse that shifts from a one-way transmission (teacher to learner) to learners engaging in two-way exchange of feedback information and taking ownership of their own learning. When seen as a progression, peer feedback creates a platform for engaging learners in interacting with the feedback for learning rather than passively accepting feedback from the teacher. As Hattie (2009) postulated, 'visible learning' occurs when students see themselves as their own teachers. When students see feedback through the lens of their own understandings, misunderstandings, and goals, informed choices can be made to invest effort in meaningful learning processes that direct them towards their learning goals.

PEER FEEDBACK

The Influence of Peer Feedback on Learning

In most classrooms, feedback is often regarded as something that occurs between teacher and student, but the influence of peers in the feedback cycle is often critical. Nuthall (2007), for example, conducted extensive in-class observations and noted that 80% of verbal feedback comes from peers, and most of this feedback information is incorrect. Teachers who do not acknowledge the importance of peer feedback can be handicapping their effects on students, and interventions that aim at fostering peer feedback are needed, particularly as many teachers seem reluctant to involve peers as agents of feedback. Nuthall (1999) argued that students' learning in the classroom is shaped by their experiences within the context of three different worlds—the public world structured by the learning activities and routines the teacher designs and manages; the semiprivate world of ongoing peer relationships; and the private world of the child's own mind.

Nuthall (2007, p. 160) demonstrated that the assumption that "all students experience essentially the same activities in the classroom when carefully planned by teachers and thus translate these experiences into expected learning outcomes" does not hold true to the research findings. Instead, learner differences as well as peer relationships and status strongly influence their opportunities for more engaging learning experiences. Thus teachers should consider the differences in background knowledge of learners, the power of peer relationships and status, and the need to constantly monitor students' learning progress, and respond accordingly. More importantly, because much of what students learn comes from their peers, teachers need to become "involved with the peer culture and work with it to manage students' learning" and build a culture of learning in the classroom that entails "mutual respect and co-operation—a culture where everyone feels he or she has something to contribute to classroom activities, where everyone takes responsibility for learning" (Nuthall, 2007, p. 162).

One method for understanding the importance of peer feedback is investigating the collaborative discourse (i.e., the interactive classroom talk) between peers (e.g., O'Donnell, 2006; O'Donnell & King, 1998; Nussbaum, 2008). Such discourse highlights that the one-way transmission model of teaching is not a realistic view of learning for most students, as they make emotional and social investments in learning, interact as much if not more with peers during the learning process, and build understandings about what it is they are supposed to be learning/doing, how they are going, and where they go next in their learning (or not). For example, Webb and colleagues (2008) found that the levels and elaborateness of explanations among students in collaborative groups predicted individual learning in mathematics, with the highest growth associated with those generating explanations. In a recent review on collaborative discourse and argumentation, Nussbaum (2008, p. 345) coined the term "critical, elaborative discourse" to emphasize the importance of students "considering different viewpoints" as well as "generating connections among ideas and between ideas and prior knowledge"—much coming from peer discussions. Peers thus provide much feedback to each other through such elaborations and purposeful discussions; they are not merely providers of right/wrong feedback but interpreters of the usefulness of feedback.

Of course, not all students provide such elaborations or quality feedback **(**Lockhart & Ng, 1995; Strijbos, Narciss, & Dünnebier, 2010). Often the more able, the more committed, and the more verbal students provide greater elaboration and critical feedback and thus, are more advantaged in peer interactions. Teachers may need to deliberately teach students these skills, structure classrooms to share this expertise, and make specific interventions to ensure all students can benefit from these peer interactions. Even though the elaborations and feedback are incorrect or misleading, the effects are still powerful and teachers may have an even more difficult task moving students to the desired success outcomes if feedback from peers is misguided or simply incorrect (e.g., Ballantyne, Hughes, & Mylonas, 2002; Topping, 1998).

One method for peers to provide feedback is via assessment of others' work. There has been a recent resurgence in research relating to the positive effects of peer assessment on student learning (e.g., Dochy et al., 1999; Falchikov & Goldfinch, 2000; Topping, 2010; Van Zundert et al., 2010). Peer assessment involves students assessing the quality of their fellow students' work and providing one another with feedback (Dochy et al., 1999). The important elements of peer assessment are that it involves students engaging in reflective criticism of other students' work, provides constructive feedback using previously defined criteria, and may consist of one or more cycles of feedback with opportunities for revisions to work done. It certainly can be plentiful. Ngar-Fun and Carless (2006) argued that involving students in peer assessment and peer feedback enables students to take an active role in the management of their own learning, helps to enhance students' self-assessment skills, and can improve learning of subject matter (Boud, 1995; Boud, Cohen, & Sampson, 1999). In contrast to comments provided by teachers, students can receive more feedback from peers, and they get this more quickly (Gibbs, 1999).

There can be resistance to using students to provide feedback and being involved in peer assessment; for example, concerns about the reliability of students' grading or marking, power relations among peers and with teachers; the fact that some students can fail to participate (social loafing), freeload off others, be impacted by friendship bonds, power relations, or collusion. Hence, effective use often occurs following deliberate training of students in providing peer feedback, ensuring that peer feedback is integrated into the lesson in a deliberate and transparent manner, and providing rubrics to the students that outline the success criteria of the lesson (Cho & MacArthur, 2010; Lundstrom & Baker, 2009; Min, 2005; Prins et al., 2006; Rollinson, 2005; Zhu, 1995). For example, Sluijsmans, Brand-Gruwel, van Merriënboer, and Bastiaens (2002) found that students who received training that involved providing feedback were more likely to use the criteria and to give more constructive comments (specific, direct, accurate, achievable, practicable, and comprehensible to the peer) than the students in the control group who did not receive training. Similarly, Min (2005) indicated that students with extensive coaching in peer reviewing generated more specific and relevant written feedback on global features of their peer's writing. In Min's study, students were trained by observing an instructor demonstrate how to comment on a peer's draft following a 4-step strategy (i.e., ask for clarification, identify a problem, explain the problem, and suggest possible revisions) and thereafter, were encouraged to apply the strategy in commenting on their peer's writing. The analysis of a peer's draft before and after training showed that students made more comments explaining problems (see also Van Steendam, Rijlaarsdam, Sercu, & Van den Bergh, 2010).

Nelson and Schunn (2009) investigated the effect of feedback features (e.g., type-praise, summary, identifying problem/solution, scope of problem/solution, localization of problem/solution, explanation of problem/solution) on mediators (e.g., understanding feedback and agreement with feedback) that were proposed to affect feedback implementation behaviour (revision of draft writing). The researchers analysed 1,073 feedback segments from writing assessed by peers via an online peer review system (SWoRD), and they found that understanding the problem had a significant effect on implementation. The student was more likely to understand the problem if a solution was offered by the peer assessor, the location of the problem or solution was given, or a summary of the problem was included. Tseng and Tsai (2007) conducted a web-based peer assessment with 10^{th} grade students (16-year-olds) involving three rounds of peer feedback, and two rounds of modifications on their projects for a computer course. Peer feedback was coded based on Chi's (1996) framework: corrective, reinforcing, didactic, and suggestive. Tseng and Tsai found that online peer assessment significantly enhanced the quality of students' projects and they concluded that learning in the peer assessment process comes from both students' adaptation of peers' feedback, and their assessment of peers' projects. Reinforcing feedback was found to be most helpful to promote quality student projects, but the reasons behind this were not provided by the authors (see also Gielen, 2007).

Ngar-Fun and Carless (2006) examined the rationale for peer feedback with the emphasis on its positive influence on learning as well as the reasons for resisting its use by academics in higher education. According to the authors, 'peer feedback' is defined as 'a communication process through which learners enter into dialogues related to performance and standards' (p. 280). The authors argued that involving students in peer assessment and peer feedback enables students to 'take an active role in the management of their own learning'. Peer feedback also helps to enhance students' self-assessment skills (Boud, 1995; Boud et al., 1999) and has the potential to improve learning of subject matter (Falchikov, 2001). Research comparing peer feedback and teacher feedback further showed that teacher feedback may not be understood by students and is often misinterpreted (Yang et al., 2006). Feedback from peers can have a greater impact since the dialogue will be in a language that students themselves are accustomed to (Sadler, 1998). Ngar-Fun and Carless further suggested that examining the works of peers offers 'meaningful opportunities for articulating discipline-specific knowledge, as well as criteria and standards' (p. 281).

While peer feedback is seen as beneficial to student learning, Ngar-Fun and Carless (2006) argued that there are four main reasons for resistance to implementing peer feedback or peer assessment. The first reason is the reliability of students' grading or marking, which is related to the second reason of perceived expertise. Power relations may be disrupted by peer assessment using grades, with both teachers and students being uncomfortable with power sharing. Giving and receiving feedback can be a confronting and potentially negative experience for many students, especially those struggling to develop social and emotional maturity. The fourth reason giving and receiving feedback is resisted is that implementing peer assessment or peer feedback may be more time-consuming than traditional assessment and thus is seen as encroaching on time needed for curriculum coverage. In light of the findings, Ngar-Fun and Carless suggested that peer feedback can be integrated with grading to motivate learners, different strategies can be used to engage learners with criteria and quality, and cultivating a collaborative environment for promoting peer interaction is important.

The Nature and Quality of Peer Feedback

In order to study the quality of peer feedback, a review of the peer feedback literature was carried out to identify the key quality indicators. An online literature search was conducted in the following databases: ERIC, PsychINFO, ProQuest Education Journal, and Education Research Complete. The inclusion criteria consisted of: (1) the article or paper should describe peer feedback in learning contexts; and (2) the study should identify quality indicators in relation to peer feedback. While a broad range of articles were found regarding peer feedback, a closer analysis of the abstracts revealed that those with explicit quality indicators of peer feedback were limited to six studies. Research on peer feedback quality has focused on various perspectives, which can be characterised in general as the use of criteria, the nature of feedback, and the depth of comments. Table 2 summarises and compares the quality indicators for evaluating peer feedback in learning.

Table 2. Summary and comparison of peer feedback quality indicators

Peer feedback studies	Peer feedback quality indicators		
	Use of criteria	Nature of feedback	Depth of comments
Sluijsmans et al. (2002)	• Use of criteria	• Positive/negative comments • Posing questions • Judging performance • Structure of feedback	• Use of 'naive words' • Constructive comments
Prins et al. (2006)	• Use of criteria	• Positive/negative remarks • Suggestions for improvement • Style and structure of feedback	• Posing reflective questions • Providing examples • Explanations of remarks
Van den Berg et al. (2006)	• "Subject" of feedback	• Comments on understanding • Suggestions for revision	• Explicit/implicit quality statements • Explanation to support evaluation
Gielen (2007)	• Appropriateness	• Readable • Positive/negative feedback • Suggestions for improvement	• Specificity • Justification • Reflective questions
Cho and MacArthur (2010)	--	• Directive/non-directive feedback • Criticism • Praise • Summary • Off-task feedback	• Types of revision – surface level change, micro-level meaning change, and macro-level meaning change, changing reference
Van Steendam et al. (2010)	--	• Error detection • Corrective feedback of the detected error • Suggestion for revision	• Exhaustiveness and explicitness of comments

Use of Criteria

In peer assessment literature, there is a particular focus on the importance of negotiation about performance criteria (Falchikov, 1995; Orsmond, Merry, & Reiling, 1996, 2000) which is seen as important and as a pre-requisite for both the giver and the receiver of peer feedback. Mehrens, Popham, and Ryan (1998) suggested that teachers should identify evaluative criteria in advance of instructional planning and communicate these clearly to students. Being clear about what constitutes "high levels of achievement" in terms of criteria ensures that teachers conceptualise and develop these criteria into their instruction and direct students' attention towards achieving these learning outcomes. When presented in the form of a scoring rubric, these evaluative criteria may be used by students for self and peer assessment. Mehrens et al. argued that this would help students to understand what it is that constitutes high quality work. A "deliberate and systematic instructional effort" (p. 21) is crucial for supporting students' use of criteria and feedback is seen as a necessary part of this process.

Sluijsmans and Van Merrienboer (as cited in Sluijsmans et al., 2002) conducted a literature review and expert interviews on the peer assessment skills that resulted in a peer assessment model in which three main skills are taken into account. These skills are: (1) defining assessment criteria—thinking about what is required and referring to the product or process; (2) judging the performance of a peer reflecting upon and identifying the strengths and weaknesses in a peer's product and writing an assessment report; and (3) providing feedback for future learning—giving constructive feedback about the work produced by a peer. Sluijsmans et al. (2002) incorporated these three skills in training student teachers on peer assessment tasks. Explicit training on defining, developing, and using criteria in peer assessment resulted in more constructive comments, higher structure and fewer naive words used.

Nature of Peer Feedback

When considering the nature of feedback, there are some commonalities in the type of indicators used. Most studies require peer feedback to include identification of areas/strengths, identification of error/mistakes/weaknesses, and suggestions for improvement. Peer feedback is also examined in terms of identifying a "learning gap" between current and desired performance (Ramaprasad, 1983; Sadler, 1989) and how best to close this gap. When assessing the quality of peer feedback, besides task-based information, some studies looked at the presentation of feedback in terms of style and structure (Prins et al., 2006) or in terms of criticism or praise (Cho & MacArthur, 2010).

Depth of Peer Feedback Comments

Most of the empirical studies examine the importance of peer feedback quality in terms of depth of comments. This involves elaborative feedback that incorporates the notion of constructiveness of feedback (Gielen, 2007), providing exemplars, explanations, and reflective questions (Prins et al., 2006). It appears that students are less able to provide comments of sufficient depth in the absence of instructional support, as evident in all these studies. Explicit instructional interventions may be necessary to bring about this change (Van Steendam et al., 2010).

INSTRUCTIONAL SUPPORT FOR PEER FEEDBACK

One of the main concerns of implementing peer feedback as a learning approach is the quality of feedback provided by peers, which is perceived as lacking in breadth and depth of content. The situation is made worse with ineffective feedback interactions between help-giver and help-seeker (Prins et al., 2006). Poor peer feedback quality is often due to lack of information and skills concerning how to provide, receive, and use peer feedback. Instructional support may take the form of procedural facilitation tools such as guiding sheets with prompts, peer review sheets with criteria, and graphic organisers. For example, Van Steendam et al., (2010) showed that training students through modelling (observing others) followed by dyadic emulation, led to more correct and explicit corrective feedback when evaluating a peer's text. They explained that the effectiveness of observation in dyadic emulations was due to a lessening of cognitive load by filtering information and focusing the assessor. The implication of this study is that for collaborative revision to be effective as a method for meeting learning criteria for writing, students need to be instructed in how to become better revisers through observational learning.

Instructional interventions also take the form of explicit training on peer feedback skills. For example, Sluijsmans et al., (2002) reported on the effects of an empirical study of peer assessment training on the performance of student teachers (n = 93), involving defining performance criteria, giving feedback, and writing assessment reports. The authors found that students in the experimental group outperformed the students in the control group in terms of quality of the assessment skills, as well as the end products of the course. The students who received training were more likely to use the criteria and to give more constructive comments (specific, direct, accurate, achievable, practicable, and comprehensible to the peer) than the students in the control group. This study highlights the important skills of defining criteria and presentation of adequate and quality feedback by the feedback giver. The authors concluded that students can be trained in assessment skills and that such training positively affects the performance level of student teachers.

There is a substantial body of research showing the usefulness of scaffolding students' learning through the use of prompts to think and ask higher order questions during discussions (King, Staffieri, & Aldelgais, 1998; Palincsar & Brown, 1984). An empirical study by Davis (2003) on students' use of generic and directed prompts for self reflection showed that students in the generic prompt condition develop more coherent understandings as they worked on a complex science project. In studies of peer feedback, Prins et al. (2006) suggested that "feedback instruments such as performance scoring rubrics with criteria, or structured feedback forms that force feedback providers to ask reflective questions and give suggestions for improvement could be valuable instruments for increasing the quality of the peer feedback" (p. 300). Gielen (2007) adopted a similar approach to structure peer assessment feedback conditions with prompts for constructive comments (a priori question form and a posterior reply form) and found positive benefits for both students giving and receiving feedback in writing tasks.

LEARNING SCIENCE IN THE LABORATORY—INTERNATIONAL PERSPECTIVE

As highlighted in Chapter 1, scientific literacy entails framing science instruction as the enactment of scientific practice and discourse. This means providing meaningful problems and explicit guidance that engage students in designing and conducting scientific investigations (Klahr & Chen, 2003; Metz, 2000, 2004), participating in scientific argumentation (Driver, Newton, & Osborne, 2000; Osborne, Erduran, & Simon, 2004), and developing scientific explanations (Sandoval, 2003; Sandoval & Reiser, 2004) and representations (Lehrer & Schauble, 2000b, 2004). The meaningful problems approach is seen as providing opportunities for students to not only develop scientific knowledge and skills in the context of their application, but to engage in scientific discourse. In order to bring about active engagement of the students with the problems, there is a need to support students and teachers to foster productive social interaction, the appropriate use of scientific language, and the effective use of scientific representations and tools.

An important component of the enactment of scientific practice is laboratory learning. Traditional views of learning science in the laboratory have been described as ‘narrowly focused’, with most research studies conducted on the influence of laboratory work on students’ acquisition of prescribed knowledge and skills (see reviews by Bates, 1978; and Hofstein & Lunetta, 1982). This simplified view of school laboratory learning was found to be evident in teachers’ laboratory teaching, expectations, and assessment practices, and was generally described as a “cookbook” approach to laboratory work (Tamir & Lunetta, 1981). The main criticism of this approach has been that laboratory activities focused students on relatively low-level tasks and led students to perceive the manipulating of equipment to get the right answer as the sole purpose of laboratory work. This approach has also been criticised for reinforcing a view that scientific knowledge is the ultimate truth, is authoritative and encourages conformity amongst students rather than emphasise intellectual independence (Hodson, 1996). Instead of following “recipe practicals” to understand laboratory experiences, students must manipulate ideas as well as materials in the school laboratory (White & Gunstone, 1992). In other words, the purpose of practical work must include not only the verification or demonstration of known concepts, but also the articulation, explanation, interpretation, and evaluation of knowledge claims in relation to supporting evidence and underlying concepts. It is also important to allow students to consider their own thinking in relation to the practical activity through the integration of metacognitive strategies and approaches. In addition, there is a need to acknowledge the importance of cooperative learning in the science laboratory (e.g., Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Tobin, 1990) as providing opportunities for interaction between students and their teachers and among peers, which are beneficial to development of scientific knowledge as well as scientific discourse.

While research has made great strides in understanding laboratory learning (Hofstein et al., 2005), a key question remains as to how to support teachers and learners in bringing about meaningful engagement in practical work. Lunetta (1998) indicated that laboratory inquiry alone is not sufficient to enable students to construct the complex conceptual understandings of the contemporary scientific community. Moreover, students lack the time, skills, or motivation to express their interpretations and beliefs and to reflect on their laboratory experiences (Gunstone, 1991). These findings suggest that students need strategic scaffolds that embed instructional guidance to enable them to do scientific tasks with a higher degree of sophistication than they could without it. The scaffolds also make the learning process or concept more explicit for learners.

Tobin (1990) and Hodson (1993) reported that although the potential benefits of laboratory learning were recognised, science teachers often failed to change their teaching approaches to bring about the desired outcomes related to laboratory learning. Often, there is a mismatch between teachers' perceived goals for laboratory work and students' perceptions of such activities (Hodson, 2001; Wilkinson & Ward, 1997). In other words, teachers need to articulate and clarify the specific learning goals to help students understand the purpose of laboratory activities and intended learning outcomes. Research in science instruction further indicates that teachers need to take into consideration learners' prior knowledge when planning and designing instruction as learners come to class with ideas and experience about science which are very different from that of professional scientists. The classroom learning environment is also important, as researchers realised that science classrooms have "composite culture" such as expecting the teacher to be the authority of knowledge, a focus on grades and teacher-dominated instruction, which may conflict with the new scientific norms of knowledge building. Indeed, all these findings suggest that instructional support for learning is crucial to ensure the orchestration of purposeful and meaningful science discourse in the laboratory.

Another research focus that is making in-roads into feedback in learning science is the area of formative assessment (Bell & Cowie, 2001; Black & Wiliam, 1998a; Duschl & Gitomer, 1997; Minstrell & van Zee, 2003; Ruiz-Primo & Furtak, 2004). Assessment in the classroom can be considered formative when information about student learning is used by both students and teachers to move towards learning goals. Bell and Cowie (1999, 2001b) view the assessment of science learning for formative purposes as a sociocultural practice and as a discursive practice (Bell, 2000). This means that assessment is a value-laden, socially constructed, and historically, socially, and politically situated activity. Assessment of science learning may be viewed as a purposeful, intentional, responsive activity involving a partnership between teacher and students; and the use of language to communicate meaning (Bell & Cowie, 2001). This suggests that teachers can use the information to provide timely and informative feedback to students, monitor the effectiveness of their own teaching and adapt instruction. Students, too, need to be involved in the assessment process by recognising, interpreting and using the feedback from teachers or peers to achieve their learning outcomes.

Black and Wiliam (1998a) carried out an extensive review of the literature on formative assessment and indicated that learning gains in interventions involving aspects of formative assessment have an effect size between d = 0.4 to d = 0.7. Despite substantial evidence of its positive impact on student achievement, research indicates that formative assessment is, in general, not a key priority for teachers (Black & Wiliam, 1998b). Empirical studies in science on formative assessment were found to be limited, with only one study by White and Frederiksen (1998) which explored peer and self-assessment in middle school science classes.

Shavelson and his colleagues (2008a, 2008b) conducted a series of studies to examine the impact of embedded formative assessment on student learning and motivation. Formal formative assessment prompts were designed and embedded in an inquiry-based middle-school science program. The learning context involved students investigating concepts on mass, volume and density, and its relation to sinking and floating. The assessment prompts were crafted by researchers to target students' procedural, schematic, and declarative knowledge. The results indicated that students in the experimental group did not significantly outperform the comparison group on either the achievement tests or the motivation measures. There was variation among students and teachers on achievement and motivation scores but the embedded formative assessment treatment did not explain this variation. On reflection, Ruiz-Primo, Furtak, Ayala, Yin, and Shavelson (2010) found that teachers managed to get students to share their ideas, but did not take action on that information to adjust the way feedback was provided for learning. The formative assessment cycle was incomplete, and teacher feedback was either not provided, insufficient or ineffective to "close the learning gap". Specific strategies were needed to help teachers address students' conceptions and move students toward learning goals. Furthermore, teachers did not necessarily have clarity about the learning goals, resulting in difficulty in determining where students were in relation to the learning goals and how they could get there. In conclusion, the administration of formative embedded assessments by themselves is unlikely to have an impact. Besides knowing where students were in their level of understanding based on the information gathered through embedded assessment, teachers need support to come up with activities and strategies that they could use with students at different levels of their learning trajectories.

LEARNING SCIENCE IN THE LABORATORY—NEW ZEALAND (NZ) PERSPECTIVE

Early research in NZ on the perceived problems with the 'practical' work in junior secondary science lessons, as part of The Learning in Science Project (LISP) at the University of Waikato, found that teachers and students had differing perceptions of the same classroom experiences (Schollum 1986; Tasker 1980, 1981; Tasker & Freyberg 1985; Tasker & Osborne 1983, 1985). These differences included the scientific context of the activity, the scientific purpose of the activity, the scientific design of the investigatory activity, doing the activity, getting the results, thinking about what was done and what happened, the impact of the experience on children's views, and the relationship to predetermined outcomes. A key message highlighted in this research was that teachers and students needed to consider practical work as a thinking activity in which each participant constructed or co-constructed understandings, rather than solely being the domain of practical skills training.

The struggle to bring about more meaningful engagement, both at the cognitive and meta-cognitive (and even affective) levels, continues to challenge teachers in laboratory learning almost three decades later. An article that compared and contrasted scientists' views of 'doing science' with the practice of 'doing science' in New Zealand classrooms (Haigh, France, & Forret, 2005), and reported that although there has been a move to introduce more open investigative work in school science programmes at both primary and secondary levels (Barker, 1999, as cited in Haigh et al., 2005), these investigative practical work continued to be used differently in secondary and primary classrooms. While in most secondary science classrooms, teachers use investigative tasks for *illustration and application*, open investigative practical work has largely been interpreted as *'fair testing'* in primary classrooms. Haigh and her colleagues argued that the current practice of 'doing science' in NZ classrooms is 'pedagogically deficient' as it focuses on a limited view of practical work and does little to inform students about scientific activity as practised by scientists. Further, they indicated that New Zealand students were more proficient at carrying out specified practical tasks than the independent problem-solving tasks that are involved in open planned investigative activities.

The above findings recognise the importance of engaging students in the practice of science beyond factual understanding and skills training. Indeed, the research points to the need for more *opportunities* that allow students to participate in purposeful and collaborative discourse through carefully designed investigative activities focusing their attention not only on content, but on using scientific language in negotiating and co-constructing meaning.

CONCLUSION

This review draws from research about feedback, peer learning, and science education to highlight the importance of peer feedback in the science classroom and the central theme of creating and supporting opportunities for meaningful peer feedback to enhance learning during science investigations. The theoretical framework presented by Hattie and Timperley (2007) provides a rich base for exploring and designing empirical studies that takes into consideration the consequential orientation and cognitive/meta-cognitive orientation in which learners interact with peer feedback. This feedback model frames the learning assumptions in peer feedback within a sociocultural perspective, involving peers as a resource for feedback exchange and negotiation. Furthermore, this framework helps in the conceptualisation of peer feedback quality, by focusing learners on cognitive and meta-cognitive outcomes rather than being judgemental, and developing a progressive view of peer feedback engagement.

The four assertions derived from Hattie and Timperley’s framework help to guide the development of ideas in this research and are reiterated as follows:

1. Peer feedback is meaningful when it is integrated into a cycle of learning.
2. Peer feedback is useful when it provides information to identify where the learner is at, direct attention towards the learning outcome, and indicates how best to achieve this outcome.

3. Peer feedback is powerful when it cues the attention of the learner to the learning task, task processing strategies and self-regulation strategies instead of directing attention to the self.
4. Peer feedback levels are viewed as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.

The proposal defended in this investigation is that in order to move towards the provision of quality peer feedback it is necessary to support learners in differentiating and using peer feedback at different levels of engagement. By focusing the learner on a hierarchical approach to peer feedback, a feedback progression can be visualised that guides and scaffolds the learning process. This makes peer feedback relevant and meaningful to the learner.

CHAPTER 3

STUDY ONE: EXPLORING THE ROLE OF PEER FEEDBACK IN PEER DISCOURSE DURING A CHEMISTRY INVESTIGATIVE TASK

INTRODUCTION

In the review of literature (Chapter 2), the central purpose of science learning is conceptualised as developing scientific literacy in students (Goodrum et al., 2001; Hodson, 2009). This involves students learning science by actively engaging in the practices of science, and recognises the importance of spoken and written discourse in meaningful knowledge construction in the classroom. It follows that a discourse analytic perspective provides a useful starting point for gaining insights into how students construct meaning through the use of language and social processes. In particular, this study explored the role of peer feedback processes as they occur through communicative approaches and peer interaction during a chemistry investigative task.

Most early research about classroom discourse in science education focused on particular ways teachers talk in communicating science knowledge and practices (Carlsen, 1991; Lemke, 1990; Moje, 1995). These studies found that science classroom discourse was predominantly teacher-led, with limited participation from the students in talking science. While this transmissive view of teacher talk was seen as necessary to control the direction and delivery of lesson content, it often led to an ideological view of science as conceivably narrow and authoritarian (Kelly, 2007). In the last several years, however, researchers have increasingly addressed the roles of student involvement in science classroom discourse (Howe, Tolmie, Duchak-Tanner, & Rattray, 2000; Mercer, 2004; Osborne et al., 2004; Scott, Motimer, & Aguiar, 2006). The focus of these studies has shifted from identifying the effects of teacher talk to considering more closely the way students use language in meaning construction as well as the discourse events or social context for bringing about student participation in the cognitive processes of talking science.

The first part of this chapter reviews some relevant research in science classroom discourse to illustrate some examples of teacher-student and student-student discursive practices. The findings from these studies suggest the need for encouraging greater student participation in using language for communicating science knowledge and practice. Drawing from the research on science classroom discourse (Mortimer & Scott, 2000, 2003) and feedback (Hattie & Timperley, 2007) as a theoretical framework, an approach for exploring the characteristics of verbal peer feedback responses during an investigative task is proposed. This approach examines peer feedback as situated within peer discourse that is characterised by communicative approaches along two dimensions (interactive/non-interactive and dialogic/authoritative) and proposes a coding scheme for analysing verbal peer feedback that considers the discursive moves by peers, their communicative function, knowledge use, and the inferred cognitive function of peer dialogue.

PEER DIALOGUE IN LEARNING SCIENCE

Review of Classroom Talk For Learning Science

In this investigation 'discourse' is broadly defined as language in use (Cameron, 2001) and typically includes acts of communication such as talking, reading and writing. In science education settings, this definition extends to using language within a social context which takes into consideration the many epistemological, ideological, pedagogical, social, and cultural dimensions of science language use in the classroom (Hodson, 2009; Kelly, 2007). As the purpose of this study is to explore peer feedback in learning science, the main focus of classroom discourse will be on peer dialogue or student-student talk during the learning task.

Studies of classroom discourse in science education have repeatedly demonstrated that teachers' talk dominates the conversation during science lessons (Dillon, 1985; Edwards & Mercer, 1987; Lemke, 1990). Newton, Driver, and Osborne, (1999), for example, noted that less than 5% of class time is devoted to group discussions and less than 2% of teacher-student interactions involve meaningful discussion of ideas and productive exchange of viewpoints. Indeed, the classic studies by Rowe (1974a, 1974b) have shown that teachers rarely allowed sufficient time for students to respond to questions before rephrasing a question, asking a different question, or asking a different student for response. The most typical form of discourse prevalent in classrooms involved teacher initiation, student response, and teacher evaluation, commonly known as 'IRE'

(Mehan, 1979) or 'IRF' when the third move is regarded as follow-up or feedback (Sinclair & Coulthard, 1975). This three-part exchange has been widely regarded as teacher-dominated discourse, and it is found to be ineffective in fostering students' collaborative dialogue (Alexander, 2004; Duschl & Osborne, 2002; Mercer & Littleton, 2007). Drawing from extensive observations of science classrooms, Lemke (1990) criticised this 'triadic dialogue' as fostering lower-order cognitive learning outcomes as teachers typically focused on using this three-part exchange to cue basic recall of facts and confirmation of declarative knowledge. One main concern was the tendency on the part of teachers to use closed initiatives, such as questions that permit a simple 'Yes' or 'No' answer or elicit a whole-class choral response. Thus, poorly structured teacher-led IRF exchanges limit the opportunity for students to engage in more productive dialogue, deprive them the chance to participate in the discourse and may even result in passivity on the part of students.

Another consequence of adopting a teacher dominated question-answer-response approach to science discourse is that it promulgated in students an ideological view of science as authoritative (Lemke, 1990) and portrays scientific knowledge and practice as straightforward and unequivocal, reduced to what Schwab (1962) referred to as a 'rhetoric of conclusions'. Research into students' epistemological beliefs provided evidence that students who hold a view that there is one scientific method or that scientific knowledge arises unchallenged from observation, may adopt a performance-oriented, rather than learning-orientated approach to learning science (Lidar, Lundqvist, & Östman, 2006). Other studies, such as Wallace, Tsoi, Calkin, and Darley (2003) and Stathopoulos and Vosniadou (2007), found that when students understand the epistemic basis of science, such as science being a process of evaluating theories against empirical evidence, they were better able to use the language of science purposefully and saw themselves as engaging in a meaningful and fruitful discourse. What these studies suggest is that the choice of discourse influences the views of science made available to students. In other words, the pedagogical approach to classroom discourse can lead to inclusion or exclusion of ways of using language as scientific discourse or talking science that is potentially beneficial to learning science.

A central role of classroom discourse in science learning involves the construction of meaning between teacher-student and student-student interactions. This meaning making process not only requires teachers and students to use the appropriate language of science for communicating scientific knowledge and practices, it also recognises the need to use language for thinking and reasoning about science, what Lemke terms 'talking science'. "Talking science does not simply mean talking *about* science. It means *doing* science through the medium of language. "Talking science" means observing, hypothesizing, describing, comparing, classifying, and analysing" (Lemke, 1990, p. 1). To promote and encourage students to talk science, teachers may demonstrate, using discourse processes and events, how purposeful use of language of science can help students to engage with scientific knowledge. The teacher's third step in IRF could promote further dialogue by scaffolding students' thoughts and ideas through reflective toss (van Zee & Minstrell, 1997), elaborative feedback (Mortimer & Scott, 2003), or responsive questioning (Chin, 2006). For example, in reflective toss, the teacher used a question that "catches" the meaning of a student's statement to engage ("throw" back to) the student to take ownership of their ideas and to think further about them. In elaborative feedback, the teacher provides feedback that encourages students to participate actively in co-construction of meaning. In responsive questioning, students were guided to generate their own inferences and conclusions by using a questioning approach that alternated between a broad, overarching question, and more focused subsidiary questions—a series of responsive 'zooming-in' and 'zooming-out' questions that engaged the student in building a cohesive and integrated framework of ideas.

A Communication Framework

With the increased emphasis on sociocultural theories in learning science, Scott (1998) argued for the investigation of science classroom discourse from a Vygotskian perspective, which takes into consideration the nature of teacher-student utterances on the interpsychological plane and its subsequent influence on conceptual thinking on the intrapsychological plane. To further examine the nature of classroom discourse, Mortimer and Scott (2000, 2003) proposed an analytical framework that characterises science teaching interactions as (a) teaching purposes, (b) content of classroom talk between teacher and student in relation to learning goals, (c) communicative approaches on addressing student ideas and concepts, (d) patterns of discourse, and (e) teacher intervention. The communicative approach is seen as a central component of the framework, which focused on describing the talk between teacher and students along each of two dimensions—dialogic-authoritative and interactive-non-interactive.

Teacher-student dialogic discourse in Mortimer and Scott's (2000, 2003) framework is seen as recursive, generative, and co-constructive, with encouragement and guidance (usually in the form of probing questions) from the teacher to engage the students in building ideas, thoughts and connecting different points of view. In contrast, the authoritative discourse is unidirectional, and focused on just one point of view. Mortimer and Scott further suggested that the communicative approach can be located on the interactive/non-interactive continuum, whereby the former promotes active participation and the latter discourages any form of involvement by other students. In the analysis of classroom discourse, the two dimensions can be combined to characterise four classes of communicative approaches enacted by teachers and students in developing ideas. A summary of the four classes of communicative approach is shown in Table 3.

Table 3. The communicative approach (Mortimer & Scott, 2003)

Class of Communication Approach	Description
Interactive/dialogic	The teacher engages students to explore and share ideas. There is opportunity for students to build on different viewpoints.
Non-interactive/dialogic	The teacher gathers and works on different viewpoints from the students but does not encourage students to consider the different ideas or suggestions.
Interactive/authoritative	The teacher controls the discussion through a sequence of questions and answers to reach a specific viewpoint.
Non-interactive/authoritative	The teacher presents a specific viewpoint.

In a study that examined the ways in which a teacher used discourse to develop scientific explanations with students in the classroom, Childs and McNicholl (2007) used the analytical discourse framework of Mortimer and Scott (2003) to describe and analyse the teacher's practice of classroom talk. Childs and McNicholl found that when the teacher was less certain of their own domain knowledge of chemistry, the communicative approach shifted more towards the authoritative end of the dialogic-authoritative dimension. This was evident when the content of the teacher's explanations appeared to be less effective in developing the empirical description into a theoretical explanation during the explanatory episode. Childs and McNicholl concluded that the analytical framework provided a sufficiently powerful method for gaining insights into a teacher's practice of using talk in order to explain science.

Carrying Out an Investigative Task—Concepts of Evidence

Investigations that require students to design, implement and evaluate experiments have been recognised as playing an important role in 'science as practice' and developing 'inquiry' skills that are reflective of scientific literary (Abd-El-Khalick et al., 2004; Duschl, Schweingruber, & Shouse, 2006). Learning science involves both an understanding of the substantive content knowledge as well as the procedures of science. In the first study reported here, a coding scheme was designed based on the work by Gott and Roberts on 'Concepts of Evidence' (2008) or 'ideas about evidence'. This list served as 'a domain specification of ideas necessary for procedural understanding' (p. 22). They used the term 'procedural understanding' to describe the understanding of ideas about evidence, or 'knowing how to proceed' (Gott & Roberts, 2008). They further highlighted 'procedural understanding' as an important sub-set of the substantive ideas in science and that a lack of these ideas would hinder students' development of procedural understanding. Rather than seeing this list as isolated and a routinised procedure, it can be a 'toolkit of ideas' that help students to apply and understand procedural knowledge when planning and carrying out practical investigations. Central to their argument was the need for a different way of conceptualising the procedural component of the curriculum. The skills perspective, which emphasised developing 'process skills', should be complemented by an understanding of ideas about evidence.

The procedural component is underpinned by a set of ideas about evidence. It requires the learner to construct meaning, particularly about validity and reliability, from specific ideas about evidence. The focus is on a set of ideas that are an integral part of science and that can then be learned, understood, and applied, rather than a set of skills that develop implicitly by practice (Gott & Roberts, 2008). Examples of concepts of evidence are shown in Table 4.

Table 4. Examples of concepts of evidence (adapted from Gott & Roberts, 2008)

'Concepts of Evidence'	Description
Variable structure	Identifying and understanding the basic structure of an investigation in terms of variables and their types.
'Fair testing'	'Fair tests' aim to isolate the effect of the independent variable on the dependent variable. By changing the independent variable and keeping all the control variables constant, validity is ensured.
Choosing values	Making informed choices about sample, relative scale, range, interval, and number of readings.
Patterns and relationship in data	Patterns represent the behaviour of variables so that they cannot be treated in isolation from the physical system that they represent.
Reliability and validity of data/design	Evaluating the whole investigation by considering the design of the investigation, ideas associated with measurement, with the presentation of the data, and with the interpretation of patterns and relationships, in relation to reliability and validity of data.

To develop an understanding of ideas about evidence, Glaesser, Gott, Roberts, and Cooper (2009) explicitly taught first year undergraduates the concepts of evidence required to conduct an investigation (such things as ideas underpinning validity and reliability, experimental design, measuring instruments, uncertainty and variation in repeated readings, descriptive statistics, and presenting data in tables and graphs). On comparing students' performance on the same open-ended investigation tasks at the beginning and the end of the teaching module, the authors found that their performance on the investigation task had improved significantly. The authors concluded by proposing that procedural ideas be incorporated into the school science curriculum and taught explicitly to enhance students' learning in science.

While the above findings showed that individual students benefited from explicit instruction on procedural ideas, there appears to be little research on the use of concepts of evidence in collaborative situations. This first study examines the use of procedural ideas in collaborative discourse during an investigative task. A coding scheme was designed, based on concepts of evidence, to identify the type of knowledge used—substantive knowledge, knowledge on process skills, or Concepts of Evidence, during students' verbal interaction when working collaboratively on a chemistry investigative task (see section on data collection and coding).

PURPOSE OF STUDY

This exploratory study is the first of three studies which examined peer feedback during a chemistry investigation, and it has a twofold purpose. The first purpose was to explore the nature of student-student discourse during a chemistry investigative task. More specifically, the four classes of communicative approach outlined above are used to characterise peer discourse and interaction. This leads to the second purpose, which was to identify the various forms of peer feedback in relation to their function in the communicative approaches. To pursue these purposes, the following two research questions were posed:

1. What are the communicative approaches in peer discourse during a chemistry investigation characterised as interactive/dialogic, non-interactive/dialogic, interactive/authoritative, and non-interactive/authoritative?
2. What role does peer feedback play in relation to the communicative approaches in peer discourse during a chemistry investigation?

METHODOLOGY

Setting and Participants

Study 1 was conducted in an Auckland secondary school, involving six pairs of female Year 13 chemistry students (16–17 years old) who had recently completed NCEA Level 3 achievement standards on investigative tasks as well as the pre-requisite content knowledge on acid base chemistry. The setting used was a preparation room where each pair of students was audio and video taped while working on a familiarisation task as well as the investigative task within a three-hour session. The pairing of students was carried out by their chemistry teacher with consideration of good attendance, being verbally expressive, being on-task, and having the ability to work well with each other. The students were of average and high ability in terms of academic achievement based on their chemistry achievement standards (AS) taken prior to the study (see Table 5).

Although the students were randomly paired, their achievement level gave an indication of their prior knowledge ability in relation to carrying out an investigative task.

Table 5. Students' chemistry achievement levels

Student	Chemistry Achievement Standards Taken								Achievement Level
	AS2.2	AS2.3	AS.4	AS2.5	AS2.6	AS2.7	AS3.1	AS3.2	
1	M*	E*	E	E	M	E	M	E	Middle
2	E	E	E	E	M	E	A*	E	Middle
3	E	M	M	M	M	M	A	E	Middle
4	M	M	M	E	M	A	M	E	Middle
5	E	M	M	E	M	M	M	E	Middle
6	M	M	M	E	E	M	A	E	Middle
7	E	E	M	E	E	E	E	E	High
8	E	E	E	E	E	E	M	E	High
9	E	M	E	E	M	E	M	E	Middle
10	E	E	M	E	E	E	E	E	High
11	E	M	E	E	A	M	M	E	Middle
12	E	E	M	E	M	M	Abs*	E	Middle

*A – achieved; M – merit; E – excellent; Abs – absent

The last pair of students (Students 11 and 12) was not taken into consideration when analysing results as one of the students was absent and thus did not meet the requirement on completion of NCEA Achievement standard 3.1.

Study Context

In 2002, the New Zealand Ministry of Education implemented a new standards-based assessment system—the National Certificate of Educational Achievement (NCEA)—as the national qualification for senior secondary school students (Year 11 to 13). NCEA is comprised of a combination of internally assessed unit standards administered and completed during the course of the year, plus achievement standards (internally or externally assessed) which the students took at the end of the year.

In Study One, the investigative task was designed based on exemplars related to NCEA Achievement Standard 3.1, which is available on the NCEA website. The main differences between this task and what is required for AS3.1, are that it involved generating an hypothesis (not a requirement in AS3.1) and manipulating variables (not stated explicitly) and that students needed to complete the task within two hours instead of the 3–4 week duration for AS3.1. Also, the research phase for AS3.1 was replaced by background information given in the student handout pertaining to the task. Although students were required to think-aloud as they worked on the task, there was spontaneous dialogue, and discussion occurred throughout the session.

The procedural demands of the investigative task involved manipulating variables (e.g., acid concentration and/or duration of exposure to acid) to compare their effects on the calcium content in two types of egg-shells. A back titration method was required for quantitative analysis purposes.

The conceptual demands required students to be familiar with stoichiometry and related back titration calculations. Conceptual understanding of acid and base reactions involving hydrochloric acid and calcium carbonate was a pre-requisite as well as how to represent the reaction using symbolic equations. Also, students need to be aware of the factors that would change the rate of this reaction—namely, the concentration, temperature, and surface area.

Procedures

The investigative task consisted of three phases of activities—planning and design, performance, analysis and interpretation. Students worked in pairs to carry out the investigative task while ‘thinking aloud’ with prompting from the researcher when necessary. The duration of the task was two and a half hours—the first half hour was allocated to familiarising the students with the think-aloud method, and the actual task commenced thereafter for another two hours. The familiarisation involved students verbalising their thoughts while working together on a simple chemistry experiment. The actual task involved student pairs designing and carrying out an investigation on the effects of acid on different types of egg shells. Their verbalisations throughout the experiment were recorded for transcription and analysis (see Table 6).

Table 6. Study One intervention procedures

Stages	Description of activities
1	• Design of investigative task.
2	• Carry out a pilot study involving a pair of students to identify issues related to task feasibility, duration, use of think aloud protocol, and use of video and audio recording. • Modify task and improve quality of recordings if necessary.
3	• Carry out the actual study involving five pairs of students on five separate sessions. • Each pair of students will be required to stay back for two and a half hours after school to carry out the investigative task in the chemistry laboratory. • Minimize any disruption to ongoing school activities.
4	• Encoding of verbal data, analysis of transcripts and written lab reports.
5	• Report on findings.

Data Collection and Coding

The main source of data for this study was audio transcriptions incorporating notes about the students' interactions from video recordings. All verbal interaction was transcribed and coded in a stepwise manner. The transcribed protocols were analysed interpretively, with a focus on student-student interactions and peer feedback.

Firstly, a unit of meaning was identified, following the approach similar to the studies by Mortimer and Scott (2000, 2003). By citing from Bakhtin's work, Mortimer and Scott (2003) defined a unit of meaning as a segment of an ongoing discourse that has clear boundaries in terms of its thematic content. In the case of this investigative task, the three phases—planning and design, performance, analysis and interpretation, provided clear thematic boundaries, and served as the *units of meaning* for analysis. For the purpose of this exploratory study, the planning stage of the investigative task was selected as the unit of meaning for in-depth analysis. An initial examination of the transcripts indicated that the planning stage of the investigation provided richer verbal interactions compared to the other stages, whereby the students were focused on carrying out the experiments and writing their laboratory reports.

Secondly, each unit of meaning or event was further broken down into sub-events, which constituted the *episodes* to be coded and analysed. The episodes were identified as corresponding to "a sense or meaning that is brought into consideration in building the broader meaning that constitutes the event" (Mortimer & Santos, 2003, p. 72). To further define the episodes, each student pair's transcribed protocol was coded by identifying the IRF moves and exchange (see coding scheme below, Table 7), usually starting with a student question or new idea related to the task and followed by another student's comment that led to further feedback which may extend, modify or start a different line of thought. Instead of using the typical teacher-led IRF discourse structure, the IRF exchange by peers was modified to include reciprocal questioning and suggestions, which proved to be more relevant to peer discussions. The *peer IRF exchange* forms the unit of analysis. Thus, each episode consisted of chains of peer feedback moves following an IRF structure and building on a common idea or ideas.

Thirdly, to capture the communicative approach that unfolds during the peer discourse, episodes involving consecutive peer IRF exchanges were further coded (see Table 7) on communicative function—informing, evaluating, elaborating and scaffolding. This coding scheme was derived after several iterations of the episodes. By analysing the relationship between IRF moves and their communicative functions, the interactive/non-interactive nature of the peer discourse can be identified.

Table 7. Coding scheme for peer discourse

Category Name	Code	Description	Examples
		Moves	
Initiate-Suggestion	I-S	Providing a new idea statement or suggestion.	We are going to investigate the effects of acids on different types of egg shells.
Initiate-Question	I-Q	Providing a new question.	How long are we going to leave the shells in the acid?
Response-Answer	R-A	Providing an answer.	OK. You are right.
Response-Suggestion	R-S	Providing a suggestion or comment.	But we don't know the concentration of HCL.
Response-Question	R-Q	Providing further questions.	Hey, is this soluble?
Response-Answer/Suggestion/Question	R-A/S/Q	Providing either an answer or suggestion followed by further questions.	Would it be easier if we just do by moles? How about we leave that open?
Feedback-Answer	F-A	Providing an answer.	Yes, so we measure it and we will know the concentration.

Category Name	Code	Description	Examples
Feedback-Suggestion	F-S	Providing a suggestion or comment.	But it’s not about human preference now. It’s about the strength of the shells.
Feedback-Question	F-Q	Providing further questions.	So, are we trying to react the calcium ion with the acid?
Feedback - Answer/Suggestion/ Question	F-A/S/Q	Providing either an answer or suggestion followed by further questions.	We make the solution and weigh the eggs. But how much acid are we going to add?
		Communicative Function	
Informing-Observation	I-O	Providing observations.	We got to look at the materials.
Informing-Generic comments	I-G	Providing generic or off-task comments.	I don’t know.
Evaluating-Affirmation	E-A	Providing acknowledgement or affirmation.	Yes.
Evaluating-Correct response	E-C	Providing confirmation or correct response.	Yes, that is standardising.
Evaluating-Errors	E-E	Detecting errors.	
Elaborating-Explanations	Eb-E	Providing explanations.	And after the acid has reacted with the calcium carbonate, there will only be a certain amount of acid left right? And then we can drain it off and titrate...
Elaborating-Alternatives	Eb-A	Exploring alternatives or extending ideas.	Should we use percentage or are we ...
Elaborating-Challenge	Eb-C	Providing challenge or counter suggestions.	No, we use titration instead.
Elaborating-Examples	Eb-Ex	Providing examples.	
Scaffolding-Prompts	S-P	Providing prompts or cues.	What reacts with calcium ions?
Scaffolding-Clarify	S-C	Checking or clarifying.	But what is it going to be? Calcium?
Scaffolding-Refine	S-R	Repeating, rephrasing or refining a response.	Do we titrate it with an acid or a base?
Scaffolding-Monitor	S-M	Monitoring statements on task.	I am just thinking why do we have ethanol and acid? Is it so that we can ...

While the above analysis focused on the structural aspect of the discourse, there was also a need to examine the content aspect to determine the dialogic/authoritative nature of the peer communicative approach. As demonstrated by Mortimer and Scott (2003), the communicative approach can fall on a continuum from a dialogic nature to an authoritative nature, depending on the way viewpoints were shared by the peers or dominated by one person in the group. In this study, the unit of meaning was taken from the planning stage of the investigative task and peer discussion revolved around using substantive knowledge (i.e., concepts of chemistry), process skills ideas (i.e., how to perform the experiment), and ideas of evidence (i.e., concepts of evidence). This implies that the type of knowledge used by students provides a useful category for content analysis of peer discourse.

In addition to coding the type of knowledge used by individual students, the cognitive function of knowledge used were also coded to reflect the way peers used the knowledge in thinking and meaning making during the discourse. Three main cognitive functions—task-based, process-based, and regulatory-based—were identified based on Hattie and Timperley's feedback model (2007). The coding schemes for the *type of knowledge used* and *cognitive function* in the peer discourse are shown in Table 8.

Table 8. Coding scheme for knowledge used and cognitive function

Category Name	Code	Description	Examples
		Knowledge Used	
Substantive knowledge	SK	Conceptual knowledge.	I don't know, because calcium ion is not a metal?
Process skills	PS	Skills on performing an experiment.	The first thing is to weigh the shell...
Concepts of Evidence	CoE	Ideas on evidence related to science investigation.	Our control variable could be the acid, right?
		Cognitive Function	
Task-based	T	Following given information to carry out the task.	Do we have to write the equation?
Process-based	P	Adopting strategies to engage the task.	So, we are dissolving the egg shells in the acid, like in the flask...
Regulatory-based	R	Monitoring and self-evaluating task progress.	We will be able to find out how much acid, but we do not want that. We want to know the calcium ion content...

Analysis of Peer Feedback Responses

Both the structural aspect (the IRF exchange and communicative function), and the content aspect (knowledge used and cognitive function) allow for an in-depth analysis of the communicative approaches adopted by peers during the discussion on the investigative task. The communicative approaches reflect the nature of discourse, which constitute the dimensions of interactive/non-interactive and dialogic/authoritative modes of discourse. The peer feedback responses can be analysed as situated within these modes of discourse. The analysis of this relationship between communicative approaches and patterns of peer feedback moves help to identify the characteristics of peer feedback responses that support different modes of communication and peer verbal interaction during the investigative task.

RESULTS

Characteristics of Peer Dialogue

Communicative approaches in peer discourse

From the five pairs of students' transcripts, 22 episodes of student-student dialogue were identified. The students' communicative approach consisted mainly of interactive/dialogic, interactive/authoritative and non-interactive/authoritative exchanges when talking about the investigative task (Table 9).

Table 9. Communicative approaches identified in each student pair's discourse episodes

Student pairs	Communication approach			
	*I/D	I/A	NI/D	NI/A
1 & 2	3	1	0	4
3 & 4	1	2	0	2
5 & 6	0	1	0	2
7 & 8	2	2	0	0
9 & 10	1	0	0	1
Total episodes	7	6	0	9

*I – interactive, NI – non-interactive, D – dialogic, A – authoritative

In episodes where an interactive/*dialogic* approach was adopted, the dialogic nature of discourse was evident in student pairs that were able to build on each other's ideas with scaffolding and elaboration, and interactivity was clearly obvious from the IRFRF...continuous chain of exchange in these episodes (see Table 10).

Table 10. Example of an episode (Student Pair 1 & 2) with interactive/dialogic communicative approach

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	S2	We have free range and barn range egg shell...ok...	I-S	I-O	PS	P
2	S1	So from these eggs the free range will be thicker because they come from healthier chickens which means the calcium content will be higher...ok...hypothesis time...	R-S	EB-E	SK/COE	T
3	S2	The calcium ion content will be higher in the free range egg shell than the calcium ions content in the barn egg shell... Are we missing anything? Why do you think there will be higher calcium...?	F-S/Q	EB-E/S-M	COE	P
4	S1	Because we see it...they are healthier... they run around more...	R-A	EB-E	PS	P
5	S2	Yeah... so they have thick shells...	F-S	E-C	SK	T
6	S1	So when acid rain is frequent...so that’s when the shells’ are fragile... shells are a lot thinner when there is lower concentration of calcium ions...	R-S	EB-E	SK	T

In contrast, student pairs that relied on their partner to lead the discussion often showed a truncated IRF exchange, as was also the case when students looked to the researcher for support in order to proceed with their task. These are episodes of interactive/*authoritative* interactions, whereby the viewpoint of one speaker takes over the discussion (Table 11). While this may seem less than productive in collaborative discourse, the authoritative approach may provide the necessary support for the students who lack the knowledge, skill, or strategy to proceed on their own.

Table 11. Example of an episode (Student Pair 1&2) with interactive/authoritative communicative approach

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	S2	Ok. If that's the case then we want the acid in the flask and base in the burette so that we can standardise sodium hydroxide in the burette which is a control variable because it has already been standardised. We will be able to find out how much acid. But we do not want that. We want the calcium ion content...	I-S	EB-E	COE	R
2	S1	Calcium content...What reacts with calcium.. .? Yeah... calcium ions? What mix with calcium ions?	R-Q	S-P	SK	T
3	S2	I don't know because calcium ion is not a metal...	F-A/Q	S-C	SK	T
4	S1	So wouldn't it be like...since we know how much is the carbonate, if we react...	I-S	EB-E	PS	R
5	S2	But we don't know how much carbonate...	R-A	EB-C	SK	T
6	S1	Yeah, if we work that out... should we titrate it? Why don't we...basic...	F-A/Q	EB-A	PS	P
7	S2	Maybe we will do a back titration.	I-S	EB-A	PS	P
8	S1	What is a back titration? Is it the one that we did with...	R-Q	S-C	SK	T
9	S2	Yeah...that's standardising. Oh, ok. We have calcium carbonate solution in the flask then we will titrate acid into it, then we will put the phenolphthalein into it and it will turn colourless...	F-A	EB-E	PS	T
10	S1	Yeah but why? Until it goes colourless?	R-Q	S-C	PS	T
11	S2	Yeah. Because like acid and carbonate with the eggs and the indicator...And that way, from the burette we will know how much acid and we will know how much carbonate, which is the same amount of calcium ions. That works, huh. They are just confusing us with the equipment. So mix the solution in the flask, we want to crush the eggs, which will turn into calcium ions and carbonate and we also add ethanol...	F-A	EB-E/S-M	SK/PS	R
12	S1	With the indicator right?	R-Q	S-C	PS	P
13	S2	Yes. With the indicator.	F-A	E-C	-	-

Table 12. Example of an episode (Student Pair 1 & 2) with non-interactive/authoritative communicative approach

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	S1	Do we have to write the equation?	I-Q	S-C	SK	T
2	S2	That's a good idea. Ok, what's going to react? That's what we need to figure out.	R-S/Q	E-C	SK	T
3	S1	Er...so...so we are trying to react the calcium ion and the eggs...with...	F-Q	I-O	SK	T
4	S2	But what is it going to be? Carbonate?	R-Q	S-C	SK	T
5	S1	So those are all the stuff that we have?	I-Q	S-M	PS	P
6	S2	Yes.	R-A	E-A	-	-
7	S2	Is carbonate 1 or 2?	I-Q	S-C	SK	T
8	S1	Carbonate?... What do you mean? CO3? Is it 2-? Yes, I think it is...yeah...	R-A	E-C	SK	T
9	S2	Ok. So it's just $CaCO_3$. It's an acid, isn't it?	I-Q	S-C	SK	T
10	S1	Carbonate? Oh yeah... or isn't it? Ok, the egg shell...	R-A	E-C	SK	T
11	S2	Is it not? Or is it a base? You use it today to get rid of the excess HCL. What are we going to react in the flask by titrating?	F-S/Q	S-C	PS	P
12	S1	Hmm...calcium carbonate... with calcium... so, if you react with acid...	I-S	I-O	PS	P
13	S2	I am just thinking why do we have ethanol and acid? Is it so that we can add acid...	R-Q	S-M	PS	P
14	S1	Yeah...what is it for...what is the ethanol for?	F-Q	S-R	PS	P
15	S2	I don't know. A reacting agent for the egg? So then it can react ethanol with HCL...so we are dissolving the eggs in the acid, like in the flask?	R-Q	S-C	PS	P

A third communicative approach that appears to hinder peer interaction was evident when students adopt a *non-interactive*/authoritative mode during the discourse (Table 12). Although the IRF moves may show that the students were involved in a dialogue, a closer look at the communicative function indicates that the response and feedback did not lead to further development of the initial idea or question posed. While the students tried to scaffold the discussion with questions for clarification and checking, the response or feedback was lacking in elaborative statements. Instead, the students tended to provide evaluative comments or simply ignored their partner's questions. In most instances, the students were able to identify some interesting aspects of the problem, but they lacked the ability to build on each other's ideas, perhaps due to a deficiency in content knowledge, feedback skills, or both. This 'monologue' was akin to what Mortimer and Scott (2003) suggested occurs in teacher-student episodes, whereby a non-interactive/authoritative approach represents the teacher giving a lecture to the class. It is *assumed* that the students are actively listening and following the lecture.

Peer feedback characteristics

The 22 episodes of peer-peer discourse comprised of 273 turns of transcribed dialogue, of which, 97 turns (36%) were identified as peer feedback moves (see Table 13). The occurrence of each communicative function, the knowledge used, and the inferred type of cognitive function were tabulated to give a quantitative view of the peer feedback characteristics of each pair of students. On average, peer feedback made up 35% of the dialogue of each pair of students. For each pair of students, the percentage occurrence of each component of the communicative function, knowledge used and cognitive function was calculated by dividing the frequency count by the total number of peer feedback moves. This data is plotted in the form of stacked bar charts as shown in Figures 2, 3 and 4.

Table 13. Peer feedback moves characterised by communication function, knowledge used, and cognitive function

Student pairs	Total turns	Peer feedback moves	Communicative function				Knowledge used			Cognitive function		
			Scaffolding	Evaluating	Elaborating	Informing	Substantive knowledge	Process skills	Concepts of Evidence	Task	Process	Regulatory
1 & 2	101	35(.35)	15(.43)	9(.26)	11(.31)	3(.09)	7(.20)	15(.43)	5(.14)	10(.29)	16(.46)	3(.09)
3 & 4	61	21(.34)	8(.38)	9(.43)	4(.19)	0(.00)	2(.10)	10(.48)	5(.24)	3(.14)	11(.52)	4(.19)
5 & 6	35	12(.34)	4(.33)	4(.33)	4(.33)	0(.00)	0(.00)	2(.17)	8(.67)	0(.00)	10(.83)	0(.00)
7 & 8	52	21(.40)	7(.33)	3(.14)	10(.48)	1(.05)	11(.52)	3(.14)	2(.10)	6(.29)	9(.43)	2(.10)
9 & 10	24	8(.33)	1(.13)	3(.38)	4(.50)	0(.00)	3(.38)	0(.00)	5(.63)	4(.50)	4(.50)	0(.00)
Total	273	97(.36)	35(.36)	28(.29)	33(.34)	4(.04)	23(.24)	30(.31)	25(.26)	23(.24)	50(.52)	9(.09)

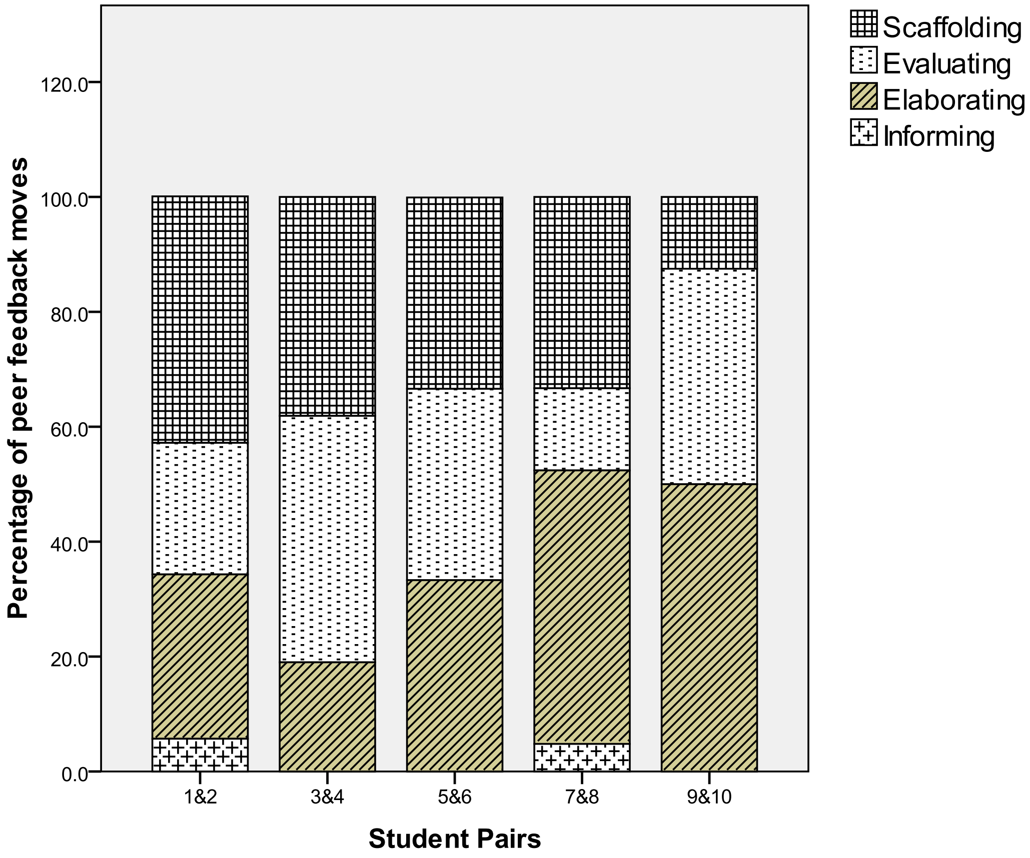

Figure 2. Communicative functions present in peer feedback for each student pair during planning of investigative task

In Figure 2, the function of scaffolding appears to be the most commonly used in peer feedback exchange, followed by elaborating and evaluating. Informing was not obvious except in Student Pairs 1 & 2, and 7 & 8. Scaffolding involves providing prompts or cues, posing questions for clarification or checking, reformulating (repeating, rephrasing, or refining a response), and monitoring the progress of the task. This form of scaffolding is seen as a mutual support between peers, working together to strengthen one another's effects. Elaboration takes the form of explanations, exploring alternatives, extending ideas, and providing challenges. In addition, students evaluate by providing acknowledgement or affirmation to their peers; sometimes taking the form of confirmation or providing a correct response. These peer feedback moves may be seen as helpful to the students in helping each other to identify the purpose of the investigation, formulate the hypothesis or testable question, and develop a workable method for implementing their experiment.

Most notable for all student pairs is the use of concepts of evidence in peer feedback exchanges (Figure 3), with Student Pairs 3 & 4, and 9 & 10 showing over 60% of usage of their total peer feedback moves. Knowledge on process skills featured prominently in the peer feedback exchange of Student Pairs 1 & 2 and 3 & 4, while Student Pairs 7 & 8, and 9 & 10 made use of substantive knowledge in much of their feedback exchange. Notably absent were the use of substantive knowledge in Student Pair 5 & 6, and the use of process skills knowledge in Student Pair 9 & 10.

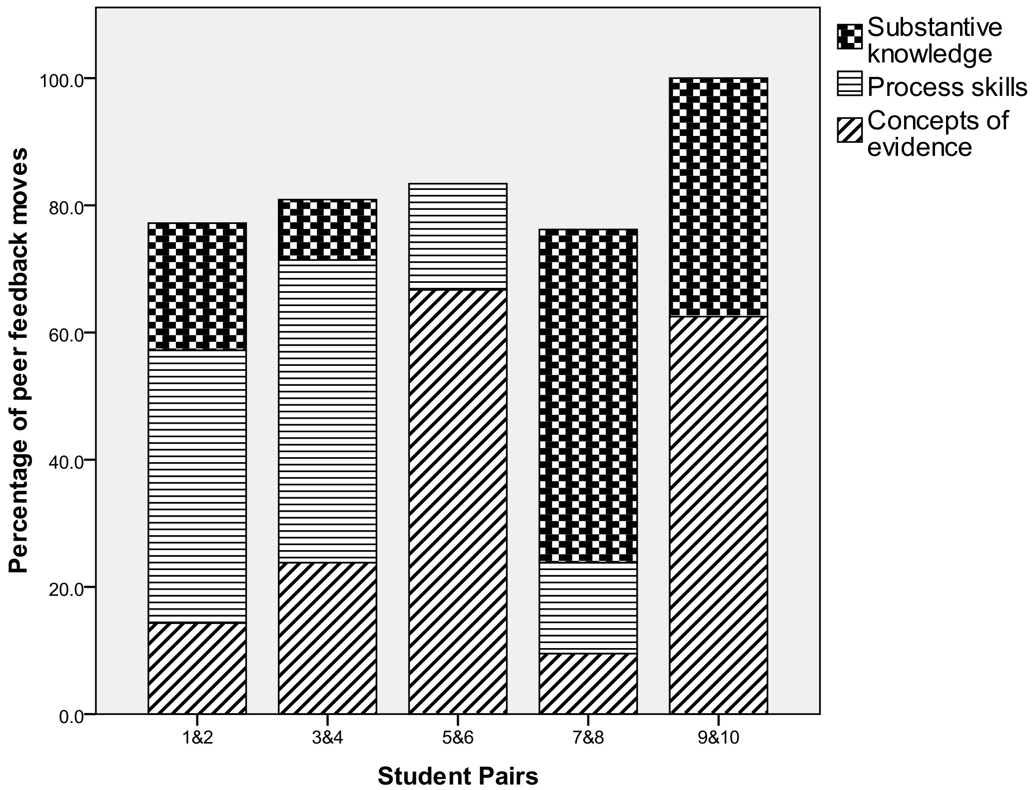

Figure 3. Knowledge used present in peer feedback for each student pair during planning of investigative task

Students were found to focus mostly on cognitive processes related to process-based function (Figure 4). Task-based processing was seen as important in all Student Pairs, except 3 & 4, while Student Pairs 3 & 4, and 9 & 10 did not show any regulatory processes in their peer feedback moves.

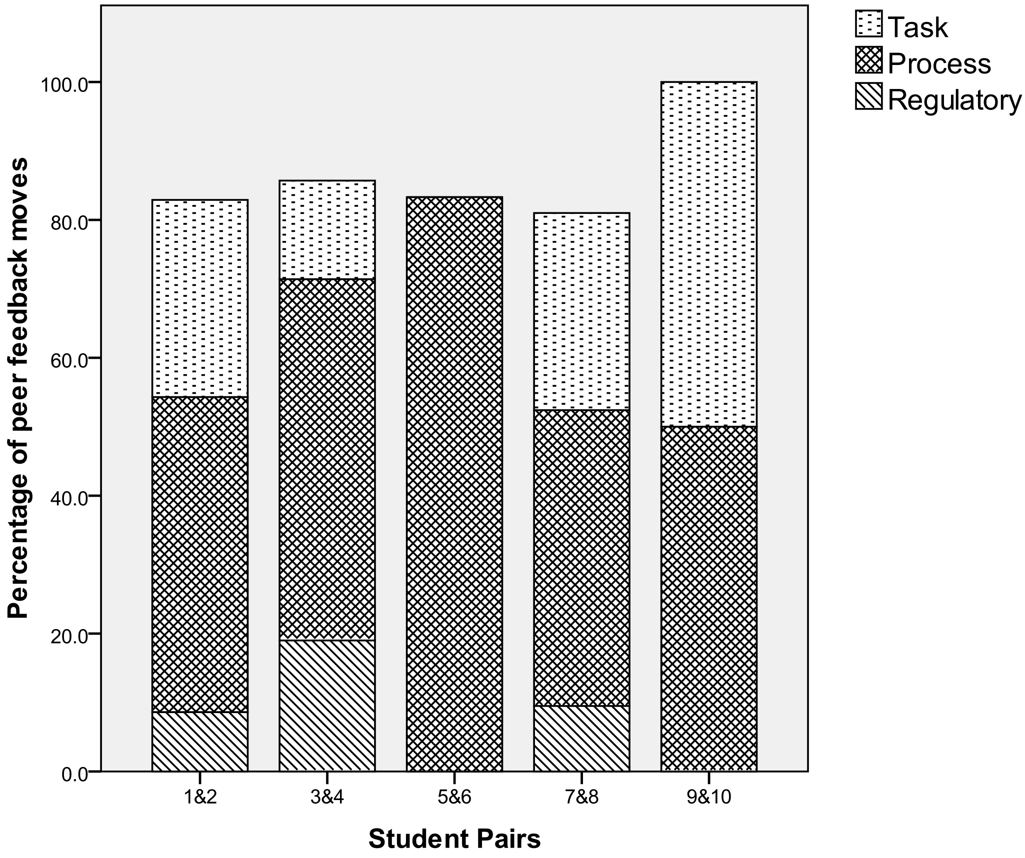

Figure 4. Comparison of cognitive function present in peer feedback for each student pair during planning of investigative task

Episodes of communicative approaches and peer feedback moves

Although the above description highlights important characteristics of peer feedback during the peer discourse, the peer feedback moves are only meaningful when analysed in relation to the initiations and responses that precede and follow each peer feedback move. In other words, peer feedback is purposeful when situated within the learning context or discursive practice during the investigative task. The discourse episodes of Student Pairs 5 & 6 and 7 & 8 are used to illustrate the peer feedback moves present within the communicative approach enacted by the students. Student Pair 7 & 8 was able to adopt interactive/dialogic and interactive/authoritative approaches to their advantage to develop a plan for their investigation. In contrast, Student Pair 5 & 6 relied on a non-interactive/authoritative approach and seemed to struggle with the formulation of a testable question for the investigation.

The investigative task required students to plan and implement an experiment to find out the effect of acid rain (represented by dilute hydrochloric acid) on the calcium ion content present in two types of egg shells (barn eggs and free range eggs).

Discourse episodes of Student Pair 7 & 8

Episode 1—Interactive/dialogic discourse by Student Pair 7 & 8 (Table 14)

After reading the handout with the problem scenario, the students started to examine the materials provided. Student 7 noted that there were two types of egg shells and suggested that the egg shells should be "crushed" into smaller pieces. She then initiated a series of IRF exchanges by taking an interactive/*dialogic* approach. Here, Student 7 used question prompts to scaffold and develop the idea of an acid base reaction (Turn 7 to 13). Student 8 was able to follow this line of thought by providing elaborative feedback on her partner's responses which helped to focus on the acid-base reaction. After identifying the carbonate ions as part of calcium carbonate and which made up the composition of egg shells (Turn 8), the dialogic exchange with her partner allowed Student 8 to establish the connection between the composition of the egg shell and the reaction of acid and base (Turn 14). It was clear in this episode that the interaction was predominantly dialogic in nature, where both students used a series of questions and feedback to direct their attention to the key problem, building on each other's ideas. Notice that although there is agreement on the acid-base reaction, other doubts were raised, such as the concentration of hydrochloric acid (Turn 15) and the feedback statement that introduced a new idea about titration and the need for mathematical manipulations (Turn 20). Interestingly, the interplay of task-based and process-based peer feedback allowed both students to connect their ideas in a productive manner.

Table 14. Episode 1

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	S7	We got to look at the materials...	I-S	I-O	SK	P
2	S8	Ok.	R-A	I-G	-	-
3	S7	Two types of egg shells... and presumably the mortar and pestles are there to crush the shells.	I-S	S-M	PS	P
4	S8	Yeah... the pestle.	R-S	I-G	-	-
5	S7	Sorry...yeah the pestle.	F-S	I-G	-	-

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
6	S8	It's ok...so is it in small pieces or the original piece?	I-Q	S-P	COE	P
7	S7	Ok so... calcium carbonate with... huh...we are doing the amount of calcium carbonate in egg shell so we...carbonate... Wait, but because we are doing the carbonate ions as opposed to calcium ions...	R-S/Q	EB-A	SK	P
8	S8	Yup. So its calcium carbonate. It's what the eggs shells are made of. Is that what they are trying to tell us? So presumably when we grind this up, we will have calcium carbonate?	F-A	EB-E	SK	P
9	S7	Carbonate is a base, right?	R-Q	S-P	SK	T
10	S8	Yup. Carbonate reacts with acid...	F-A	EB-EX	SK	T
11	S7	Base?	R-Q	EB-A	SK	T
12	S8	Reacts with sodium hydroxide...	F-S	EB-E	SK	T
13	S7	Then will react with hydrochloric acid...	R-S	S-R	SK	T
14	S8	Oh, is that really what you think? Because we haven't really...	F-Q	S-M	SK	T
15	S7	But we don't know the concentration of the hydrochloric acid.	R-S	S-P	SK	R
16	S8	Ok. You are right.	F-A	E-A	-	-
17	S7	But this is a pretty decent concentrated HCL.	R-S	S-P	SK	T
18	S8	1 mole per litre.	F-A	E-C	SK	T
19	S7	That's better than 0.05.	R-S	S-R	SK	T
20	S8	Yes you are right, may be it will work. So we just...that needs to be a titration. So we need to find out exactly how much...that's the base. Right? We do actually need to do the calculation for this? We probably do right?	F-A/Q	EB-A	PS	P

Episode 2—Interactive/authoritative discourse by Student Pair 7 & 8 (Table 15)

In Episode 2, Student 7 first explored the idea brought up by Student 8 by asking her to elaborate further. This exchange developed the notion of 'concentration of acid' as another important variable in the investigation. The feedback from Student 7, which involved several scaffolding questions and elaborative feedback, cued her partner to exclaim that "It's the concentration in general..." (Turn 8) and developed the idea of finding the concentration from the reaction of acid and the calcium carbonate in the egg shells. The elaborative feedback in Turn 9 by Student 7 introduced the concept of moles to quantify the concentration of acids and this led both student to formulate a chemical equation involving the acid and the calcium carbonate. This verbalisation of the use of moles and the subsequent writing of the chemical equation was seen as a crucial step in this planning process, as it drew the connection of using the chemical equation to carry out mathematical manipulation of the concentration of variables. In other words, the students were able to develop a method to measure the key variables—concentration of acid and calcium ions present.

Table 15. Episode 2

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	S7	So you are saying do barn eggs or free range eggs contain more calcium carbonate?	I-Q	S-R	SK	R
2	S8	No... it's the ability to withstand the acid rain.	R-A	S-R	SK	P
3	S7	The ability to withstand or...?	F-Q	S-P	-	R
4	S8	Ok. We missed it.	R-A	S-M	-	R
5	S7	No, no, no. We put the shells in the acids, then carbonate and eggs react with acid so...	F-S	EB-E	PS	P
6	S8	Right, so the concentration of carbonate in this...	R-S	EB-A	SK	P
7	S7	So it's not just how much...?	F-Q	S-R	COE	P
8	S8	It's the concentration in general. So it means we have to take a section of the eggs and weigh it. For this have to be equal and so...	R-A	EB-A	COE	P

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
9	S7	And we put it in an amount of acid that we know how many moles of acid in there. And after it has finished reacting...	F-A	EB-E	COE	P
10	S8	So how many moles of acid in these?	R-Q	S-P	SK	T
11	S7	Yes so we measure it up and we will know like ...we will know the concentration...and we know how much it is and we will know how many moles...	F-A	EB-E	SK	P
12	S8	HCL + CaCO3...(*Writing the chemical equation*)	R-S	S-M	SK	T
13	S7	HCL.	F-S	S-M	SK	T
14	S8	Hey, is it soluble? Calcium chloride?	R-Q	S-M	SK	T
15	S7	So its H2O and...	F-Q	S-M	SK	T
16	S8	Calcium chloride...	R-A	S-M	SK	T
17	S7	Yup. That will be it. And so ...after the acid has reacted with the calcium carbonate there will only be a certain amount of acid left, right? And then we can drain it off somehow and titrate it again...Yup. Then you can titrate the remaining amount...when you put the acid in the egg shell, some of it will react with the carbonate and it will only have some left. So drain that off and you can tell how much is left by titrating it with an alkali then it will give you an amount of acid left and then you minus it off from the amount that you originally put it in and it will give you the amount that is used up by the calcium carbonate and it will hint how much calcium carbonate there was in that egg shell...	F-A	EB-E	PS	P

Toward the end of this episode, Student 7 demonstrated her overall understanding of the problem by summarising both her thoughts as well as her partner's, acknowledging and building on her partner's ideas (Turn 17). This episode had a clear interactive/*authoritative* nature and peer feedback was seen as serving a role of promoting a particular point of view in this peer discourse. It seemed that Student 7 had some initial ideas about the task and by sharing her ideas with her partner, she was able to clarify and refine her ideas to make it more concrete and workable. The feedback moves were elaborative, allowing her to engage her partner to follow her line of thought and eventually resulting in the reformulation of her ideas.

From these two episodes of peer discourse, it was clear that peer feedback served not only as an acknowledgement of a response, but also helped in co-constructing ideas by scaffolding and elaborating peer responses. Although both authoritative as well as dialogic communicative modes suggest that ideas may be derived from one party or co-constructed, a combination of peer feedback moves such as clarifying, prompting, rephrasing, and reformulating appears to be beneficial to promote the interaction and development of ideas.

The communicative episodes of Student Pair 5 & 6

Episode 1—Non-interactive/authoritative discourse by Student Pair 5 & 6 (Table 16)

In the first episode, it was clear that both Students 5 & 6 were experiencing problems in drawing connections between calcium carbonate (or calcium ions) present in the egg shells and the reaction of this compound with acid. Student 5 had come up with an idea of testing both types of egg shells with the acid provided (Turn 3), but she was unsure of how to proceed from there. Student 6 appeared to be helping Student 5 by suggesting the need to keep the amount of egg shells used constant (Turn 6). Student 5 seemed to be aware of this fact, but continued to focus on her initial idea of testing the egg shells. Although Student 6 failed to pick up on this idea, Student 5 was able to develop her own idea further by asking her partner how they could quantify the amount of calcium carbonate before and after the test (Turn 13). Thus, an authoritative IRF interaction was established early in this exchange by Student 5, and Student 6 was content in playing a supporting role, albeit, a less than productive one. It can be observed from this episode that although an IRF chain of interactions was evident, there was clearly a mismatch between peer feedback and responses, and both students struggled to complement each other, resulting in a communicative approach that remained largely *non-interactive*/*authoritative*.

Table 16. Episode 1

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
1	5	We need to see if acid rain will affect the strength of the egg shell...bigger egg shell has more calcium ions but then we need to find out whether the acid actually affects the egg shell...	I-S	I-O	SK	T
2	6	Just thinking why we have to do...why there are so many acids?	R-Q	S-C	PS	P
3	5	We need to see if acid rain affects the egg shells and acid rain is not very strong and it could probably add a little bit of acid to the egg shell so that calcium content decreases...	F-A	EB-A	PS	P
4	6	I think acid rain...[reading the question again]	R-S	I-G	-	-
5	5	The first we just need to see...the first thing is to make the shell...or weigh...	I-S	I-O	PS	P
6	6	We will need the same amount...	R-A	EB-A	COE	P
7	5	I guess so. Maybe like...but that would be really hard. I was thinking if we could make it into fine powder and then add diluted acid to see...	F-S	S-R	PS	P
8	6	On the whole egg?	I-Q	S-C	PS	P
9	5	No, not the whole egg. Just a little bit and make it into powder.	R-A	E-C	PS	P
10	6	But we need the same amount of the powder because we are looking at the calcium ions.	F-S	EB-E	COE	P
11	5	Yup, but then we don't know which one is affected by the acid rain. We need to see if acid rain decreases the amount of calcium and so	I-S	EB-E	PS	P

Turn	Speaker	Utterance	Move	Communicative Function	Knowledge Used	Cognitive Function
		we need to add acid rain like dilute acid and water? So we need to add dilute acid to egg shell and leave it for a while and test it to see if the calcium content has decreased?				
12	6	Yeah, but we will have the same amount of egg shell right?	R-Q	S-C	COE	P
13	5	Yup. But first of all before we start we need to see whether how much calcium is there and after that how much there is. I don't know how to find that out.	F-A	S-M	PS	P/R

Episode 2—Interactive/authoritative discourse by Student Pair 5 & 6 (Table 17)

In Episode 2, although both students were able to offer different points of view in response to what their partner had said, they were unsuccessful in building on each other's ideas. Here, both students were unsure what the key variables of the experiment were and while Student 6 was suggesting that the independent variable was the amount of acid required (Turns 3 & 6), Student 5's feedback did not attempt to address this but instead focused on the control variable. This disconfirmation seemed to create an opportunity for clarification and exploration of ideas but neither student was able to develop this further. Towards the end of the episode, Student 6 responded by adopting the idea of Student 5 (Turn 10) which was agreed upon by a feedback acknowledgement from Student 5 (Turn 11).

Table 17. Episode 2

Turn	Speaker	Utterance	Move	Communicative function	Knowledge used	Cognitive function
1	5	So the control variables will be the calcium carbonate and the acid?	I-S	S-P	COE	P
2	6	Yup.	R-A	E-A	-	-
3	5	That's what we are controlling...what would the dependent and independent variables be?	F-Q	S-R	COE	P
4	6	The independent would be	R-A	E-C	COE	P

Turn	Speaker	Utterance	Move	Communicative function	Knowledge used	Cognitive function
		the acid, wouldn't it?				
5	5	Yeah... no, I don't think it's... we are using the egg shells, do we have to break it?	I-A/Q	S-C	PS	P
6	6	Yes, into powder.	R-A	E-C	PS	P
7	5	Yeah, we could do that and we need to do one type of egg at a time so that it cannot be mixed up. And we need to test the amount of calcium that was there before and after we have added the diluted acid. We must then see if there has been a decrease? What are the independent variables? I still don't know...	F-A/Q	EB-A	COE	P
8	6	The amount of acid that we put in?	R-A	E-C	COE	P
9	5	No, do we put like the control variables... would be the amount of dilute acid... shouldn't that be controlled because if we add more, we will affect them...	F-A/Q	E-A	COE	P
10	6	Yup. The control would be the x amount of acid used which dissolves the egg shell and will have excess acid left.	R-A	E-C	COE	P
11	5	Ok	F-A	E-A	-	-

Comparing the two episodes from Student Pair 5 & 6 with those of Student Pair 7 & 8, it appears that peer feedback which matched the partner's response and further scaffolded or elaborated on the response may have been more productive in generating more ideas or making connections that were meaningful for both students.

CONCLUSION AND DISCUSSION

The two research questions addressed in this first study are:

What are the communicative approaches in peer discourse during a chemistry investigation characterised as interactive/dialogic, non-interactive/dialogic, interactive/authoritative, and non-interactive/authoritative?

What role does peer feedback play in relation to the communicative approaches in peer discourse during a chemistry investigation?

From the analysis of the five pairs of students, the nature of communication identified in peer discourse during the planning of an investigation had varied mostly between interactive/dialogic, interactive/authoritative and non-interactive/authoritative approaches. Furthermore, the in-depth analysis of Student Pairs 5 & 6, and 7 & 8 demonstrates that communicative approaches may shift from dialogic to authoritative depending on the way IRF exchanges are played out during the dialogue between peers. It is clear from this analysis that the discursive practice of peer feedback opens up opportunities for students to use scientific language and knowledge, especially concepts of evidence, in collaborative meaning making during the investigative task.

The analysis of IRF moves in relation to communicative functions, knowledge use and cognitive functions provides fresh insights into the role of peer feedback. The findings suggest that peer feedback can be instrumental in guiding the talk towards the generation of a shared idea, as in the case of a dialogic approach, or the *disconfirmation* of an idea, and leading to further elaborations, as in the case of an authoritative exchange. In both instances, peer feedback was enacted as part of the IRF moves through *scaffolding* speech acts which involved prompting, checking, clarifying, reformulating, or monitoring, as well as *elaborative* moves that includes exploring, explaining, extending, and challenging ideas (see Figure 2).

While there are potential benefits in facilitating a peer feedback discourse, the peer feedback moves may not come easily for most students. First, peer feedback responses are seen as implicit and dependent on the student's ability to verbalise and negotiate with their peers both their own ideas as well as their peer's ideas. This requires a certain level of communication skills that involves not only speech acts such as asking questions and providing explanations, but also be able to connect and reformulate differing viewpoints into workable suggestions. It follows that for peer feedback to promote the co-construction of ideas during a discourse, students need to be able to match their feedback to their partner's response. In other words, students need to interpret the response correctly and react accordingly. This will probably require some form of instructional support to help students engage with the feedback information received. Thus, there is a need to further explore ways of supporting discursive peer feedback that leads to meaningful sharing of knowledge and skills.

Second, students do not necessarily react to feedback questions as scaffolds, because they expect them to be followed by an evaluation, which is typical of teacher-student discourse in the classroom. As demonstrated in the review, one of the contributing factors to the lack of participation in classroom discussion is the teacher-dominated science lessons (Duschl & Osborne, 2002; Mercer & Littleton, 2007). By providing opportunities to give and receive peer feedback, an avenue could be opened up for students to practice talking science, and facilitate the meaningful cognitive processes that have the potential to target not only the task level knowledge but the process and regulatory levels as well.

COMMENTS ON INSTRUMENTS AND LIMITATIONS

While the analysis of peer discussion indicated that feedback by peers is a common and potentially beneficial practice during group investigation, it also highlighted the need for a purposeful learning context. The investigative task required students to work together to plan, design and implement an experiment to examine the effect of acid on egg shell or calcium carbonate. The semi-open nature of the investigative task means that students need to engage in idea sharing, negotiation and drawing connections to complete the task. In other words, a carefully chosen learning task can facilitate the active participation of students, which encourages co-constructive discourse (Mortimer & Scott, 2003). Thus, this first study provided a basis for developing and improving on the semi-open investigative task to elicit and engender peer feedback. The usefulness of a semi-open investigative task in promoting discussion and peer feedback was further demonstrated in studies two and three.

Another development from this exploratory study is the coding scheme used for analysing peer feedback. The use of concepts of evidence was found to be an important element in peer feedback during investigative task discussions. In addition, the coding for cognitive function (task-based, process-based and regulatory-based) provided another dimension to examine peer feedback, which is in line with developing the notion of peer feedback quality using Hattie and Timperley's model.

One limitation of this study is that the analysis and interpretation of peer discourse using verbal data is at best inferential (Barnes & Todd, 1995). For example, the peer feedback moves are derived from an interpretation of a series of initiation-response-feedback episodes and do not capture the full discourse structure enacted during the investigative task. A second limitation is the small sample size due to the exploratory nature of this study, which thus limits the generalisability of the findings. In this experimental setting, the student pairs were able to participate actively to collaborate on the task but in a normal classroom setting, this may not be the case. At times, partners may not respond, give irrelevant feedback and the dialogue may simply digress from the task itself.

IMPLICATIONS FOR THE NEXT STUDY

Peer feedback, when viewed within each communicative approach, can be argued to adopt different roles and these roles were seen to both constrain and promote the sharing, development and contribution of each student to the negotiation of meaning during the learning task. This exploratory study has highlighted the important role of peer feedback in promoting an interactive and meaningful discourse. Students need to be able to recognise that their peer's feedback questions can be building blocks for their ideas, and feel empowered to contribute actively to the discourse.

In the next study, a larger sample of participants will be used to examine peer feedback from another dimension of peer discourse, the giving and receiving of written peer feedback. The shift to written discourse allows the implicit nature of peer feedback moves to be investigated more closely and to focus on developing and supporting the quality notion that takes into consideration the consequential and engagement aspect of peer feedback. Thus, students are seen as having greater opportunity to be actively involved in peer feedback exchange and using peer feedback for revising their work; and peer feedback becomes a recursive and embedded part of learning.

CHAPTER 4

STUDY TWO: THE EFFECTS OF PROMPTS ON FORMULATING PEER FEEDBACK IN CHEMISTRY INVESTIGATIVE TASK

INTRODUCTION

The term ‘scaffolding’ was originally introduced as a metaphorical notion of guidance provided to a child or novice by a more knowledgeable person to “solve a problem, carry out a task or achieve a goal which would be beyond his (sic) unassisted efforts” (Wood, Bruner, & Ross, 1976, p. 90). Since then, the notion of scaffolding has been used more broadly to include support that not only assists learners in task completion but also to engage learners actively in the learning process (Berthold, Nuckles, & Renkl, 2007; Davis & Linn, 2000; Reiser, 2004). This means that besides the teacher, scaffolding in the classrooms may be mediated by other students, visualisation tools or knowledge representation and organisation tools.

While study one revealed that peer feedback could play an active role to support a meaningful verbal discussion, this mutual scaffolding on using peer feedback was not spontaneous. Building on the findings of study one, study two incorporates the use of prompts to scaffold the peer feedback process. The shift from verbal to written peer feedback extends the scope of research to investigate more closely the two proposed quality indicator of peer feedback – the consequential impact and the cognitive/ meta-cognitive engagement of peer feedback. Specifically, study two examined the effects of prompts on students’ formulation of written peer feedback during an investigative task in six New Zealand Year 12 NCEA chemistry classes. The prompts (guiding questions) were proposed to scaffold students’ generating feedback which is informative in identifying the learning gap and providing constructive suggestions that may lead to active uptake for revision of work done.

FRAMING PEER FEEDBACK AND PROMPTING

A Review of Prompts and Their Effect on Classroom Learning

Prompts are generally regarded as guiding questions, sentence openers, or question stems which provide cues, hints, suggestions, and reminders to help students complete a task. Prompts serve two key functions in students' learning—scaffolding and activation.

Prompts act as scaffolding tools to help learners by supporting and informing their learning processes. Prompts may also be conceived as "strategy activators" which "induce productive learning processes" (Berthold et al., 2007, p. 566). Here, the assumption was that learners possess the learning strategies but lacked the skills to demonstrate these strategies spontaneously or to a satisfactory degree while engaging with the learning task. Superficial processing by the learner is a common issue in the use of learning strategies (e.g., planning, monitoring and elaborating) and prompts are seen as tools for overcoming this by encouraging learners to apply more enhanced cognitive and meta-cognitive strategies (Berthold et al., 2007). The following review examines more closely the role and impact of prompts in relation to procedural, cognitive, and meta-cognitive skills of the learner.

Procedural prompts

Prompts may differ in their purpose, mode, and timing of delivery, as well as specificity (Davis, 2003). The use of prompts is very much dependent on its purpose. Prompts can be designed to target procedural, cognitive, and meta-cognitive skills of the learner. Task-oriented prompts are usually procedural in nature and provide cues or hints to focus the learner on the approach or steps required for task completion. For example, Scardamalia and Bereiter (1985) proposed the use of procedural prompts, such as "An example of this …" and "Another reason that is good …," to guide learners with explicit procedures and suggestions in planning their writing.

Cognitive prompts

In addition to task-oriented activities, prompts are provided to promote cognitive engagement. Learners are often provided with question prompts to help them in explaining, summarizing, making connections, drawing inferences, and generalization, and elaborating on ideas and experiences. For example, Chi, deLeeuw, Chiu and

LaVancher (1994) used question prompts to elicit learners' self-explanations in problem-solving. Content-specific prompts were designed such that learners were required to provide explanations by "knowledge inferences" (p. 448). For instance, "Why would the distribution of oxygen be less efficient if there is a hole in the septum?" or "Why doesn't the pulmonary vein have a valve in it?" This type of prompt "encourages learners to utilise commonsense knowledge" (p. 449) by directing their attention to reason and infer about related concepts. In a series of studies, King (1989, 1990; King & Rosenshine, 1993) carried out instructional interventions on small-group discussion by using a cognitive strategy known as 'guided cooperative questioning'. The approach required students to use a set of question stems such as "What are the strengths and weaknesses of …?" "Why is … important?" to self-formulate specific questions about the learning task and then use these questions to ask their peers and provide reciprocal answers to the questions posed by their peers. Findings indicated that students performed better on comprehension material when prompted with the questions and elicited more complex knowledge construction through elaborative explanations, inferences, justifications, hypotheses, and speculations. The authors attributed the effectiveness of the guiding questions to the *format*, which helped learners to focus on generating *specific kinds of questions* that further prompted them to think and discuss the learning material in meaningful ways. The result was that learners were able to construct *richer and more elaborated mental representations* which enhanced recall as well as being more stable and durable over time (King & Rosenshine, 1993). Besides providing structure and focus on self-generated questions, the specificity (e.g., high level or low level) of question prompts could give rise to more enhanced knowledge construction outcomes. For example, King (1994) compared the effects of training students to use experience-based questions and lesson-based questions. The results indicated that the use of experience-based questions prompted students to access and use more of their prior knowledge and experience during knowledge construction. Although carefully designed question prompts can result in meaningful knowledge construction, it does not imply that learners would spontaneous employ (i.e., transfer) these strategies when carrying out new learning tasks (Berthold et al., 2007; King, 1994).

Meta-cognitive prompts

Besides procedural and cognitive prompts, learners can also be provided with meta-cognitive prompts. These prompts are designed to help learners to monitor and reflect on their own learning approaches, such as problem-solving strategies, inquiry processes, and self-explanations. In a computer-based learning environment, Lin and Lehman (1999) found that justification prompts helped students to understand when, why, and how to employ experimental design principles and strategies, which in turn promoted the transfer of their understanding to solving a novel problem. They argued that when students were prompted to explain and provide reasons for their own decisions and actions (reason justification prompts), they may "engage in self-assessment comparable to meta-cognitive processes such as planning, monitoring, evaluating and revising" (p. 840). Examples of reason justification prompts include: "What is your plan for solving the problem?" "How did you decide that you have enough data to make conclusions?" On analysis of their qualitative data, the authors revealed that the prompts supported students by helping them to: a) organise, plan and monitor their actions by making their thinking explicit, b) identify specific areas that they did not understand and what they needed to know, and c) use domain-specific knowledge to reason about the approach they adopted to solve the problem.

Davis and Linn (2000) also looked at meta-cognitive prompts that were intended to elicit planning and monitoring. They used the term 'directed prompts' to describe prompts that provided students with hints on what to think about, for example, "When we critique evidence, we need to..." "In thinking about how these ideas all fit together, we're confused about..." These prompts are also seen as contextualised within specific activities, such as in self-monitoring about the task, "What we are thinking about now is…" or to check for understanding, "Pieces of evidence we didn't understand very well included…" (p. 824). Building on this research, Davis (2003) further compared the effects of generic prompts with directed prompts on students' reflection in a complex science project. 'Generic prompts' are prompts that are non-specific, being designed with the intention of allowing the learner the opportunity to choose "any of the knowledge integration processes" (p. 99). An example of a generic prompt is, "What we're thinking about now is..." The finding of this study indicated that generic prompts provided more 'freedom' for students to reflect on their learning whereas directed prompts may misguide some students with a 'false sense of comprehension'. Students' level of autonomy was found to interact with their use of generic prompts for reflection, with middle level autonomy students gaining most from the reflection prompts, as they "were allowed to direct that reflection themselves" (p. 135).

Combination of prompts

Prompts may also work in combination to scaffold the learning process. For example, Berthold et al. (2007) studied the effects of different types of prompts (cognitive prompts, meta-cognitive prompts, a combination of cognitive and meta-cognitive prompts, or no prompts) when writing learning protocols. The authors found that prompts were able to elicit cognitive and meta-cognitive learning strategies, which in combination, fostered learning outcomes. They attributed the effects to the ability of prompts to activate the learning strategies in learners, which mediated the effect on learning outcomes. Although prompts were effective in helping learners with learning strategies, learners who received effective prompts did not perceive the prompted strategies as more helpful than learners in the unprompted control group. Possible explanations included learners' reluctance to invest effort in using the prompts, lack of confidence in the outcome, and the need for informed training to increase learners' awareness of the benefits of these prompted strategies.

Problem-solving and reflection prompts may also influence students' capacity to solve real-world problems within a simulated Web-based learning environment. In a recent study, Kauffman, Ge, Xie, and Chen (2008) found that problem-solving prompts did improve problem solving and writing by clarifying the assignment goals. In particular, they served as "process goals", such as, identifying the problem and justifying the nature of the problem. The result was that students had a clear direction in solving the problem, leading to better self-monitoring on how they approached the problem, i.e., to focus more on "*how* to get to the solution rather than *what* that solution is" (p. 130). On the effect of reflection prompts, the authors indicated that providing students with the opportunity to reflect on their own work was effective only if they had a clear understanding of the problem-solving process, i.e., they needed to "know *what* to reflect on" (p. 131).

Different types of prompts may interact differentially with learner characteristics such as prior knowledge and experience. The effects of question prompts and peer interactions in scaffolding students' problem-solving processes were studied by Ge and Land (2003, 2004). The authors confirmed that question prompts can facilitate ill-structured problem solving through enhanced knowledge representation and directing student attention to key information, especially in justification, monitoring and evaluation aspects which are often overlooked by novice problem solvers. However they also suggested that additional strategies, such as instructor modelling and monitoring, were needed to ensure that learners actively used the prompts to guide their learning.

Using a combination of web-based integration and procedure question prompts, Chen (2010) examined how explicit instruction on the use of prompts differentially affected students' knowledge acquisition and ill-structured problem solving skills, such as representing problems, developing solutions, and monitoring and evaluating a plan of action. The results indicated that "intentional guidance through integration prompts can enhance the construction of a deeper understanding of a subject" (p. 9) as revealed by the students' thorough explanations, descriptions, and clarity of relationships among concepts. Chen further claimed that the use of integration prompts led students to develop cognitive schema that facilitated problem representation but did not help in the development of solutions to the problem. While procedure prompts alone were found to be ineffective in knowledge acquisition and generating solutions, the combination of integration and procedure prompts showed better student performance in both areas of solving the ill-structured problems.

Prompting Peer Interaction

The preceding review shows that carefully designed prompts not only promote task-learning, but work directly to enhance the cognitive and meta-cognitive skills of the learner. Besides individual support, the use of prompts may also influence learning in social contexts. In general, most peer learning situations involve prompts which were specifically designed for use by students to engage their peers in collaborative discourse (e.g., Palincsar & Brown, 1984; Webb & Farivar, 1999; Mercer & Littleton, 2007). The main argument was that learners did not spontaneously engage in productive collaborative activities or assume positive social modes, and consequently failed to achieve the desired learning outcomes (e.g., Brown & Palincsar, 1989; Cohen, 1994; O'Donnell, 1999). In order to support learners in productive collaborative processes, peer learning situations should be structured with learner role-assignment, scripts, and prompts.

Prompts can be incorporated as part of a script which cues or directs learners to adopt different roles during collaborative learning. Roles provide the structure to facilitate collaboration and task completion (Morris, 2008) and can be conceptualised as procedural/functional or cognitive/intellectual (Palincsar & Herrenkohl, 2002). Functional roles are task-oriented, such as note taker, presenter, or editor, while cognitive roles focus on the thinking related to the task and may be classified by type of thinking, processing or cognitive engagement. By assigning roles, learners are provided with a scaffold to work interdependently and responsibly, foster cognitive and collaborative support as well as perceive a sense of security to participate in the learning process. The suggestion was that social or epistemic scripts (Weinberger, Ertl, Fischer, & Mandl, 2005) provide step by step descriptions of how to fulfil a role and that prompts are necessary to guide the actions within that role. A computer-based learning, instructional and research tool, *gStudy* (Winne, Hadwin, & Gress, 2010), was designed to investigate the different ways in which roles, scripts and prompts can support collaborative learning. In *gStudy*, for example, there is an online discussion forum or *gChat,* where students may be assigned a particular role and be provided with access to role-specific prompts. The prompts are designed as quick sentence starters and statements that students can use. A student with a 'clarifier' role is supported by prompts such as "Are there any other interpretations?" "How can we make sense of that?"

From Prompts to Peer Feedback Quality

A common theme in the use of prompts seems to be the need to find the optimal amount of structure for supporting meaningful engagement of the learner in the learning process, while at the same time considering the learner's current level of understanding (e.g., novice and experienced learners), taking care not to impose unnecessary constraints on learners and ultimately, fading out the use of prompts to allow learners to self-regulate their own learning in new contexts. This suggests that prompts may be beneficial as instructional support to guide and scaffold learners in formulating peer feedback that promotes procedural as well as cognitive/meta-cognitive engagement.

In peer feedback research, prompts are commonly used to support the provision of meaningful feedback that results in task completion or follow-up revision activities (Gielen, 2007). The need for students to provide relevant and useful feedback means that prompts are seen as serving a predominantly functional role. In fact, most peer feedback research makes the assumption that prompts act as *criteria* to assess or evaluate the work of a peer as well as elicit comments for further corrective actions. For example, criteria prompts usually take the form of probing questions and may be incorporated into a rubric (Cho & MacArthur, 2010), a step-by-step strategy tool (Van Steendam et al., 2010), or detailed guidance sheet (Min, 2006). Although it is acknowledged that there is a link between prompts and quality of peer feedback, this relationship is more implicit than explicit and few empirical studies have focused on examining this relationship in greater depth. It follows that the questions surrounding the prompting of peer feedback may warrant ongoing scrutiny.

AIM OF PRESENT STUDY

In the literature review (Chapter 2), four assertions were made based on Hattie and Timperley's (2007) feedback model. Three of these assertions related to the quality of peer feedback are investigated here in Study Two.

Assertion 1: *Peer feedback is meaningful when it is integrated into a cycle of learning.*

Assertion 2: *Peer feedback is useful when it provides information to identify where the learner is at, direct attention towards the learning outcome, and indicates how best to achieve this outcome.*

Assertion 3: *Peer feedback is powerful when it cues the attention of the learner to the learning task, task processing strategies, and self-regulation strategies instead of directing attention to the self.*

Assertion 1 suggests that we rethink feedback as a terminal activity, to one where the process can be experienced in terms of an iterative cycle or 'loop' that allows the learner to differentiate within this loop a series of 'steps' or 'phases' as potential opportunities where constructive feedback interaction is possible (Hounsell, McCune, Hounsell, & Litjens, 2008). This feedback cycle opens up opportunity for instructional support that is directed at giving and using peer feedback more effectively to engage the learners with the learning task. In short, it is argued that identifying areas where peer feedback is useful and designing learning tasks with cycles of peer feedback as well as instructional support will enhance the feedback process. It focused the learner on the consequential actions to make peer feedback meaningful.

Assertion 2 proposes the need to identify a learning gap and use peer feedback to close this gap. To support students in formulating peer feedback, question prompts that help learners identify the learning gap, and offer suggestions for improvement are included in feedback forms. There is also an emphasis on the use of criteria in formulating peer feedback, which allows students to see their performance against those learning goals. Assertion 2, like assertion 1, focused the learner on the consequential impact of peer feedback; proposing that besides being recursive, peer feedback needs to be received, interpreted and purposefully used in revision of work done.

The third assertion suggests the use of feedback levels (i.e., in Hattie and Timperley's model) to conceptualise peer feedback as information which engages the learner at different levels of understanding. As explored in study one, the three levels that played a part in coding cognitive function during peer feedback discussion are: task-based, process-based and regulatory-based functions. In study two, these feedback levels are further developed as a coding scheme for written peer feedback statements. Learning using *task level feedback* involves providing information or knowledge about the correctness of one's performance. Learners who engage in *process level feedback* make use of strategies and information search approaches for task processing or completion; while those who engage in s*elf-regulatory feedback* utilise reflective or probing questions to self-evaluate or monitoring the learning progress (see section on Coding written peer feedback). If learners are to become proficient in giving and receiving useful peer feedback, they need to develop the capacity to evaluate quality learning in a given context, and challenge their own and others' understandings by explicitly seeking, interpreting, and applying task level to self-regulatory level feedback. This assertion suggests the active interaction of the learner with peer feedback that focus on cognitive and meta-cognitive engagement.

Drawing on these assertions, the research questions for study two were:

1. *Does the use of prompts in giving/receiving peer feedback improve students' performance in a rate of reaction concept test?*
2. *What are the effects of prompts in giving/receiving peer feedback?*
3. *How does students' written peer feedback differ in relation to task, process, self-regulation, and self levels?*
4. *Does prompted peer feedback help students to revise their lab reports?*

METHODOLOGY

Setting and Participants

A total of 15 schools, with classes offering the New Zealand NCEA chemistry curriculum were invited to take part in this study and three schools responded. Six classes of Year 12 chemistry students (16–17 year olds) from three New Zealand urban secondary schools agreed to participate in this study (n = 121; 75 females and 46 males). The criteria for selecting schools include having Year 12 chemistry classes, availability of laboratory resources, and that the students had already been taught the topic on 'rate of reaction' in the same year of the study. All the participants had completed the topic on 'rate of reaction' and had experience with practical work involving planning and implementing experiments.

Experimental Design

The study adopted a quasi-experimental pre-test→treatment→post-test design. There were two treatment conditions: peer feedback with prompts, and peer feedback without prompts. The six classes were randomly assigned to one of the two conditions, with four classes in the peer feedback prompt condition, and two classes without prompting. A constraint for not having equal number of control classes was that the participating schools preferred to have more classes exposed to a 'new' or different learning approach rather than the traditional approach. The class teacher for each class assisted with obtaining the practical materials and conducting the investigative task, while the researcher acted as observer. Each class was allocated four lessons to carry out the research study. Students worked individually on their investigations but provided reciprocal written feedback to an assigned partner on their report in two feedback-revision cycles (Figure 5). The pairing of students was carried out by the class teacher, who allocated the partnership based on high and low ability pairing using previous test scores as well as observations of prior encounters of the students' group work in the laboratory.

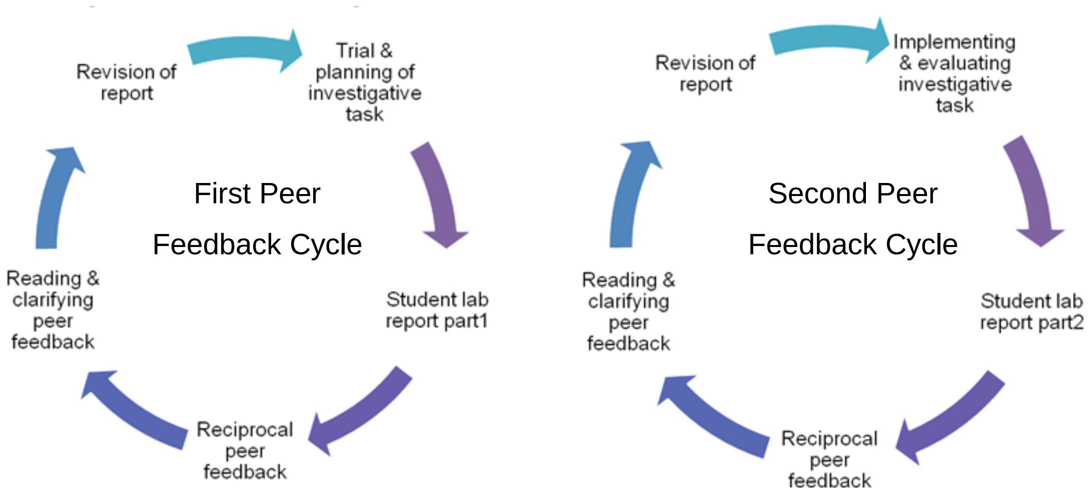

Figure 5. Research design involving two feedback cycles

The Learning Content

Students' ideas on rate of reaction

The topic of interest in this study is on rate of reactions. Chemical kinetics is a fundamental topic in almost every secondary school chemistry syllabus because of its importance in the understanding of basic concepts in chemical reaction processes. Students (14–16 years old) are usually introduced to the basic concepts of reaction rate by a descriptive account of how the rate changes as a reaction progresses. Most textbooks include graphical representation to illustrate how a measured quantity, usually the concentration of a reactant/product, changes over time. The colliding particle model is the predominant model used to explain how changes in factors such as temperature, concentration, or catalyst will affect how fast or slow a reaction is going to progress (Justi, 2002).

Students often have misunderstandings about how chemical reactions are explained at the molecular level. For example, they tend to maintain a view of how reaction occurs at the particulate level that is more towards their everyday life experiences rather than based on a scientific model of explanation (Cachapuz & Maskill, 1987; Garnett, Garnett, & Hackling, 1995). Cakmakci, Donnelly, and Leach (2005, 2006) studied the written response of students, from secondary to university level, using diagnostic questions designed to assess their understanding of relationships between the concentrations of reactants/products and reaction rate. The researchers found that many students used conceptions not consistent with scientific perspectives, and had conceptual difficulties in understanding the relationship between concentration and reaction rate. Students also had difficulties in 'making transformations within and across different modelling/representational forms. For example, many undergraduates were able to provide an explanation for the phenomenon using the particulate model, but they had difficulties in representing that knowledge symbolically or mathematically. To address these aforementioned concerns, teachers need to be aware that chemical kinetics is composed of two distinct but complementary lines of development: the "empirical" and the "theoretical" (Logan, 1984) and can be explained in terms of particulate modelling as well as represented/quantified by mathematical modelling. This implies that instructional approaches must take into consideration students' conceptualisation of the interrelationship between the observed phenomenon and the different models used to explain and represent that phenomenon.

Practical work consisting of rate of reaction experiments is also prevalent in most New Zealand secondary chemistry curricula and tends to involve students in manipulating variables and observing and measuring the changes in reaction rate. In most instances, the main aim of the activity is to "re-confirm" the concepts taught during class hours, often with little chance for students to engage in discussion about the link between empirical evidence and theoretical models. In order to move away from this, the learning task in this study was chosen to provide more opportunities for collaborative learning and discourse.

The learning task for this study involved students planning, implementing, and writing a report of a semi-open investigation on the rate of a reaction. This investigative task was designed based on the NCEA Level 1 chemistry unit standard 'Investigate factors that affect the rate of a chemical reaction'. This topic was taught by the respective class teacher prior to the research study being carried out. As there was a constraint on the time allowed for implementing the study during regular class time, a semi-open investigation was designed with guiding background information and generic criteria for performing each section of the task.

Procedures

Prior to the intervention, students in both prompted and unprompted conditions were administered the concept test and perception questionnaire. The intervention consisted of two peer feedback cycles: the first cycle involved experimental trial and drafting a plan, followed by peer feedback and revision of the report. The second cycle began when students used their revised plan to conduct their experiments, collect and analyse their data, and write a full laboratory report. This was followed by another round of peer feedback and revision (see Table 18). Students then took the concept test and perception questionnaire as post-test.

Table 18. Lesson schedule with activities

Lessons	Description of activities
1	• Pre-test, student questionnaire, selected dyad interviews. • Introduction to peer feedback form and etiquette.
2	• Students carried out planning stage of investigative task. • Students carried out a trial and write their plans. • First round of peer feedback. • Revision of plan, followed by conducting the planned experiment.
3	• Students analyse their data and write their report. • Second round of peer feedback. • Revision of final report.
4	• Post-test, student questionnaire, selected dyad interviews.

Measures

The data sources for this study include students' laboratory reports, their written feedback to peers, their pre/post concept tests, pre/post perception questionnaire and selected interviews. The outcome measures from these data sources are summarised in Table 19 and discussed in the following sections.

Table 19. Outcome measures summary

Outcome Measures	Instrument	Description
Concept test scores	Pre/post concept test	Measures students' conceptual understanding on factors affecting rate of reaction.
Students' laboratory report scores	Laboratory report on investigative task	Measures how well students report on their investigative task. For each feedback cycle, there is a draft score and a revised report score.
Concepts of evidence score	Peer feedback form	Measures the use of concepts of evidence in writing peer feedback.
Frequency counts of written peer feedback statements	Peer feedback form	• Measures the type of peer feedback statements (coding categories: knowledge of correct response, knowledge of errors, suggestions for improvement). • Measures the use of task, process, self-regulation and self levels in writing peer feedback.
Uptake of suggestions	Laboratory report and Peer feedback form	Measures the use of peer suggestions for revision of laboratory report.
Student perceptions on peer feedback importance and effectiveness	Pre/post student perception questionnaire	Describes how important and effective students perceive the feedback they received from their peers.
Student perceptions of usefulness of peer feedback and prompts	Structured interview questions	Describes students' view on the usefulness of peer feedback and the question prompts in the feedback form.

Concept test

A pre-post concept test was designed based on the NZ Year 12 curriculum on the topic of rate of a chemical reaction. Students answered six structured questions that required them to provide explanations and justification using their conceptual understanding on factors affecting rate of reaction. This test measures students understanding of rate of reaction concepts (See Appendix 1 and 7).

Laboratory report

Students were required to write an individual report on the investigative task, using the task booklet provided. The booklet consists of two sections, a) experimental trial and planning and b) implementation, results and evaluation (See Appendix 2). For each section, students wrote a draft and then revised this draft based on the peer feedback received. The revisions were carried out using a different coloured pen, to allow the researcher to identify and take note of the uptake of peer feedback suggestions.

Coding students' use of concepts of evidence in peer feedback

The content of feedback was examined by using a rubric to score the written feedback statements on five categories—use of variable structure, fair-testing, choosing values, patterns and relationship in data, and reliability and validity of data/design (based on Gott & Roberts, 2008). The rubric is shown in Table 20.

Table 20. Scoring rubric for the use of 'Concepts of Evidence' in peer feedback content

'Concepts of Evidence' in feedback	Description	0	1	2
Variable structure	Identifying and understanding the basic structure of an investigation in terms of variables and their types.	No or erroneous use.	State criteria on variables.	Elaborate on independent and dependent variables.
'Fair testing'	'Fair tests' aim to isolate the effect of the independent variable on the dependent variable. By changing the independent variable and keeping all the control variables constant, validity is ensured.	No or erroneous use.	State criteria on fair testing.	Elaborate on manipulating variables.
Choosing values	Making informed choices about sample, relative scale, range, interval and number of readings.	No or erroneous use.	State the criteria on values.	Elaborate on choice of values.
Patterns and relationship in data	Patterns represent the behaviour of variables so that they cannot be treated in isolation from the physical system that they represent. In this investigation, the relationship between temperature and initial rate of this reaction is linear/proportional and the pattern of association is seen as causal.	No or erroneous use.	State the relationship between variables.	Elaborate on types of relationship between variables and patterns in data.
Reliability and validity of data/design	Evaluating the whole investigation by considering the design of the investigation, ideas associated with measurement, with the presentation of the data and with the interpretation of patterns and relationships, in relation to reliability and validity of data.	No or erroneous use.	Cursory mention on reliability and validity.	Elaborate on aspects of reliability and validity.

Peer feedback form with question prompts

The feedback form, designed by the researcher, consisted of two parts—Cycle 1: Trial and Planning, and Cycle 2: Implementing and Evaluating, each with three sections (see Appendix 3). For each section, three question prompts (adapted from Gielen, 2007) were designed to elicit written feedback from the students. The prompts were:

- What did he/she do well? Give explanations to support your feedback.
- What didn't he/she do well? Give explanations to support your feedback.
- How can he/she improve on the current piece of work? Give explanations to support your feedback.

Coding written peer feedback

The written peer feedback was coded on the types of feedback—knowledge of correct response, knowledge of errors and suggestions for improvement, and the levels of feedback. The coding scheme for the types of feedback (see Table 21) was developed based on feedback research which identified these three common types of feedback in the classroom (Mory, 2004; Narciss, 2008).

Table 21. Coding scheme on peer feedback types

Main category	Definition	Example
Knowledge of correct response	Provides correct answers or results.	He wrote the prediction accurately and provided a reason for the prediction.
Knowledge of errors	Indicates incomplete, incorrect or missing responses.	She did not include the equipment needed for this experiment in the step-by-step methods.
Suggestions for improvement	Provides solution, strategies and corrective approaches.	He could have described the steps accurately to ensure a fair test so that another person could follow the steps to repeat the experiment.

The coding scheme for feedback levels was developed from Hattie and Timperley's (2007) feedback model (as shown in Table 22).

Table 22. Coding scheme on peer feedback levels

Main category	Definition	Example
Task-level (TL)	Provides information about the correctness of the learner's responses. Also informs the learner of the correct answer, but without suggesting how to revise the response. May provide indication of error/incorrect response or location of mistakes.	"She explained the limitations well but didn't really say why it was reliable and didn't refer to the data in drawing conclusions." "He wrote the predictions accurately but didn't give a reason for his prediction, which could have increased the quality of his answer."
Process-level (PL)	Provides strategies/cues/hints/examples for error detection, information search or steps to revise report. May suggest explanation or justification for correct/incorrect response and reason for the use of a particular search strategy or revision approach.	"He has clearly showed the controlled variables. He should emphasise on fair testing in the method by highlighting the use of controlled variables." "She carried out the experiment well but could've given a better evaluation on results by explaining why these results have occurred, e.g., explain why the results are not accurate."
Self-regulation level (SL)	Provides reflective or probing questions that guide the learner in self-evaluation, seeking additional information, or monitoring of learning progress.	"What would happen if you changed the gap between temperatures by a larger amount?" "Why do you think this outcome (prediction) will occur?"
Praise (P)	Remarks that are directed to the 'self' mainly to give encouragement or affirmation and contains little or no task-related information.	"You are doing great!" "Well done!" "Carried out the experiment well."
Others (OT)	Comments that are ambiguous or unrelated to the task.	"He didn't finish because he was absent." "Improve on spelling."

Student questionnaire

A student questionnaire was developed by the researcher and given to participants before and after the study (see Appendix 4). This questionnaire asked the participants to rate the perceived importance of giving/receiving peer feedback and the perceived effectiveness of peer feedback during the practical/investigation on a Likert scale with scores ranging from 1 to 5 (1 = not important/effective; 5 = extremely important/effective). Table 23 shows the items categorised based on three common characteristics of feedback identified from the feedback research literature (Narciss, 2008).

Table 23. Peer feedback questionnaire items

Categories	Items
	Feedback Content
Q1	Directs you towards specific mistakes.
Q2	Indicates the quality of your work.
Q3	Suggests how to improve your work.
Q4	Success criteria to help you think deeper about the feedback content.
Q5	Clarifies your doubts about the task.
Q6	Clarifies your doubts about your understanding of concepts.
Q7	Clarifies your doubts about your understanding of procedures.
Q8	Helps you to correct your mistakes.
	Feedback Functions
Q9	Helps you to elaborate on your ideas.
Q10	Provides explanations on how to improve your work.
Q11	Provides justifications on how to improve your work.
Q12	Helps you to learn concepts better.
Q13	Helps you to learn practical procedures better.
Q14	Helps you to revise your work.
Q15	Helps you to monitor your thinking about your strategies (e.g., problem-solving) and actions during the task.
Q16	Meets your learning goals.
Q17	Motivates you to learn better.
Q18	Recognises your effort in the work done.
	Presentation of Feedback Contents
Q19	Is timely.
Q20	Guiding questions help you formulate peer feedback.
Q21	Guiding questions help you think deeper about the feedback content.
Q22	Peer discussions help you understand the received peer feedback.
Q23	Peer discussions on the feedback help you to elaborate and extend your ideas, concepts or knowledge about the topic.
Q24	Reflection on the received peer feedback helps you improve your work.
Q25	Guiding questions help you to reflect on the received peer feedback.

Structured interviews

Three selected student pairs from each class were interviewed before and after the study to identify their understanding of peer feedback and to find out their perception of the usefulness of peer feedback and the question prompts. A set of interview questions was used for both pre- and post-intervention interviews (see Appendix 5).

Data Analysis

Analysis of the quality of peer feedback statements

The quality of peer feedback was first analysed based on the frequency of statements related to suggestions for improvement and students' uptake of suggestions to revise their report. Another indication of feedback quality was the analysis of students' use of concepts of evidence in formulating peer feedback.

Analysis of effects of prompts on peer feedback and test performance

A multivariate ANOVA technique was used to investigate the impact of prompts on the quality of feedback, uptake of feedback for revision, and test performance on the six intervention classes. Effect size measures were based on Cohen's *d* and calculated using the following formula:

$$\text{Effect size} = [\text{Mean}_{\text{end of treatment}} - \text{Mean}_{\text{beginning of treatment}}] / \text{SD}_{\text{pooled}}$$

Analysis of student perception questionnaire

A combination of exploratory and confirmatory procedures was used to study the pre- and post-student questionnaire to identify dimensions that students perceived to be related to peer feedback importance and effectiveness. The exploratory factor analysis of the student questionnaire was performed using maximum likelihood extraction and oblique rotation. Confirmation of the exploratory model for the constructs was carried out in AMOS.

Analysis of students' comments on giving and receiving peer feedback

The student interviews were transcribed and analysed to identify what students perceive as useful in peer feedback and how useful were the question prompts in the feedback form.

RESULTS AND DISCUSSION

Test Performance and Laboratory Report Writing

Does the use of prompts in giving/receiving peer feedback improve students' performance in rate of reaction concept test?

The overall test reliability has a Cronbach's alpha of .70 for the six items. In both prompted and unprompted conditions, students performed better in the post-test than in the pre-test (Table 24).

Table 24. Mean and standard deviation for pre-post concept test by conditions

Concept Test	Treatment Classes (N = 77)		Control Class (N = 44)	
	M	*SD*	*M*	*SD*
Pre-test	10.73	5.89	8.95	4.97
Post-test	11.96	5.59	11.15	3.96

Further analysis of the individual classes indicated that there were class differences (Table 25). In the prompted condition, students in class 1, 3 and 6 benefited from the use of prompts as indicated by the moderate effect size (Cohen's *d*) of their test scores, while students in class 4 seemed to have a small increase in performance after using prompted peer feedback. In the unprompted condition, students in Class 5 appeared to show a large improvement in performance compared to the other classes.

Table 25. Mean and standard deviation for pre-post concept test by classes

Classes	Pre-test		Post-test		Effect Size
	M	*SD*	*M*	*SD*	*ES*
			Prompted		
1	6.18	5.02	8.55	4.37	0.50
3	13.27	4.23	14.88	3.67	0.41
4	4.43	4.15	4.50	3.03	0.02
6	14.53	3.70	15.42	2.91	0.27
			Unprompted		
2	10.48	5.07	10.74	4.26	0.06
5	6.75	4.03	11.75	3.53	1.32

While this result indicated that prompting alone may not be responsible for the effect on performance, it does suggest that the presence of peer feedback has a positive effect on the students' performance on the concept test. This could be attributed to the fact that students in both conditions have the opportunity to engage in providing peer feedback, as well as interpreting and using the feedback for revision. This finding is in accordance with other research studies on the positive impact of peer feedback on performance in learning tasks (Falchikov, 2005; Gielen et al., 2010; Topping, 1998).

To further investigate the effects of prompts on performance, data on students' laboratory report writing were analysed (Table 26). The results from the analysis of the lab report for the two peer feedback cycles indicated that both experimental and control classes improved on their laboratory reports after receiving peer feedback. Again, the positive influence of peer feedback is evident here. In addition, the inclusion of two feedback cycles may also have contributed to a greater opportunity for students to work on their understanding of the concepts, to clarify their doubts and to interact with the peer feedback in relation to the learning task.

Table 26. Test scores of students' lab report from peer feedback Cycles 1 and 2

Class	N	Draft 1		Revised 1		PF Cycle 1	Draft 2		Revised 2		PF Cycle 2
		M	*SD*	*M*	*SD*	ES	*M*	*SD*	*M*	*SD*	ES
Prompted											
1	14	6.00	1.710	6.57	1.651	0.34	6.14	1.791	6.71	2.199	0.29
3	26	4.46	0.859	6.12	1.107	1.68	6.08	1.809	6.62	2.021	0.28
4	15	3.93	0.704	4.47	1.060	0.60	4.80	1.859	5.13	2.066	0.17
6	22	6.05	1.290	7.77	1.771	1.13	7.55	2.425	8.86	2.867	0.50
Unprompted											
2	23	4.09	0.900	4.43	1.080	0.35	4.57	1.619	4.65	1.668	0.05
5	21	4.81	1.436	5.38	1.396	0.40	5.05	1.802	5.43	2.039	0.20

Although the above findings revealed that prompts alone did not improve the performance on the learning task, the moderate to large effect sizes for students in the prompted condition suggests that the effects of prompts may be mediated by the quality of written peer feedback, i.e., the consequential impact of peer feedback and its cognitive/ meta-cognitive engagement with the learner.

Consequential influences

What are the effects of prompts in giving/receiving peer feedback?

The content of peer feedback statements in both prompted and unprompted conditions were analysed by using the concept of evidence rubric (Table 27). The findings indicated that students in all the classes included concepts of evidence in their feedback to their peers. It appears that students who were more familiar with concepts of evidence would use these ideas in written peer feedback.

Table 27. Mean and standard deviation for each class on the use of concepts of evidence

		Variable structure		Fair Test		Choosing values		Patterns		Reliability	
Classes	N	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
						Prompted					
1	14	.50	.519	.71	.825	.14	.363	.29	.469	.43	.646
3	26	.54	.706	.85	.732	.31	.549	.69	.471	.69	.471
4	15	.07	.258	.13	.352	.00	.000	.07	.258	.00	.000
6	22	.64	.658	1.09	.610	.32	.646	.59	.590	.82	.733
						Unprompted					
2	23	.57	.507	.57	.507	.22	.422	1.00	.426	.61	.583
5	21	.14	.359	.62	.740	.10	.301	.43	.507	.29	.463

The presence of concepts of evidence ideas in the peer feedback exchange may have helped students in both conditions to improve on their draft reports as indicated in table 26. It also means that prior knowledge involving concepts of evidence is a necessary pre-requisite for carrying out the investigative task, formulating useful peer feedback and writing a full lab report. This is evident in the case of students in class 4, whose poor performance in the concept test and report writing can be attributed to the low level of knowledge of concepts of evidence demonstrated.

When comparing the types of peer feedback, students in the prompted classes were able to formulate more peer feedback that focused on knowledge of errors (M = 3.19, SD = 1.76) and suggestions for improvement (M = 3.27, SD = 2.09) (Table 28). This probably resulted in greater uptake of suggestions (M = 1.35, SD = 1.40) by these students. In contrast, students using a generic feedback form without prompts only managed to formulate about one feedback statement for each type of feedback and hardly any suggestions were used by the students to revise their work (*M* = 0.20, *SD* = 0.59). Students in prompted conditions also gave more peer feedback at the task and process levels to their peers compared to students in the unprompted condition. Overall, the prompted condition resulted in more peer feedback than the unprompted condition.

Table 28. Mean and standard deviation for peer feedback types and levels in prompted and unprompted classes

	Treatment classes (N = 77)		Control class (N = 44)		Effect Size
	M	*SD*	*M*	*SD*	*ES*
Knowledge of correct response	5.14	2.91	5.59	3.54	-0.14
Knowledge of errors	3.19	1.76	1.95	1.77	0.70
Suggestions for improvement	3.27	2.09	1.07	1.52	1.22
Uptake of suggestions	1.35	1.40	0.20	0.59	1.15
Total task level feedback	9.27	5.12	7.32	3.95	0.43
Total process level feedback	1.29	1.61	0.34	0.61	0.85
Total self-regulatory level feedback	0.06	0.25	0.02	0.15	0.21
Total praise	0.45	0.77	0.84	1.38	-0.36
Total 'others'	0.53	1.24	0.09	0.29	0.58
Total peer feedback	11.61	5.89	8.61	4.32	0.59

What the findings suggest is that prompts provided a structured approach to formulate peer feedback that focus on error detection and explicit suggestions for improvement. This finding is in line with other research on the use of prompts, which highlighted the need for scaffolding in productive peer feedback process (Cho & MacArthur, 2010; Gielen, 2007; Min, 2006).

To compare the peer feedback types and feedback levels with the experimental conditions, a MANOVA was conducted. The results revealed a main effect for the use of prompts on formulating different types and levels of feedback, Wilks' Lambda = 0.598, F (1, 112) = 9.427, $p < .001$. Further analysis, using univariate ANOVA, showed that there are significant differences between the two conditions in knowledge of errors, suggestions for improvement, uptake of suggestions, task level and process level feedback (Table 29).

Table 29. Comparison of prompts on feedback types and levels

Effect	*F*	*df*	*Error df*	*p*
Knowledge of correct response	0.57	1	112	0.453
Knowledge of errors	13.85	1	112	0.001
Suggestions for improvement	37.48	1	112	0.001
Uptake of suggestions	26.58	1	112	0.001
Task level feedback	4.77	1	112	0.031
Process level feedback	14.06	1	112	0.001
Self-regulation level feedback	1.05	1	112	0.308
Praise	3.92	1	112	0.050

Does prompted peer feedback help students to revise their lab reports?

The results indicated that prompts had a significant effect on students formulating peer feedback with suggestions for improvement, $F(1, 112) = 37.48$, $p < .001$, and subsequent uptake of these suggestions for revision of the lab reports, $F(1, 112) = 26.58$, $p < .001$. The feedback information was also richer in 'knowledge of errors', which further helped in identifying where and what to improve on, $F(1, 112) = 13.85$, $p < .001$ (Table 29).

How does students' written peer feedback differ in relation to task, process, self-regulation, and self levels?

The use of prompts had a significant effect on students' provision of process level feedback for their peers. This impact was not evident in task level feedback, even though students predominantly gave this type of feedback to their peers (Table 30). It seems that for students to formulate feedback at process and self-regulation levels, further instructional support may be necessary.

Table 30. Mean and standard deviation for each class on peer feedback levels (task, process, self-regulation, and praise)

Classes	Task level feedback		Process level feedback		Self-regulation level feedback		Praise		Others	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Prompted										
1	5.93	4.25	1.21	2.05	0.14	0.36	0.07	0.27	0.00	0.00
3	11.00	4.92	1.54	1.17	0.08	0.27	0.54	0.86	0.69	1.74
4	5.93	3.94	0.00	0.00	0.00	0.00	0.47	0.52	1.27	1.22
6	11.64	4.45	1.91	1.85	0.05	0.21	0.59	0.96	0.18	0.50
Unprompted										
2	7.65	3.88	0.39	0.66	0.04	0.21	0.61	0.99	0.09	0.29
5	6.95	4.09	0.29	0.56	0.00	0.00	1.10	1.70	0.10	0.30

Student Perceptions on Peer Feedback (Interviews)

Students were interviewed about their opinions on the use of the peer feedback form, as well as giving and receiving peer feedback. Most students agreed that the criteria and question prompts in the peer feedback forms helped them to evaluate their peer's work and focused attention on what to give feedback on. Some examples of student comments follow:

> I think it was useful because it had the structure already given to you, which kind of makes it easier to focus on specific areas rather than getting confused by talking about the whole thing.

> I thought it was really good as I now could see what I have done wrong and the things that I missed out by mistake; then, I could like go back and improve on it. The example given by my friend in the suggestion part is really useful.

> I think it is good because she doesn't just tell me what to write but she has given me feedback on what I haven't done and how is it I could improve on and let me work it out myself. It's a real help otherwise I guess you are not really learning.

> The guiding questions are useful as they start you thinking with the headings and allow you to elaborate further on it.

> It's quite time-consuming but then, in the end, it can pay-off; like it's easier to go in-depth using the form because it asks you so much more questions and keeps developing your ideas while you are giving feedback.

The main concern students had about using the peer feedback form was their lack of content knowledge in providing accurate and detailed feedback to their friends. The students' comments further confirm the earlier findings on the need for acquiring the content knowledge related to the learning task before being able to give peer feedback confidently and meaningfully. Examples of students' comments are as follows:

> It can be difficult to point out things that we are doing wrong as we are still learning together.

> Sometimes, you are not sure of what to write as you do not have the knowledge as compared to the teacher.

Students' comments on giving and receiving peer feedback revealed that they were open to feedback from their peers, held dichotomous views of peer feedback (i.e., positive or negative peer feedback perspective), and were sensitive to the interpersonal dimensions of how they gave or received peer feedback. Most of the students interviewed found peer feedback relevant and useful as a learning resource for making comparisons, drawing attention to important aspects of their work which were previously ignored, highlighting errors, providing alternative perspectives or strategies, and filling in the gaps in terms of their own content knowledge related to the task. In this respect, most students viewed peer feedback as information provided by someone of equal status and they facilitated task completion. Some examples of students' comments were as follows:

> Peer feedback is about coming up with ideas together, picking out weaknesses and gaining support from your friends. When you make a mistake, they can help to correct you. You get to exchange ideas with your friends as they are easier to talk to, whereas with the teacher, you feel more pressured.

> Peer feedback is basically constructive criticism from people your own age...someone your own age telling you and evaluating you on how you did something and how you can improve.

> Basically, peer feedback is having someone who is at the same learning level as you, evaluating your work and has to be constructive, otherwise it's not really feedback but criticism. So it's like something that you can work on, to improve your work.

> Often by looking at other people's work, you realise things that you could improve on.

Some of the students' responses indicated that peer feedback was useful as it provided an alternative source of explanation, relative to the teacher's comments. However, feedback as explanations was uncommon unless actively sought after through conscious help-seeking efforts. In most cases, students claimed that they would turn to their teacher first for explanations when in doubt and cited the reason that the teacher was the authority figure in terms of knowledge and ability to provide clear explanations. Indeed, most students held the dual view that teacher feedback was more reliable and credible compared to peer feedback, as the latter was usually seen as deficient in terms of experience in judging work done, identifying problem areas, and offering accurate, sound, and in-depth advice. Some examples of students' comments follow:

> I think for me I trust teacher feedback more than student feedback; because for students, sometimes, they can only explain it the way they understood but teachers can explain it in different ways.

> I think the main problem with peer feedback is that my friend could tell me what to do but there is always that kind of little doubt in the back of your head, like we are both at the same level and none of us is more advanced than the other.

At times, students found peer feedback useful as it motivated them by increasing their confidence in their work by being able to give feedback to their peers. For example, a student commented:

> Sometimes you feel more confident to work with your friends. If you can give feedback, it means you are growing in your own chemistry knowledge, you are also acknowledging that you friends have grown in theirs and this helps to boost your confidence as well as that of your friends.

While students appreciated the help received from their peers, this peer support process was perceived as occurring informally and as a 'just-in-time' measure of getting help when uncertainty surfaced. Students' interviewed further suggested that peer feedback was differentially received and interpreted, depending on how they perceived the source of information, and the level of mitigation involved. In fact, students interviewed were clear about what they looked for in terms of peer feedback and were aware of the effects of mitigation by their peers. Examples of students' comments were:

> I prefer peer feedback to be constructive rather than just praise alone. Sometimes, in order not to hurt my feelings, they will not be too critical in their feedback.

> Friends will usually be kind to you while the teacher will be more critical in giving feedback.

> Sometimes it is difficult to tell your friend that she is doing something wrong, in the first place, because you feel bad about it when you see that they are working hard and they think they are doing it right.

> I think, with peer feedback, it's not the person who is doing it wrong which has the issue; it's like the person who is giving it. They don't like their friends to think badly of them...to be offended by their remarks.

Although students recognised the impact of interpersonal nature on how they received and interpreted peer feedback, the common approach adopted was to selectively accept, reject, or ignore the peer feedback provided instead of asking for further clarification. Thus, the opportunities for engaging in a productive peer feedback discourse were undermined, and in most cases, mitigated feedback could lead to miscommunication as the student failed to understand or partly understood the intended feedback message (Hyland & Hyland, 2006).

Student Perceptions on Peer Feedback (Questionnaire)

Exploratory factor analysis of pre-test on 'importance'

The 25 items from the pre-test student perception questionnaire on the 'Importance' of peer feedback were subjected to maximum likelihood factor analysis, with an oblimin rotation. It was possible to identify three interpretable factors, explaining 51.4% of the total variance. The pattern matrix for these three factors is shown in Table 31. Factor One on 'Function' (eigenvalue = 8.88) of peer feedback accounts for 35.5% of the common variance; Factor Two on 'Content' (eigenvalue = 2.22) of peer feedback accounts for 8.9% of the shared variance; and Factor Three on 'Presentation' (eigenvalue = 1.74) of peer feedback accounts for 7.0% of the common shared variance. The goodness of fit statistic χ^2 (288) = 307.36, $p < .01$, indicates good specification of the three factor model. Items were assigned to factors based on their highest loading (in most cases > .30).

Five items did not appear to load on the factors as proposed. On further inspection of the cross-loadings, item 12 has a factor loading of .391, which may load on Factor One instead of Factor Two. Although, the other four items have poorer loadings, they were not discarded due to their contribution to overall high reliability of the factors. The post-test factor loadings showed that most items loaded well, and only items 17 and 24 did not load for that factor. In the case of item 17, the factor loading of .216 means that it could load on Factor One instead of Factor Two.

Table 31. Factor loading on student perception on importance of peer feedback (pre-test)

		Factor		
Student perception of peer feedback items (pre-test on importance)	No	1 Function	2 Content	3 Presentation
How important is it that peer feedback provides explanations on how to improve your work?	10	**.833**	-.096	.273
How important is it that peer feedback helps you to revise your work?	14	**.692**	.143	-.065
How important is it that peer feedback provides justifications on how to improve your work?	11	**.679**	-.237	.132
How important is it that peer feedback helps you to elaborate on your ideas?	9	**.591**	-.094	-.052
How important is it that peer feedback suggests how to improve your work?	3	**.567**	-.209	-.044

Student perception of peer feedback items (pre-test on importance)	No	Factor 1 Function	2 Content	3 Presentation
How important is it that peer feedback recognises your effort in the work done?	18	**.545**	.123	-.143
How important is it that peer feedback meets your learning goals?	16	**.535**	-.020	-.221
How important is it that peer feedback helps you to monitor your thinking about your strategies (e.g., problem-solving) and actions during the task?	15	**.474**	-.005	-.302
How important is it that peer feedback indicates the quality of your work?	2	**.409**	-.107	-.072
How important is it that peer feedback motivates you to learn better?	17	**.390**	-.182	-.290
How important is it that peer feedback helps you to learn practical procedures better?	13	**.365**	-.202	-.223
How important is it that peer feedback is timely?	19	**.275**	.116	-.275
How important are success criteria (learning objectives) to help you think deeper about the feedback content?	4	**.244**	.125	-.177
How important is it that peer feedback clarifies your doubts about your understanding of concepts?	6	-.053	**-.807**	-.065
How important is it that peer feedback clarifies your doubts about the task?	5	-.029	**-.688**	-.108
How important is it that peer feedback clarifies your doubts about your understanding of procedures?	7	.178	**-.687**	-.053
How important is it that peer feedback helps you to learn concepts better?	12	.391	**-.445**	-.102
How important is it that peer feedback helps you to correct your mistakes?	8	.404	**-.416**	.023
How important is it that peer feedback directs you towards specific mistakes?	1	.299	**-.383**	-.117
How important are guiding questions to help you formulate peer feedback?	20	-.150	-.215	**-.757**
How important are guiding questions to help you think deeper about the feedback content?	21	-.002	-.044	**-.730**
How important are guiding questions to help you reflect on the received peer feedback?	25	.010	.093	**-.704**
How important are peer discussions to help you understand the received peer feedback?	22	.051	-.158	**-.623**
How important are peer discussions on the feedback to elaborate and extend your ideas, concepts or knowledge about the topic?	23	.152	-.051	**-.596**
How important is reflection on the received peer feedback to help you improve your work?	24	.254	-.077	**-.398**
Factor correlations				
1		-	-.365	-.509
2			-	.212
3				-

Exploratory factor analysis of post-test on 'importance'

The 25 items of the post-test student perception questionnaire on 'Importance' of peer feedback were subjected to a maximum likelihood factor analysis, with an oblimin rotation. It was possible to identify three interpretable factors, explaining 50.7% of the total variance. The pattern matrix for these three factors is shown in Table 32. Factor One on 'Function' (eigenvalue = 9.21) of peer feedback accounts for 36.8% of the common variance; Factor Two on 'Content' (eigenvalue = 1.92) of peer feedback accounts for 7.7% of the shared variance; and Factor Three on 'Presentation' (eigenvalue = 1.55) of peer feedback accounts for 6.2% of the common shared variance. The goodness of fit statistic, χ^2 (288) = 342.62, $p < .01$, indicates good specification of the three factor model.

Table 32. Factor loading on student perception on importance of peer feedback (post-test)

		Factor		
Student perception of peer feedback items (post-test on importance)	No	1 Function	2 Content	3 Presentation
How important is it that peer feedback meets your learning goals?	16	**.906**	-.109	-.051
How important is it that peer feedback helps you to learn concepts better?	12	**.699**	.182	-.168
How important is it that peer feedback helps you to monitor your thinking about your strategies (e.g., problem-solving) and actions during the task?	15	**.666**	.022	.093
How important is reflection on the received peer feedback to help you improve your work?	24	**.644**	-.094	.137
How important is it that peer feedback helps you to revise your work?	14	**.614**	.083	.043
How important is it that peer feedback provides explanations on how to improve your work?	10	**.477**	.202	.165
How important is it that peer feedback provides justifications on how to improve your work?	11	**.410**	.161	.243
How important is it that peer feedback helps you to elaborate on your ideas?	9	**.404**	.109	.201
How important is it that peer feedback helps you to learn practical procedures better?	13	**.368**	.360	-.130
How important is it that peer feedback clarifies your doubts about the task?	5	-.065	**.686**	-.025
How important is it that peer feedback directs you towards specific mistakes?	1	-.005	**.675**	.197
How important is it that peer feedback clarifies your doubts about your understanding of concepts?	6	-.002	**.655**	.013

Student perception of peer feedback items (post-test on importance)	No	Factor 1 Function	Factor 2 Content	Factor 3 Presentation
How important is it that peer feedback helps you to correct your mistakes?	8	.041	**.614**	-.111
How important is it that peer feedback clarifies your doubts about your understanding of procedures?	7	.131	**.609**	-.153
How important is it that peer feedback indicates the quality of your work?	2	-.022	**.539**	.173
How important are success criteria (learning objectives) to help you think deeper about the feedback content?	4	.000	**.444**	.220
How important is it that peer feedback suggests how to improve your work?	3	.116	**.439**	.232
How important is it that peer feedback motivates you to learn better?	17	.216	**.272**	.243
How important are guiding questions to help you formulate peer feedback?	20	-.097	-.002	**.739**
How important are guiding questions to help you think deeper about the feedback content?	21	.174	-.027	**.542**
How important is it that peer feedback recognises your effort in the work done?	18	.228	.018	**.502**
How important are peer discussions to help you understand the received peer feedback?	22	.313	.076	**.474**
How important are peer discussions on the feedback to elaborate and extend your ideas, concepts or knowledge about the topic?	23	.399	.051	**.449**
How important is it that peer feedback is timely?	19	.020	.246	**.433**
How important are guiding questions to help you reflect on the received peer feedback?	25	.145	.179	**.324**
Factor correlations				
1		-	.569	.472
2			-	.379
3				-

Exploratory factor analysis of pre-test on 'effectiveness'

The 25 items of the pre-test student perception questionnaire on 'Effectiveness' of peer feedback were subjected to maximum likelihood factor analysis, with oblimin rotation. It was possible to identify three interpretable factors, explaining 53.0% of the total variance. The pattern matrix for these three factors is shown in Table 33. Factor One on 'Presentation' (eigenvalue = 10.00) of peer feedback accounts for 35.5% of the common variance; Factor Two on 'Content' (eigenvalue = 1.69) of peer feedback accounts for 6.8% of the shared variance; and Factor Three on 'Function' (eigenvalue = 1.54) of peer feedback accounts for 6.2% of the common shared variance. The goodness of fit statistic $\chi^2(288) = 318.32,\ p < .01$, indicates good specification of the three factor model.

Although the factor analysis came up with the three factors that were expected (as seen for 'Importance' above), it appears that there were more items in the pre-post test for 'Effectiveness' of peer feedback that failed to load on the factors as proposed. Again, these anomalous items were retained in their conceptual pattern as the reliability of the respective factor is high (see Table 30 above).

Table 33. Factor loading on student perception on effectiveness of peer feedback (pre-test)

Student perception of peer feedback items (pre-test on effectiveness)	No	Factor 1 Presentation	Factor 2 Content	Factor 3 Function
How effective were the peer discussions on the feedback in elaborating and extending your ideas, concepts or knowledge about the topic?	23	**.793**	.183	.057
How effective was reflection on the received peer feedback in helping you to improve your work?	24	**.693**	.008	.070
How effective were guiding questions (when provided) in helping you to formulate feedback?	20	**.690**	-.085	-.130
How effective were the guiding questions (when provided) in helping you to reflect on the received peer feedback?	25	**.689**	-.111	.098
How effective were the guiding questions (when provided) in helping you to think deeper about the feedback content?	21	**.644**	-.227	-.169
How effective were the peer discussions in helping you to understand the received peer feedback?	22	**.588**	-.127	.047
How effective was the timing of your peer's feedback provided?	19	**.468**	.070	.114
How effective was your peer's feedback in helping you to learn practical procedures?	13	**.456**	-.094	.114
How effective was your peer's feedback in helping you to monitor your thinking about your strategies and actions during the task?	15	**.454**	-.176	.156
How effective were the success criteria (learning objectives) in helping you to think deeper about the feedback content?	4	**.394**	.179	.226
How effective was your peer's feedback in clarifying your doubts about your understanding of concepts?	6	-.038	**-.813**	.114
How effective was your peer's feedback in clarifying your doubts about the task?	5	.287	**-.527**	-.017
How effective was your peer's feedback in clarifying your doubts about your understanding of procedures?	7	.230	**-.523**	.188
How effective was your peer's feedback in helping you to learn concepts better?	12	.218	**-.443**	.265

Student perception of peer feedback items (pre-test on effectiveness)	No	Factor 1 Presentation	Factor 2 Content	Factor 3 Function
How effective was your peer's feedback in helping you to correct your mistakes?	8	.000	**-.421**	.410
How effective was your peer's feedback in helping you to revise your work?	14	-.039	.145	**.759**
How effective was your peer's feedback in indicating the quality of your work?	2	-.030	-.101	**.658**
How effective was your peer's feedback in providing justifications on how to improve your work?	11	.089	-.156	**.609**
How effective was your peer's feedback in meeting your learning goals?	16	.283	.057	**.594**
How effective was your peer's feedback in suggesting on how to improve your work?	3	.091	-.270	**.488**
How effective was your peer's feedback in directing you towards specific mistakes?	1	.205	-.078	**.460**
How effective was your peer's feedback in providing explanations on how to improve your work?	10	.085	-.242	**.455**
How effective was your peer's feedback in helping you to elaborate on your ideas?	9	.050	-.218	**.444**
How effective was your peer's feedback in motivating you to learn better?	17	.354	-.110	**.370**
How effective was your peer's feedback in recognising your effort in the work done?	18	.289	.054	**.318**
Factor correlations				
1		-	-.401	-.609
2			-	-.343
3				-

Exploratory factor analysis of post-test on 'effectiveness'

The 25 items of the post-test student perception questionnaire on 'Effectiveness' of peer feedback were subjected to a maximum likelihood factor analysis, with an oblimin rotation. It was possible to identify three interpretable factors, explaining 55.2% of the total variance. The pattern matrix for these three factors is shown in Table 34. Factor One on 'Presentation' (eigenvalue = 10.55) of peer feedback accounts for 42.2% of the common variance; Factor Two on 'Content' (eigenvalue = 1.76) of peer feedback accounts for 7.1% of the shared variance; and Factor Three on 'Function' (eigenvalue = 1.48) of peer feedback accounts for 5.9% of the common shared variance. The goodness of fit statistic χ^2 (288) = 366.62, $p < .01$, indicates good specification of the three factor model.

Table 34. Factor loading on student perception on effectiveness of peer feedback (post-test)

Student perception of peer feedback items (Post-test on effectiveness)	No	Factor 1 Presentation	 2 Content	 3 Function
How effective was your peer's feedback in recognising your effort in the work done?	18	**.773**	.107	.057
How effective was your peer's feedback in meeting your learning goals?	16	**.771**	-.049	.035
How effective was reflection on the received peer feedback in helping you to improve your work?	24	**.741**	.205	-.089
How effective were the guiding questions (when provided) in helping you to reflect on the received peer feedback?	25	**.726**	.083	-.135
How effective was your peer's feedback in providing justifications on how to improve your work?	11	**.658**	-.062	-.084
How effective was your peer's feedback in helping you to revise your work?	14	**.647**	-.098	-.023
How effective were the guiding questions (when provided) in helping you to think deeper about the feedback content?	21	**.633**	-.022	.266
How effective was your peer's feedback in helping you to monitor your thinking about your strategies and actions during the task?	15	**.573**	-.118	.024
How effective was your peer's feedback in motivating you to learn better?	17	**.560**	-.217	.066
How effective was your peer's feedback in providing explanations on how to improve your work?	10	**.554**	-.178	-.191
How effective was your peer's feedback in helping you to elaborate on your ideas?	9	**.522**	-.227	-.035
How effective was your peer's feedback in helping you to learn concepts better?	12	**.501**	-.182	-.196
How effective was the timing of your peer's feedback provided?	19	**.492**	-.091	-.156
How effective were the peer discussions on the feedback in elaborating and extending your ideas, concepts or knowledge about the topic?	23	**.472**	-.335	.143
How effective were guiding questions (when provided) in helping you to formulate feedback?	20	**.435**	-.291	.306
How effective were the peer discussions in helping you to understand the received peer feedback?	22	**.393**	-.384	.021
How effective was your peer's feedback in directing you towards specific mistakes?	1	.017	**-.872**	.261
How effective was your peer's feedback in helping you to correct your mistakes?	8	-.138	**-.756**	-.186
How effective was your peer's feedback in indicating the quality of your work?	2	.103	**-.593**	.018
How effective was your peer's feedback in suggesting on how to improve your work?	3	.127	**-.546**	-.125

Student perception of peer feedback items (Post-test on effectiveness)	No	Factor 1 Presentation	2 Content	3 Function
How effective was your peer's feedback in clarifying your doubts about the task?	5	.099	**-.514**	-.234
How effective was your peer's feedback in clarifying your doubts about your understanding of concepts?	6	.205	**-.472**	-.287
How effective were the success criteria (learning objectives) in helping you to think deeper about the feedback content?	4	.253	**-.333**	.086
How effective was your peer's feedback in clarifying your doubts about your understanding of procedures?	7	.264	-.222	**-.616**
How effective was your peer's feedback in helping you to learn practical procedures?	13	.384	-.217	**-.402**
Factor correlations				
1		-	-.597	-.155
2			-	.160
3				-

Descriptive statistics on 'importance'

The Cronbach's alpha reliability statistics for the 25 items for pre- and post-test are shown in Table 35. The reliability for each factor is above .75 and overall item reliability is above .90, which suggests that it is meaningful to interpret the scores on each factor.

Table 35. Estimates of reliability (alpha) for students' perception questionnaire

Items	Importance		Effectiveness	
	Pre-test (α)	Post-test (α)	Pre-test (α)	Post-test (α)
Content: Q1–8	0.79	0.83	0.83	0.85
Function: Q9–18	0.88	0.87	0.88	0.90
Presentation: Q19–25	0.83	0.85	0.81	0.82
Overall: Q1–25	0.92	0.93	0.94	0.94

The mean and standard deviation for students' perception of 'Importance' of peer feedback is shown in Table 36. For the pre-test, the mean rating on individual items ranged from a high of 3.79 (Item 8—peer feedback helps you to correct your mistakes) to a low of 2.94 (Item 19—peer feedback is timely), with a mean rating for all items of 3.37. For the post-test, the mean rating on individual items ranged from a high of 3.94 (Item 8—peer feedback helps you to correct your mistakes) to a low of 3.12 (Item 16—peer feedback meets your learning goals), with a mean rating for all items of 3.51.

Table 36. Mean and standard deviation for students' perception on 'importance' of peer feedback

No.	Importance of peer feedback	Pre-test		Post-test	
	Items	*M*	*SD*	*M*	*SD*
1	Peer feedback directs you towards specific mistakes.	3.36	0.931	3.56	0.903
2	Peer feedback indicates the quality of your work.	3.36	0.956	3.49	0.886
3	Peer feedback suggests how to improve your work.	3.60	0.996	3.74	0.899
4	Success criteria (learning objectives) to help you think deeper about the feedback content.	3.38	1.035	3.36	1.032
5	Peer feedback clarifies your doubts about the task.	3.48	0.984	3.62	0.977
6	Peer feedback clarifies your doubts about your understanding of concepts.	3.45	0.974	3.54	0.922
7	Peer feedback clarifies your doubts about your understanding of procedures.	3.66	1.005	3.61	0.840
8	Peer feedback helps you to correct your mistakes.	3.79	1.016	3.94	0.888
9	Peer feedback helps you to elaborate on your ideas.	3.31	0.921	3.47	0.941
10	Peer feedback provides explanations on how to improve your work.	3.51	1.034	3.68	0.942
11	Peer feedback provides justifications on how to improve your work.	3.33	1.113	3.44	1.064
12	Peer feedback helps you to learn concepts better.	3.51	1.042	3.55	1.000
13	Peer feedback helps you to learn practical procedures better.	3.55	1.025	3.61	0.969
14	Peer feedback helps you to revise your work.	3.32	1.142	3.27	1.057
15	Peer feedback helps you to monitor your thinking about your strategies and actions during the task.	3.36	1.133	3.26	1.053
16	Peer feedback meets your learning goals.	2.95	1.132	3.12	1.092
17	Peer feedback motivates you to learn better	3.34	1.045	3.42	1.070
18	Peer feedback recognises your effort in the work done.	3.19	1.128	3.47	1.081
19	Peer feedback is timely.	2.94	1.098	3.36	1.125
20	Guiding questions to help you formulate peer feedback.	3.17	1.085	3.60	0.971
21	Guiding questions to help you think deeper about the feedback content.	3.15	1.062	3.44	1.040
22	Peer discussions to help you understand the received peer feedback.	3.55	1.072	3.51	1.017
23	Peer discussions on the feedback to elaborate and extend your ideas, concepts or knowledge about the topic.	3.44	1.132	3.63	1.001
24	Reflection on the received peer feedback to help you improve your work.	3.31	1.055	3.45	1.057
25	Guiding questions to help you reflect on the received peer feedback.	3.16	1.033	3.51	1.026

Descriptive statistics on 'effectiveness'

The mean and standard deviation for students' perception of 'Effectiveness' of peer feedback is shown in Table 37. For the pre-test, the mean rating on individual items ranged from a high of 3.51 (Item 8—peer feedback helps you to correct your mistakes) to a low of 2.83 (Item 16—peer feedback meets your learning goals), with a mean rating for all items of 3.19. For the post-test, the mean rating on individual items ranged from a high of 3.65 (Item 8—peer feedback helps you to correct your mistakes) to a low of 2.90 (Item 16—peer feedback meets your learning goals), with a mean rating for all items of 3.25.

Table 37. Mean and standard deviation for students' perception on 'effectiveness' of peer feedback

No.	Effectiveness of peer feedback	Pre-test		Post-test	
	Items	*M*	*SD*	*M*	*SD*
1	Peer feedback directs you towards specific mistakes.	3.16	.922	3.35	.981
2	Peer feedback indicates the quality of your work.	3.25	.906	3.26	.909
3	Peer feedback suggests how to improve your work.	3.21	.976	3.45	.939
4	Success criteria (learning objectives) to help you think deeper about the feedback content.	3.07	1.058	3.20	1.046
5	Peer feedback clarifies your doubts about the task.	3.36	.866	3.29	1.068
6	Peer feedback clarifies your doubts about your understanding of concepts.	3.26	.892	3.25	.924
7	Peer feedback clarifies your doubts about your understanding of procedures.	3.47	.904	3.31	1.015
8	Peer feedback helps you to correct your mistakes.	3.51	.950	3.65	1.039
9	Peer feedback helps you to elaborate on your ideas.	3.13	.957	3.26	.988
10	Peer feedback provides explanations on how to improve your work.	3.26	.988	3.36	1.025
11	Peer feedback provides justifications on how to improve your work.	3.10	1.068	3.15	1.152
12	Peer feedback helps you to learn concepts better.	3.21	1.050	3.15	1.085
13	Peer feedback helps you to learn practical procedures better.	3.45	1.048	3.38	1.149
14	Peer feedback helps you to revise your work.	3.12	1.100	3.08	1.085
15	Peer feedback helps you to monitor your thinking about your strategies and actions during the task.	3.17	1.101	3.08	1.077
16	Peer feedback meets your learning goals.	2.83	1.054	2.90	1.128
17	Peer feedback motivates you to learn better.	3.14	.977	3.10	1.221
18	Peer feedback recognises your effort in the work done.	3.16	1.057	3.18	1.190
19	Peer feedback is timely.	2.90	1.036	3.05	1.094
20	Guiding questions to help you formulate peer feedback.	3.05	1.063	3.41	1.160

No.	Effectiveness of peer feedback	Pre-test		Post-test	
	Items	*M*	*SD*	*M*	*SD*
21	Guiding questions to help you think deeper about the feedback content.	3.03	.957	3.24	.975
22	Peer discussions to help you understand the received peer feedback.	3.26	1.094	3.36	.999
23	Peer discussions on the feedback to elaborate and extend your ideas, concepts or knowledge about the topic.	3.28	1.010	3.31	1.057
24	Reflection on the received peer feedback to help you improve your work.	3.20	1.005	3.29	1.076
25	Guiding questions to help you reflect on the received peer feedback.	3.07	1.058	3.27	1.072

The key finding of the student perception questionnaire suggests that students perceive peer feedback to be most important and effective in the *correction of mistakes* and least important and effective in *meeting learning goals*. One possible reason for this result is that students hold a 'functional view' of using peer feedback, which sees feedback predominantly as information for corrective action or improvement of work done. This is evident from the student interview responses mentioned above on what they think peer feedback means. While this view indicates that students actively use feedback for revision, it also suggests that students fail to recognise the potential of peer feedback for developing their ideas, and helping them to think deeper or monitor their learning progress.

Confirmatory factor analysis

The path diagrams for the structural equation model depicting two second-order latent factors, students' perceived *importance* and *effectiveness* of peer feedback, and three first-order variables—*content* of peer feedback, *function* of peer feedback and *presentation* of peer feedback, are presented schematically in Figure 6 and Figure 7. It is hypothesised that the two second-order latent factors are correlated and each second-order factor is hypothesised to be explained by three first-order factors.

The model test results showed that while the correlation between perception of importance and effectiveness is high for both pre-test and post-test, in both the pre- and post-test models, the various baseline comparisons were not acceptable (CFI = .58, RMSEA = .11). This inferior goodness-of-fit is not uncommon for measurement models drawn from one study data (but not for structural models) and the results suggest that

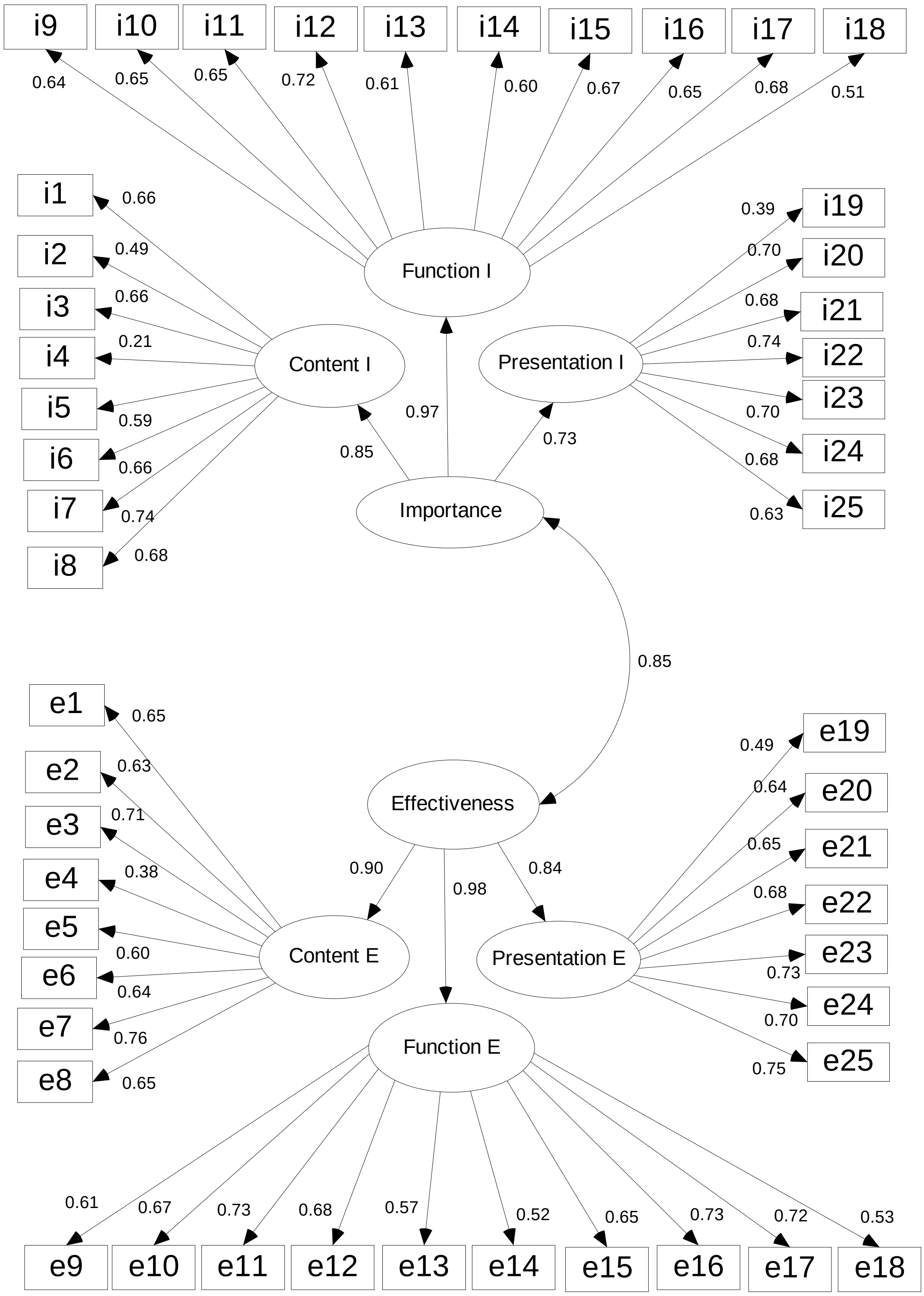

Figure 6. Path diagram for student perception questionnaire (pre-test)

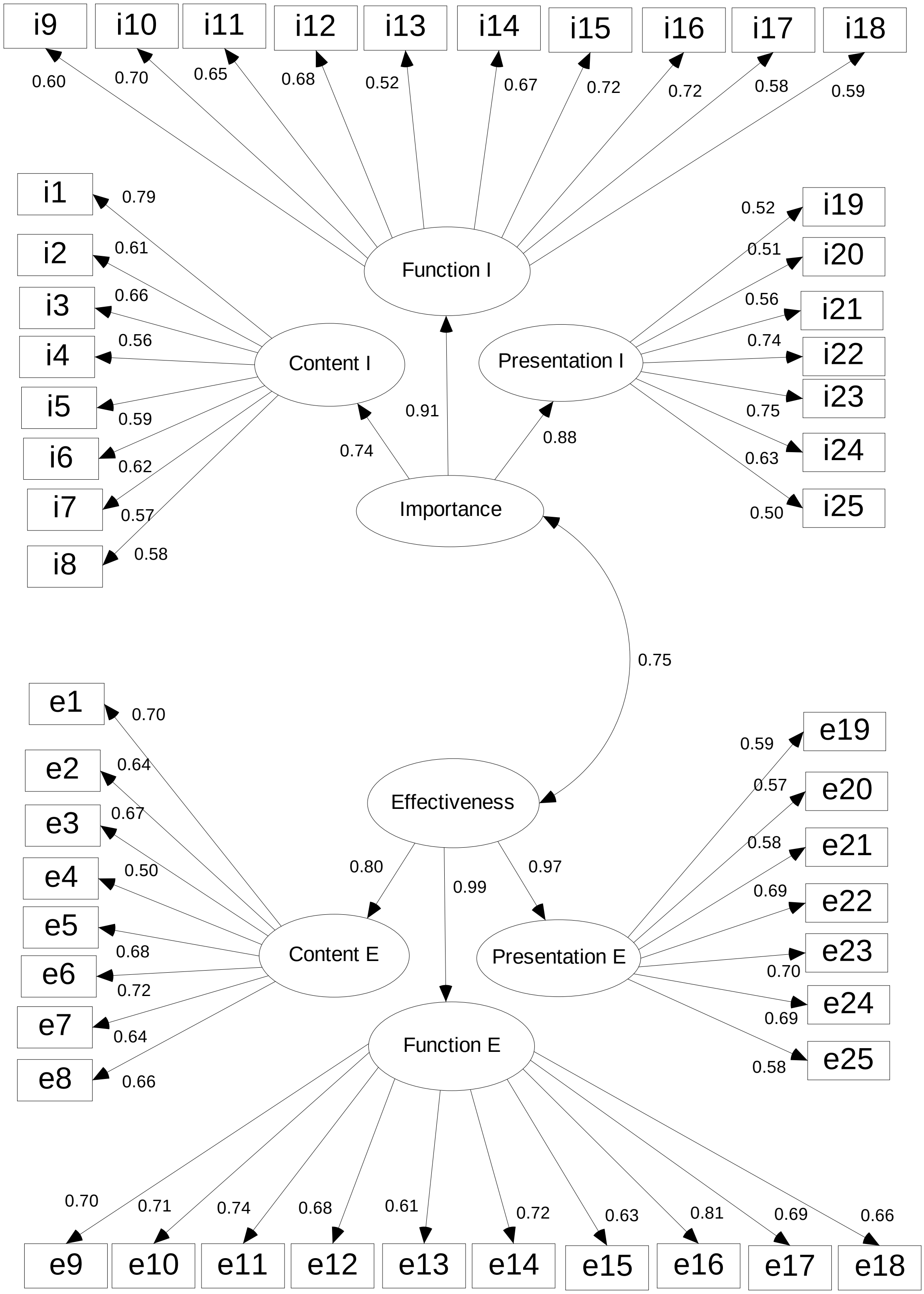

Figure 7. Path diagram for student perception questionnaire (post-test)

Table 38. Confirmatory factor analysis of student perception of peer feedback

MODEL FIT SUMMARY

CMIN

Model	Pre-Test Model NPAR	CMIN	DF	P	CMIN/DF	Post-Test Model NPAR	CMIN	DF	P	CMIN/DF
Test model	107	2809.371	1168	0	2.405	107	2892.261	1168	0	2.476
Saturated model	1275	0	0			1275	0	0		
Independence model	50	5134.668	1225	0	4.192	50	5305.01	1225	0	4.331

Baseline Comparisons

Model	Pre-Test NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI	Post-Test NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Test model	0.453	0.426	0.586	0.56	0.58	0.455	0.428	0.583	0.557	0.577
Saturated model	1		1		1	1		1		1
Independence model	0	0	0	0	0	0	0	0	0	0

RMSEA

Model	Pre-Test RMSEA	LO 90	HI 90	PCLOSE	Post-Test RMSEA	LO 90	HI 90	PCLOSE
Test model	0.108	0.103	0.113	0	0.111	0.106	0.116	0
Independence model	0.163	0.158	0.168	0	0.167	0.162	0.171	0

the model is acceptable as a set of hypotheses for further investigation—clearly other dimensions need to be added to the questionnaire (and thus the model) to make it more acceptable.

Comments on Instruments and Limitations

Acknowledging that the results from this intervention study are limited in generalisability due to the non-random selection of the treatment groups and the short duration of the intervention, the findings were positive in suggesting that question prompts guided students in formulating peer feedback that directed their peers to the learning gaps and indicated to them how best to improve their performance.

The concepts of evidence rubric was found to be useful in identifying the ideas related to the five key evidence used by students during the peer feedback process. The use of fair-testing is a common occurrence, which confirms the claim by research studies that students tend to concentrate solely on ensuring a fair test in designing experiments as a result of daily practical work being dominated by activities on fair testing (Haigh et al., 2005; Hodson, 2009). The results further indicate that students need to develop evidence ideas related to other aspects such as identifying patterns and relationships as well as concepts of reliability and validity when working on data or experimental design.

The coding scheme for feedback levels was developed further in this study by improving on the descriptors. While this has helped in the coding of peer feedback statements in terms of task, process, and self levels, it raised doubts about how to conceptualise self-regulation as a coding for peer feedback statements. The notion of self-regulation encompasses a wider conception of a dynamic learning process involving executive control over one's own learning and influenced by a multitude of factors, such as personal characteristics, social circumstances and learning conditions (see Boekaerts, 2006). The peer feedback statements by students would probably not fall under this category and thus, a more appropriate descriptor is warranted. The analysis of peer feedback from the six classes of students suggests that beyond process level feedback, students' feedback exchange involved the use of meta-cognitive strategies, such as provide cues on *when* and *why* in using a procedure or a concept of evidence. This proved useful in developing the notion of peer feedback as *conditional knowledge* and is investigated in study three.

CONCLUSION

Summary of Findings

The results of this study indicated that prompts, which cue students to identifying the learning gap and providing suggestions for improvement, were effective in fostering more directed and meaningful peer feedback. Despite the fact that both prompted and unprompted students performed better in the post-test than in the pre-test, the implementation resulted in better quality written peer feedback in the treatment classes than in the control classes. Students perceived peer feedback to be important and effective as corrective information but they also believed that peer feedback had little impact on their learning goals.

Implication for the Next Study

Although prompted peer feedback allowed students to formulate more task level feedback, the number of process and self-regulation level feedback episodes was still low. In light of the findings, it appears that more support is needed to help students to formulate feedback at the process and self-regulation levels. At the same time, there is a need to help students recognise a wider purpose of peer feedback that involves not only corrective actions, but also the potential for cognitive and meta-cognitive engagement. In the next study, students were given explicit coaching on formulating peer feedback at different levels to examine the impact of this instructional intervention on peer feedback quality.

CHAPTER 5

STUDY THREE: THE EFFECTS OF EXPLICIT INSTRUCTIONAL SUPPORT ON FORMULATING PEER FEEDBACK AT TASK, PROCESS, AND SELF-REGULATION LEVELS

INTRODUCTION

Dylan Wiliam, in a review on feedback and formative assessment, wrote that "the most effective feedback focuses attention prospectively rather than retrospectively" (2010, p. 19). Here the distinction is made on knowing what has been done and what needs to be done, and it is the latter that makes feedback meaningful to the learner. In study two, this notion of focusing on the consequential aspect of peer feedback was investigated by prompting students to formulate suggestions for improvement while at the same time, creating opportunities for revision and further peer feedback. Although the use of prompts resulted in more improvement suggestions, the quality notion of cognitive and meta-cognitive engagement with peer feedback is not evident.

In study three, it is proposed that instructional support through explicit coaching on the feedback levels will enhance students in formulating differentiated peer feedback in terms of task, process, and self-regulatory levels. Specifically, this study investigates assertion 4:

> Peer feedback levels are viewed as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.

This assertion suggests that the positive effects of peer feedback are maximised when students are conscious of the feedback levels and how to interpret them in relation to their current level of understanding. This assertion also recognises that students need support in the form of a visual tool to help scaffold the way they provide peer feedback that facilitates cognitive and meta-cognitive engagement with the learning task.

INSTRUCTIONAL SUPPORT AND PEER FEEDBACK

The following review of literature on instructional support for peer feedback in learning are classified into five key areas, derived from Topping's model of peer learning (2005). Topping proposed five main sub-processes which influence peer learning effectiveness—organisation and engagement, cognitive conflict, scaffolding and error management, communication, and affect. The sub-processes are described as leading towards shared understanding between helper and helped, which may facilitate peer feedback and subsequent regulation of learning.

Organisational Support of Learning Interaction

Most peer learning situations in the classroom involve some form of organisational or structural support, usually in the form of groupings, role assignment, choice of learning materials, and time allocation. For example, Cho and MacArthur (2010) found that when students received feedback from multiple peers, it could lead to more complex revisions of their writing than when receiving feedback from a single peer or an expert reviewer. By grouping students in peer review teams, Cho and MacArthur claimed that more comments were provided that were more manageable for the student. At the same time, the reviewers had the opportunity to read and comment on not one but a few of their peers' work, which may in turn have provided further feedback for their own writing.

Cognitive Support—Cognitive Conflict and Challenge

Topping (2005) suggested that one way to enhance peer learning was to engage peers in conflict and challenge to 'loosen cognitive blockages' and 'liquify primitive cognitions and beliefs'. For example, Chi (1996) found that tutor actions that challenged and elicited tutee's self-explanations may have been beneficial to deep learning (by removing misconceptions). An in-depth case study revealed that tutee learned from interactions with the tutor in the form of question-asking by the tutee, scaffolding (in the form of hints by the tutor), and direct corrective feedback (telling the tutee what to do). Although this was not an empirical study on instructional support, the findings indicate that providing opportunities for peer tutors to scaffold the learning process (in this case, problem-solving strategies) that fostered tutor-tutee interaction with successive series of questioning and feedback, may lead to co-construction of knowledge. A more recent review by Roscoe and Chi (2007) showed that tutors benefited from explicit training in reflective knowledge-building skills that incorporated self-explanations, giving new examples, discussing underlying principles and applications, connecting ideas, or elaborating upon source materials.

Cognitive Support—Scaffolding

From an expert-novice paradigm, expert helpers are seen as having more in-depth knowledge of evaluative criteria, strategies for using criteria in task completion or problem-solving and evaluative skills in error detection, correction, and revisions. Novice or inexperienced helpers lack cognitive resources during evaluation and revisions. The processes of critical reading, detecting, diagnosing, and providing suggestions for revision often result in cognitive overload in working memory. For these reasons, procedural facilitation tools are often used to guide and prompt students on peer feedback strategies and skills. For example, peer review sheets and evaluation rubrics have been used to focus students on the criteria and on how to formulate revision strategies (Cho & MacArthur, 2010; Min, 2006). In one study of peer feedback effectiveness for learning (Gielen et al., 2010), students were provided with feedback forms, a ‘priori’ question form and a ‘posteriori reply form’. The feedback form contained guiding question prompts to focus on strengths, weaknesses, and suggestions for improvement. The priori question form required students to suggest what they needed further feedback on. The posteriori reply form asked the students to reflect on their peer’s feedback. These scaffolding instruments were found to have a significant learning benefit, resulting in more effective feedback.

Students who undergo peer review training incorporate a significantly higher number of reviewers’ comments into revisions. Min (2005, 2006) found that after receiving extensive coaching to be effective peer reviewers, a group of English as a foreign language (EFL) students were capable of generating more specific and relevant written feedback on global features of their peers’ compositions. The first phase of instructional support consisted of a demonstration by the instructor on how to use a four-step strategy when commenting on a peer’s draft. Students were encouraged to practice and use the four steps: (a) ask for clarification, (b) identify a problem, (c) explain the problem, and (d) suggest possible revisions. This was followed by a second phase involving teacher-student conferences, in which, the teacher provided content and procedural assistance to each individual student on their written peer feedback (i.e., reviewer comments).

Another form of scaffolding is learning by observation. Van Steendam et al. (2010) designed and implemented modelling by observing more competent peers as an instructional support to help novices to become better revisers. Helpers were first instructed to observe two expert peers in dyadic interaction modelling the application of revision strategies and criteria for revision to a peer's English text. This was followed by emulation, in which the helpers used the criteria for giving peer feedback. This observational learning approach was argued to be more effective for acquiring evaluative criteria and revision strategies than traditional practising only. The findings showed that observational learning, as an instructional support, needed to be accompanied by collaborative emulation, to be effective in learning about criteria and revision for writing.

Communication

Supporting communication skills is important to ensure that peers are able to articulate (both verbal and written) feedback clearly and in a way that best represents their own interpretation of the evaluation of their peer's work. Stanley (1992) carried out extensive coaching (7 hours over 4 weeks) with a class of 15 students enrolled in a freshman composition course. Students were provided with a series of drafts (from rough first draft to polished fourth draft) written by previous students of the course, and they were asked to identify unclear sections of text, make judgement on claims and assumptions, and compare the reworkings and repairs in subsequent drafts. The students were then required to report what the strengths and shortcomings of the essay were, as well as describe what they felt was the best way to communicate these thoughts to their peers. This 'how-to-say-it' aspect of evaluation was role played by pairs of students, and later discussed by the whole class. Strategies for effective communication emerged as shared consensus, trust for one another's responses, and active participation in seeking assistance. When compared to an uncoached group, Stanley found that students made "substantially more comments in every response category" and showed "more commitment to the task of understanding their partners' draft and to making sure that their partners understood theirs" (p. 227). The conclusion was that students needed time to be explicitly taught how to socialise in the 'microculture of the peer-evaluation group’, and to learn the rules of effective group interaction, etiquette, and tact. At the same time, they needed to develop skills in writing evaluation, and how to communicate their response in a coherence and meaningful way to their peers.

Supporting Affect

Topping (2005) suggested that the affective component of peer learning might also prove very powerful. Peers, who see their friend as trustworthy and holds no position of authority, will be more willing to disclosure their ignorance or misconception, allowing further evaluation and correction. The building of confidence can be reciprocal, with the helper gaining self-confidence in successful attempts at helping, and the helped being influenced by the enthusiasm and competence modelled by their peer. Villamil and de Guerrero (2006) studied peer feedback in second-language writing classrooms by using a sociocultural framework to illustrate and explain the socio-cognitive dimensions of joint interaction. The authors identified three forms of mediation used by students as they worked jointly on revising a text: artefact-mediation, self-mediation, and other-mediation. A microgenetic study of one pair of students revealed that the students employed several scaffolding mechanisms in other-mediation situation (de Guerrero & Villamil, 2000). The authors found that contingent responsivity and psychological differentiation (Lidz, 1991, cited in de Guerrero & Villamil, 2000) were key scaffolding behaviours that led to high levels of affective involvement during the interaction. Contingent responsivity was displayed by the reader’s ability to “read the partner’s cues and signals related to learning, affective, and motivational needs, and then respond in a timely and appropriate way” (Lidz, 1991, cited in de Guerrero & Villamil, 2000). The management of the affective dimension of the interaction also involved the reader reminding the writer that he or she is taking the role of giving feedback on revision and thus, responding to psychological differentiation which clarified the role of reader (helper) and the partner’s role as the author (helped). This mutual support by peers suggested the need to consider the affective aspect of peer interaction as part of instructional intervention in peer feedback.

Role of Teacher During Peer Feedback Instruction

The most common approach for peer feedback training is direct instruction on feedback skills or strategies by the teacher. Zhu (1995) investigated the effects of training on students' ability to give feedback to their peers on their writing by first showing the students a video demonstration on how to provide feedback on one another's writing. This was followed by a teacher-student conference, where the teacher interacted with the students (in groups of three) to identify their concerns, check for comprehensibility of feedback, and explained a strategy for providing effective feedback. The author argued that conferencing allowed the instructor to provide both 'substantive' and 'procedural' facilitation. Substantive facilitation took the form of the teacher collaborating with students to simulate peer performance and feedback, while, procedural facilitation was provided by "directing students' attention to procedural decisions through use of various oral prompts" (p. 499). The findings showed that explicit coaching via teacher-student conferences had a significant impact on both the quantity and quality of feedback students provided on peer writing. Zhu concluded that participants' knowledge and skills about feedback affected peer interaction, and that helping students to develop skills and strategies needed for peer response was an effective way to assist interaction and negotiation among students.

Explicit instructions also takes the form of teacher modelling of feedback behaviour and this is seen as an effective instructional intervention to convey the skills and knowledge required for the provision of quality peer feedback (Berg, 1999; Min, 2006). For example, Berg trained students how to participate in peer response to writing using an 11-step approach. The teacher modelled the peer response by focusing on the progression from the first draft to the last draft, and on how peers' comments helped improve the writing. The modelling process also took into account the use of appropriate vocabulary and expressions. The results of this intervention study indicated that trained peer responses positively affected English as a second language (ESL) students' revision types and quality of texts.

SUPPORTING PEER FEEDBACK ENGAGEMENT

As the above review shows, besides organising students into different roles and groupings, most studies of instructional support involved some form of cognitive and meta-cognitive scaffolding, with the teacher playing a key role in preparing the students, implementing the peer feedback process, mediating the process, and evaluating and adjusting instruction to further enhance the feedback and learning process. It follows that instructional intervention has a central role to play in preparing and helping students to engage in the peer feedback process and at the same time, use peer feedback in meaningful learning.

In study three, the instructional intervention takes the form of explicit coaching on what feedback levels mean and how to use them in formulating peer feedback on an investigative task. A common theme examined throughout study one and two is the way students provide peer feedback that incorporates the three levels in Hattie and Timperley's feedback model (2007). The conceptualisation of task, process and self-regulation levels of feedback as a key indicator of peer feedback quality entails knowing what feedback looks like at each level and what this means to the learner. The findings of study two suggest that peer feedback at the self-regulation level may involve probing or reflective questions that require the use of meta-cognitive strategies or knowledge. This implies that peer feedback at the self-regulation level can be envisaged as *conditional knowledge*, which includes information that helps the learner in "knowing *when* or *why* to apply various actions" (Paris, Lipson, & Wixson, 1983, p. 303). This view also lends itself to the notion of meta-cognitive engagement, which is seen as the active use of conditional knowledge in formulating peer feedback. Thus, the coding scheme for peer feedback levels can be extended to include ideas of the three key knowledge domains – declarative, procedural and conditional, and this provides a useful measure for cognitive and meta-cognitive engagement of learner with peer feedback. The revised coding scheme is presented in the Methodology section (see Table 43).

To help students in visualising the peer feedback levels, a graphic organiser is developed by first designing question prompts that cue students in formulating peer feedback at each level (Table 39). The prompts are then connected together to show the flow from one feedback level to the next. The graphic organiser is presented in the methodology section (see Figure 9).

Table 39. Question prompts for graphic organiser

Feedback level	Question prompts
Task-level	• Does his/her answer meet the success criteria? • Is his/her answer correct/incorrect? • How can he/she elaborate on the answer? • What did he/she do well? • Where did he/she go wrong? • What is the correct answer? • What other information is needed to meet the criteria?
Process-level	• What is wrong and why? • What strategies did he/she use? • What is the explanation for the correct answer? • What other questions can he/she ask about the task? • What are the relationships with other parts of the task? • What other information is provided in the handout? • What is his/her understanding of the concepts/knowledge related to the task?
Self-regulation level	• How can he/she monitor his/her own work done? • How can he/she carry out self-checking? • How can he/she evaluate the information provided? • How can he/she reflect on his/her own learning? • What did you do to ...? • What happened when you ...? • How can you account for...? • What justification can be given for ...? • What further doubts do you have regarding this task? • How does this compare to...? • What do all these information have in common? • What learning goals have you achieved? • How have your ideas changed?

Graphic organisers are seen as effective to help learners in information processing due to their ability to provide a clear categorisation of ideas, and to make the relationship between the ideas explicit and easily accessible. Scaife and Rogers (1996) attributed the cognitive benefits of graphical representations, such as graphic organisers, to three central characteristics—computational offloading, re-representation and graphical constraining. Computational offloading refers to "the extent to which differential representations reduce the amount of cognitive effort to solve informationally equivalent problems" (p. 188). For example, graphic organisers help in computational offloading as they categorise information by location or hierarchy and this greatly reduces the amount of mental resources needed for information searches. Another property that makes graphic organisers effective is re-representation. This refers to "how different representations that have the same abstract structure make problem solving easier or more difficult" (p. 189). In other words, structural similarity in the representation prompts students to focus more closely on those relationships inherent in the problems. Scaife and Rogers refers to constraining as "the way graphical elements in a graphical representation are able to constrain the kinds of inferences that can be made about the underlying represented world" (p. 189). By limiting the kinds of interpretations that can be made from a graphic organiser, constraining facilitates information processing by putting a boundary on the size and complexity of search space.

The use of graphic organiser with feedback levels also ties in with assertion 4, which proposes a progressive view of peer feedback, with information that moves the learner from basic task understanding to self-regulatory skills. This visual/spatial hierarchical display of peer feedback provides a mental map that may enable students to draw connections between the work done and the level of feedback required. In other words, this matching of peer feedback with work done provides a starting point for developing a progressive view of feedback.

AIM OF PRESENT STUDY

In this study, students are explicitly coached to identify task, process and self-regulation level feedback and practice on formulating peer feedback at each level. In particular, this study addressed the question:

> Does explicit instruction on feedback levels (task, process, regulation, and self) lead to the formulation of higher quality written peer feedback?

METHODOLOGY

Setting and Participants

Eight classes of students (14–15 year olds) from four secondary schools in Singapore participated in this study (n = 332, 197 females, and 135 males). All students were in their first year of a two-year chemistry course, leading to GCE 'O' level certification. Prior to this, students had two years of general science studies, which included basic ideas of physics, chemistry, and biology. Scheduled practical sessions had been incorporated into their science curriculum, and students had experience with hands-on guided investigative tasks in the school laboratory. The students were generally motivated, attentive, on-task, and ranged from average to above average ability.

Experimental Design

This study adopted a quasi-experimental pre-test→treatment→post-test design. There were two conditions: peer feedback with coaching condition, and peer feedback without coaching. In both conditions, students were provided with a feedback form with prompts (as used in Study Two). Students in the coaching condition received explicit instruction on the different feedback levels (task, process, and self-regulation) and practise using a graphic organiser (designed with feedback levels) to formulate peer feedback. Students in the control group were given a lecture on the design of investigation and practise using the feedback form to give feedback on a crafted task without a graphic organiser (see Table 40). The coaching was carried out by the researcher over two lessons, with each lesson lasting 50 minutes.

Table 40. Summary of experimental design

Before Intervention	Intervention	After Intervention
Experimental Group (7 classes x 40 students)		
• Student survey form. • Giving written peer feedback on researcher-crafted student report 1 (pre-training measures).	• Peer feedback training • Using graphic organiser (see Figure 9).	• Student survey form. • Giving written peer feedback on researcher-crafted student report 2 (post-training effects).
Control Group (1 class x 40 students)		
• Student survey form. • Giving written peer feedback on researcher-crafted student report 1 (pre-training measures).	• No training. Participants given a lecture on the design of investigations.	• Student survey form. • Giving written peer feedback on researcher-crafted student report 2 (post effects without training).

The Learning Materials

Criteria for investigation report writing

In Study Two, students were able to conduct the investigation, give and receive peer feedback, and use the feedback for revision of their lab report. This design was not possible in Study Three as there were constraints by schools on the amount of curriculum time for carrying out the intervention. In addition, the students were new to the Chemistry course, and to conduct a full investigative experiment would have been too demanding on their knowledge and skills. With these considerations in mind, specific criteria for evaluating an investigation report were designed, and these were used by the students throughout the sessions. A sample of the criteria is shown in Figure 8.

Criteria For Writing An Experimental Report

Testable question or prediction or hypothesis:

- Write down a testable question or problem statement
    - *E.g., How does the volume/type/concentration of acid used affect the volume of carbon dioxide produced in this reaction?*
    - *E.g., To compare the time taken for three different types of metals to react with hydrochloric acid.*
    - *E.g., To study the effect of temperature on the time taken for a reaction to happen.*

- Predict changes to the dependent variable (what you are going to measure) as a result of a change in independent variable (what you are going to change)
    - *I predict that the higher the temperature the shorter the time taken for this reaction to occur. So, an increase in temperature will increase the rate of the reaction.*

- Give a reason to support your prediction

Figure 8. Sample of criteria used by students in giving peer feedback

Peer feedback graphic organiser

Using the three main feedback levels (task, process, and self-regulation), a graphic organiser was developed with question prompts at each level, and with indications as to the connections between levels. This visual tool was used in coaching as well as practise tasks. This graphic organiser is shown in Figure 9.

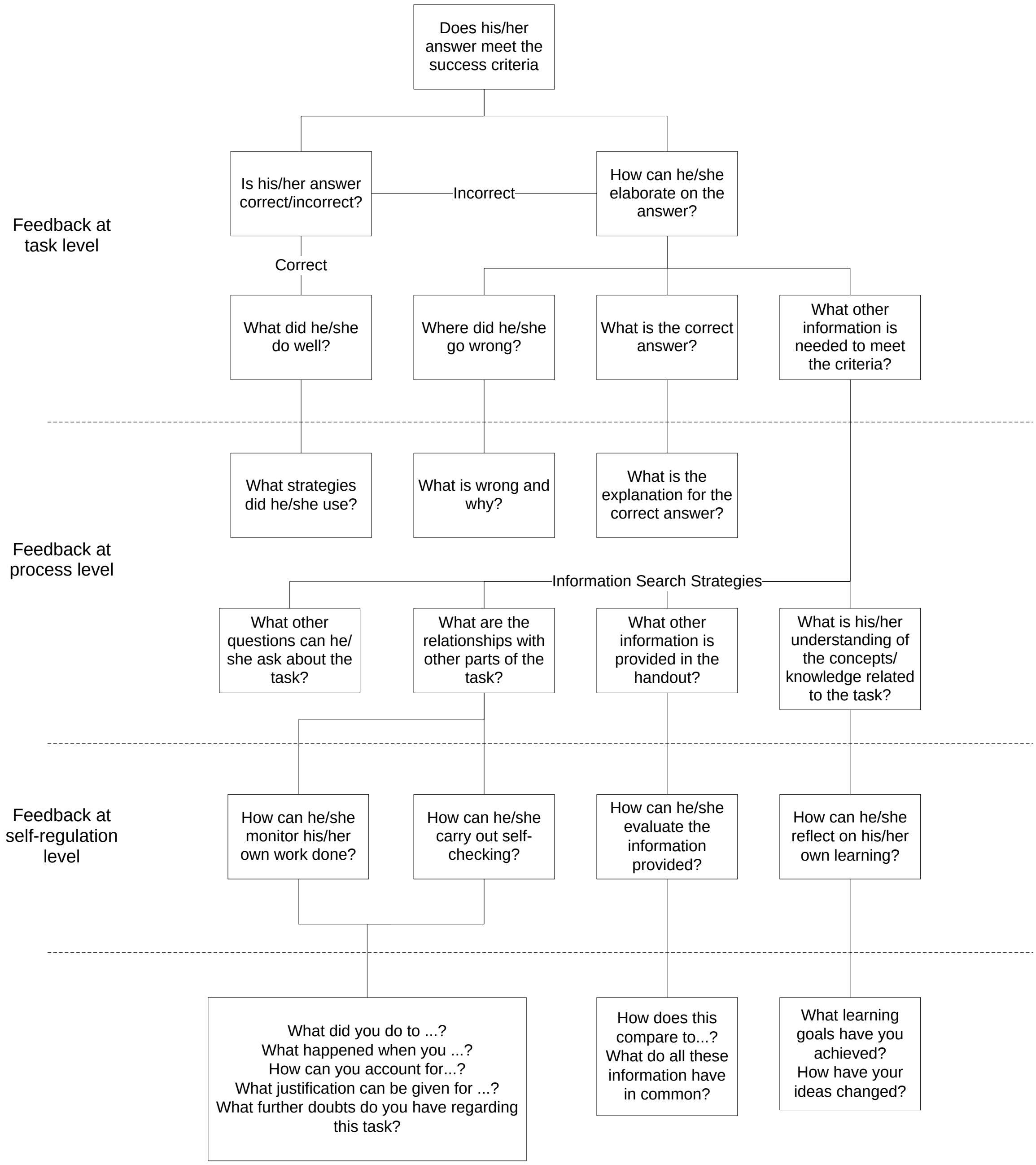

Figure 9. Peer feedback graphic organiser

Practice tasks

Two sets of practice tasks were designed to firstly allow students to formulate feedback using examples and the graphic organiser. Students were also required to identify peer feedback (with a partner) based on the three levels. Secondly, individual students were given a crafted student's report with written peer feedback and practised using the feedback levels to modify or revise the peer feedback towards process and self-regulation level. In both tasks, peer and whole class discussions were facilitated by the researcher after the students had attempted the tasks.

Lecture and practice materials for control group

A lecture on the design of an investigation was conducted for the control group with emphasis on the criteria for each phase of an investigation. Students in the control group also practiced using the peer feedback form to give written feedback on a crafted student report, but they had no instruction on the peer feedback levels, nor on how to use these levels in formulating peer feedback.

Procedures

The intervention was carried out by the researcher over a period of eight weeks, with four lessons for each of the eight classes. Students in the treatment classes were introduced to the notions of feedback level, criteria for report writing and provided with examples of how feedback at each level looks like. The researcher then modelled the use of the graphic organiser to formulate feedback at each level, and this is followed by students practice on using the graphic organiser to give feedback on a sample of lab report. The students were encouraged to discuss the peer feedback with a partner by commenting on their peer's written feedback in terms of feedback levels and how to re-formulate from one level to the next. Students in the control class were lectured on how to carry out an investigation, and practiced using criteria to give feedback on sample lab reports (Table 41).

Table 41. Scheme of research activities in schools

Lesson per class	Timing (50 min session)	Activities for Experimental Group	Activities for Control Group
1	10 mins	a) Introduction to peer feedback.	a) Introduction to peer feedback.
	20 mins	b) Pre-test: students give written peer feedback on researcher-crafted student report (with criteria).	b) Pre-test: students give written peer feedback on researcher-crafted student report (with criteria).
	20 mins	c) Students answer perception survey.	c) Students answer perception survey.

Lesson per class	Timing (50 min session)	Activities for Experimental Group	Activities for Control Group
2	20 mins	a) Introduction to criteria in report writing (using examples) and practise using criteria to give written peer feedback on researcher-crafted student report.	a) Introduction to criteria in report writing and practise using criteria to give written peer feedback on researcher-crafted student report.
	30 mins	b) Researcher modelled the use of peer feedback levels in graphic organiser. Students practise using organiser to compare different levels of feedback in researcher-crafted student reports.	b) Lecture on the design of investigation.
3	50 mins	a) Practise using criteria and graphic organiser to give written peer feedback on crafted high and low quality student report. b) Exchange peer feedback with a partner and use graphic organiser to assign the levels, then discussion.	a) Lecture on the design of investigation. b) Students practice using peer feedback form, with criteria, to give written feedback in researcher-crafted student reports
4	20 mins	a) Post-test: same as pre-test	a) Post-test: same as pre-test
	20 mins	b) Students answer perception survey.	b) Students answer perception survey.
	10 mins	c) Researcher provides a summary of study.	c) Researcher provides a summary of study.

Measures

The data sources for this study include students' written feedback in a pre/post laboratory report crafted by the researcher, their concepts of evidence scores and pre/post survey written responses. The outcome measures from these data sources are summarised in Table 42 and discussed in the following sections.

Table 42. Outcome measures summary

Outcome Measures	Instrument	Description
Frequency counts of written peer feedback statements	Pre/post test – a student laboratory report with prompts to elicit feedback.	Measures students' use of task, process, self-regulation and self levels in writing peer feedback.
Concepts of evidence score	Peer feedback statements in pre/post test.	Measures the use of concepts of evidence in writing peer feedback

Outcome Measures	Instrument	Description
Student perceptions on usefulness of peer feedback	Pre/post student survey form.	Describes students' perceived usefulness of peer feedback.

Pre- and post-test

A student report of an investigation task was crafted by adapting student samples from Study Two and used as a pre-post test of the participant's written feedback for both experimental and control classes. Students in the experimental group were required to give written feedback on the report, with the help of the graphic organiser. Students in the control group gave written feedback without the graphic organiser. The nature of the investigation was adapted from a study of the effects of temperature on the rate of an acid-base reaction. An overview of the investigation is provided in the test and the crafted report provided further content details to allow students to proceed with formulating their feedback comments. A sample of the test instrument is shown in Appendix 6.

Student survey form

A student survey was given to participants before and after the study. Participants were asked to give written response to three open-ended questions:

- What do you find most useful about your peer's feedback on your work and why?
- What do you find least useful about your peer's feedback on your work and why?
- How can you use your peer's feedback for revising / improving your work and why? Please give an example of how you use your peer's feedback for improving your work.

Data Analysis

Analysis of peer feedback statements by levels

The feedback level coding scheme developed in studies one and two was further modified and used to analyse individual student's written peer feedback for the pre- and post-test. In this study, the descriptors for each level were revised to more closely reflect the peer feedback generated by the students. Table 43 shows the coding scheme with examples.

Table 43. Peer feedback coding scheme, with definitions and examples

Categories	Definition	Examples
Task-level (TL)	Provides declarative knowledge or information about the correctness of the learner's responses. Also informs the learner of the correct answer, but without suggesting how to revise the response.	"She explained the limitations well but didn't really say why it was reliable and didn't refer to the data in drawing conclusions." "He wrote the predictions accurately but didn't give a reason for his prediction, which could have increased the quality of his answer." "Able to justify limitations and reliability issues."
Process-level (PL)	Provides procedural knowledge or strategies and examples for error detection, information search, or steps to carry out revision of work done.	"He has clearly showed the controlled variables. He should emphasise on fair testing in the method by highlighting the use of controlled variables." "She is able to control variables by keeping the temperature constant and changing the concentration of acid."
Self-regulation level (SL)	Provides conditional knowledge, usually in the form of reflective or probing questions, which guides the learner on when, where and why in selecting or employing task and process level knowledge and strategies. Peer feedback at this level helps to identify the demands of the specific learning situation and directs attention to strategies that are most appropriate for that situation.	"What would happen if you changed the gap between temperatures by a larger amount?" "Why do you think this outcome (prediction) will occur?" "Why would an increase in temperature affect your results?
Praise (PR)	Remarks that are directed to the "self" mainly to give encouragement or affirmation and contains little or no task-related information.	"You are doing great!" "Well done!" "Carried out the experiment well."

Categories	Definition	Examples
Others (OT)	Comments that are generic, ambiguous or unrelated to the task.	"He didn't finish because he was absent." "Improve on spelling."

Analysis of peer feedback statements by concepts of evidence

The scoring rubric (Table 44) developed in study two was used to analyse the students' use of concepts of evidence (Gott & Roberts, 2008) in formulating feedback. Peer feedback content is scored based on five key concepts of evidence—variable structure, fair-testing, choosing values, patterns and relationship in data, and reliability and validity of data/design.

Table 44. Scoring rubric for the use of 'concepts of evidence' in peer feedback content

'Concepts of Evidence' in Feedback	Description	0	1	2
Variable structure	Identifying and understanding the basic structure of an investigation in terms of variables and their types.	No or erroneous use.	State criteria on variables.	Elaborate on independent and dependent variables.
'Fair testing'	'Fair tests' aim to isolate the effect of the independent variable on the dependent variable. By changing the independent variable and keeping all the control variables constant, validity is ensured.	No or erroneous use.	State criteria on fair testing.	Elaborate on manipulating variables.
Choosing values	Making informed choices about sample, relative scale, range, interval and number of readings.	No or erroneous use.	State the criteria on values.	Elaborate on choice of values.
Patterns and relationship in data	Patterns represent the behaviour of variables so that they cannot be treated in isolation from the physical system that they represent. In this investigation, the relationship between temperature and initial rate of this reaction is linear/proportional and the pattern of association is seen as causal.	No or erroneous use.	State the relationship between variables.	Elaborate on types of relationships between variables and patterns in data.

'Concepts of Evidence' in Feedback	Description	0	1	2
Reliability and validity of data/design	Evaluating the whole investigation by considering the design of the investigation, ideas associated with measurement, with the presentation of the data and with the interpretation of patterns and relationships, in relation to reliability and validity of data.	No or erroneous use.	Cursory mention on reliability and validity.	Elaborate on aspects of reliability and validity.

Analysis of the effect of coaching on peer feedback

A chi-square test provided an initial analysis of the significance level in the difference between the treatment and control groups based on the frequency of feedback by types for the pre-test, followed by the post-test.

Repeated measures MANOVA technique was used to study the quality of the written peer feedback before and after the instructional intervention. The effects of coaching (predictor variable) were analysed based on frequency counts of peer feedback statements coded in terms of feedback levels (outcome variables). Effect size measures were based on Cohen's *d*.

Analysis of students' comments on giving and receiving peer feedback

Students' written comments about their perception of peer feedback were grouped based on common themes identified after transcript iterations. This resulted in the analysis of the perceived usefulness of peer feedback on three categories—source, function, and presentation.

RESULTS AND DISCUSSION

Effects of Explicit Instructional Support on Written Peer Feedback

Does explicit instruction on feedback levels (task, process, regulation, and self) lead to the formulation of higher quality written peer feedback?

The analysis of students' written feedback levels between pre- and post-test for the treatment classes showed that prior to instruction, students managed to formulate feedback mostly at the task (about 67%) and process levels (about 25%), with hardly any self-regulation level feedback (about 0.3%). In contrast, with explicit coaching and practice on differentiating and formulating feedback based on levels, students were able to provide their peers with feedback at task (about 64%), process (about 23%), as well as self-regulatory levels (about 9%). Moreover, there was a decrease in use of praise (from 4% to 2%), and likewise a reduction in feedback that was not related to criteria (from 4% to 2%). In the control class, there is an increase in task level feedback in the post-test (from 67% to 81%) but no indication of students formulating self-regulatory level feedback to their peers (from 2% to 0.3%). The results are shown in Table 45.

Table 45. Summary of peer feedback levels across treatment and control classes

	Treatment classes (N = 203)				Control class (N = 32)			
	Pre-test		Post-test		Pre-test		Post-test	
	n	%	n	%	n	%	n	%
Total task level feedback	1811	67.1	1681	63.9	334	67.7	265	81.3
Total process level feedback	669	24.8	609	23.1	114	23.1	44	13.5
Total self-regulatory level feedback	8	0.3	277	8.6	5	1.0	1	0.3
Total praise	100	3.7	55	2.1	12	2.5	3	0.9
Total 'others'	112	4.1	60	2.3	28	5.7	13	4.0
Total peer feedback	2700	100.0	2632	100.0	493	100.0	326	100.0

There were no statistically significant difference between the treatment and control groups in the frequency of feedback by types for the pre-test ($\chi^2 = 9.92$, $df = 4$, $p > .05$). Importantly, a statistically significant difference was found in the post-tests ($\chi^2 = 64.10$, $df = 4$, $p < .001$) and it was the much greater number of self-regulation feedback comments in the treatment group that was the major contributor (CR = 28.16, $df = 1$, $p < .001$).

The following table shows the descriptive statistics for peer feedback levels at pre- and post-test for each class (see Table 46). The pre-test results showed that students were able to formulate feedback to their peers at the task and process levels but hardly at the self-regulation level. When students were coached explicitly on peer feedback levels, all treatment classes indicated a larger increase (mean value from < 0.2 in pre-test to > 0.4 in post-test) in written peer feedback at the self-regulation level.

To compare the experimental groups on the five feedback levels, a repeated measures MANOVA was performed on peer feedback level scores for all eight classes. The results revealed an overall main effect for class and time, but more importantly, a time by class interaction (Table 47).

Table 46. Mean and standard deviation for each class on peer feedback levels in pre- and post-test

Classes	Task Level Feedback		Process Level Feedback		Self-Regulation Level Feedback		Praise		Others	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pre-test										
A	6.00	2.85	3.46	2.47	0.00	0.00	1.00	1.19	0.46	0.92
B	7.64	2.80	2.03	1.87	0.03	0.16	0.38	0.78	0.23	0.54
C	6.35	2.69	3.03	1.86	0.05	0.22	0.38	0.84	0.43	0.81
D	7.29	2.41	1.79	1.84	0.03	0.17	0.35	0.49	0.44	0.79
E	7.48	3.28	1.05	1.47	0.00	0.00	0.10	0.44	0.71	1.01
F	6.42	1.98	1.84	1.77	0.00	0.00	0.05	0.23	0.95	1.03
G	8.47	2.88	3.67	3.27	0.07	0.26	0.60	0.83	0.33	0.62
H (Control)	8.00	2.81	3.03	1.81	0.16	0.63	0.38	0.75	0.59	1.04
Post-test										
A	8.43	2.79	3.40	2.35	0.71	1.53	0.60	0.81	0.23	0.65
B	7.21	2.17	4.41	2.31	1.44	2.27	0.05	0.22	0.05	0.22
C	7.13	2.72	2.95	2.41	0.73	1.34	0.08	0.35	0.45	0.68
D	6.71	2.36	1.62	1.79	1.24	1.69	0.50	0.79	0.24	0.43
E	8.81	3.19	2.00	1.55	0.71	1.79	0.14	0.36	0.29	0.56
F	6.95	2.99	2.11	1.45	0.42	0.77	0.11	0.46	0.37	0.60
G	7.33	2.80	1.47	1.30	2.00	2.39	0.33	0.62	0.13	0.35
H (Control)	8.03	2.62	1.22	1.16	0.03	0.18	0.09	0.30	0.41	0.67

Table 47. Repeated measures multivariate test on class effects over time

Effect	Wilks' Lambda	*F*	df	*p*
Class	0.546	4.159	35	0.001
Time	0.731	16.449	5	0.001
Time*Class	0.520	4.525	35	0.001

An inspection of univariate tests on time by class using the Greenhouse-Geisser correction indicates that there were significant differences for task level feedback, *F*(7,

227) = 3.63, *p* < .001; process level feedback, *F*(7, 227) = 11.29, *p* < .001; and, self-regulation level feedback, *F*(7, 227) = 3.73, *p* < .001. Praise and other feedback were not statistically significant. The results of this analysis are shown in Table 48.

Table 48. Comparison of time and class effects on feedback levels

Effect	*F*	df	*p*
Task level	3.63	7	0.001
Process level	11.29	7	0.001
Self-regulation level	3.73	7	0.001
Praise	1.75	7	0.098
Others	1.00	7	0.430

The plots of mean difference between pre- and post-test for task, process and self-regulation levels are shown below (Figure 10, Figure 11, and Figure 12).

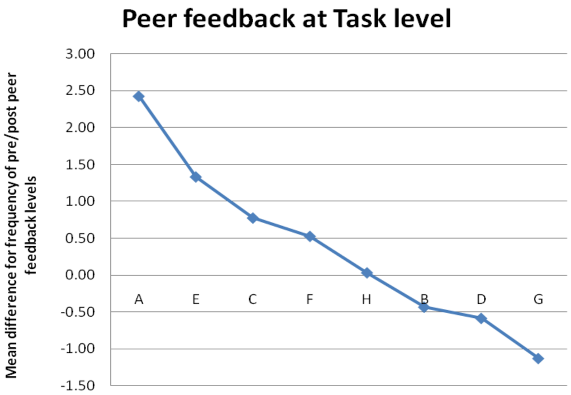

Figure 10. Mean difference for pre- and post-test on peer feedback at task level

Students in classes A, E, C, and F provided more task level feedback from pre- to post-test while students in B, D and G provided lesser task level feedback after the intervention. Students in the control class H appeared to have little change in formulating task level feedback.

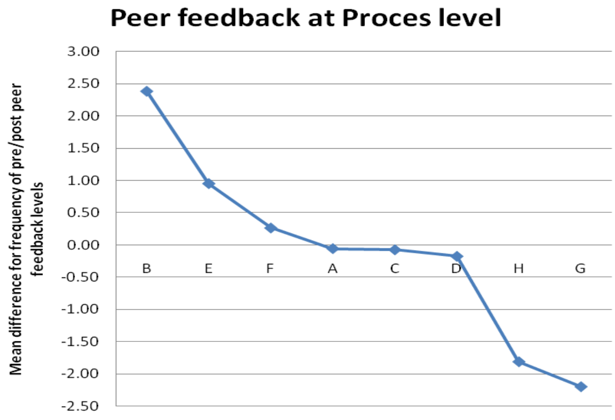

Figure 11. Mean difference for pre- and post-test on peer feedback at process level

While there was little difference in providing process level feedback for classes A, C and D, students in B, E and F formulated more process level feedback after intervention. Students in G and H showed a decrease in the frequency of process level feedback provided (see Figure 11).

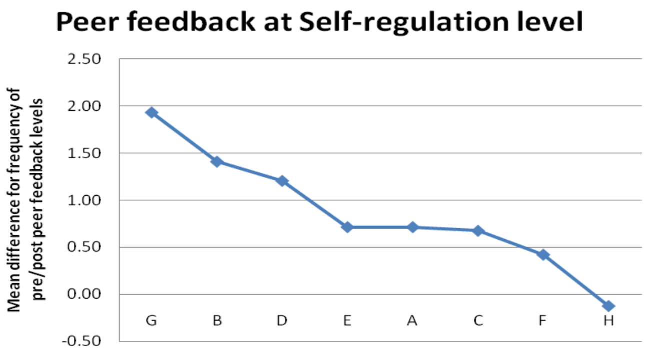

Figure 12. Mean difference for pre- and post-test on peer feedback at self-regulation level

In this plot (Figure 12), students in all the experimental classes showed an increase in the frequency of self-regulation level feedback formulated, which was not observed in the control class H.

A closer look at the effect size of individual classes (see Table 49) showed that for all the treatment classes, there was a large effect on students providing more self-regulation level feedback to their peers (d > .80). This was not observed in the control class, which showed a low effect for all three feedback levels (d < .01).

Table 49. Effect size of feedback levels by class

Classes	N	Effect sizes*					
		Total Peer Feedback	Total Task Level Feedback	Total Process Level Feedback	Total Self-Regulatory Level Feedback	Total Praise	Total 'Others'
A	35	0.71	0.86	-0.02	0.94	-0.40	-0.29
B	39	1.00	-0.18	1.14	1.16	-0.66	-0.47
C	40	0.46	0.29	-0.04	0.87	-0.51	0.03
D	34	0.14	-0.25	-0.10	1.30	0.23	-0.34
E	21	0.73	0.41	0.63	0.80	0.12	-0.55
F	19	0.23	0.21	0.16	1.10	0.15	-0.71
G	15	-0.51	-0.40	-0.96	1.46	-0.37	-0.41
H (Control)	32	-0.90	0.01	-1.22	-0.31	-0.54	-0.22

* Effect sizes in terms of Cohen's d

This finding indicates that, instructional intervention which engaged students to recognise and differentiate feedback at task, process, self-regulation, and praise, and providing opportunities to practice and interpret different feedback levels (using graphic organiser and question prompts), enhanced students' ability to generate higher-order peer feedback. This higher-order peer feedback was seen as self-generated questions that prompted students to regulate their learning. The progression from predominantly formulating task level feedback to more regulatory level feedback also suggests that students acquired a more diverse notion of feedback that included corrective statements on declarative or procedural knowledge, as well as reflective questions that directed attention of the learner to conditional knowledge and strategies. By formulating feedback in the form of reflective questions, the students demonstrated an understanding of the hierarchical nature of feedback and how best to guide their peers towards thinking further about their work. Examples of peer feedback statements at the self-regulatory level are shown in Table 50.

Table 50. Comparison of peer feedback statements for the same entry in pre- and post-test

Students	Peer Feedback Written At Pre-Test	Feedback Level	Peer Feedback Written At Post-Test	Feedback Level
Alfred	The student can give a reason why or how the temperature would affect the rate of the reaction.	Task	How does the reason link to the explanation? Why does hydrochloric acid react faster at a higher temperature?	Self-regulatory
	The student should have given an example to show that there is a trend in the result of the investigation.	Process	Do you think you have repeated some points? Do you think you should do something about the limitations so that the results are more accurate?	Self-regulatory
Susan	The student showed that the results matched his prediction. Describe more details.	Task	So, what if the results match your prediction? What happens if you include more readings?	Self-regulatory
	Explain the limitations.	Task	What theory is used to explain this in terms of rate of reaction conditions?	Self-regulatory
Gary	The student did not explain why or how the temperature affected the rate of reaction.	Process	What did you do to keep the temperature constant? What happened if you take different size of the snail shell and how will this affect the result?	Self-regulatory
	One of the headings [in the table] is wrong. It should be ‘after 5 min in acid of shell’ instead of ‘mass after 5 min in acid’.	Task	What did you do to obtain a more accurate result? What can you conclude from this experiment?	Self-regulatory

Content of Peer Feedback

What is the effect of coaching in the use of concepts of evidence in written peer feedback?

The analysis of the content of peer feedback showed that students’ use of concepts of evidence had increased after intervention (Table 51).

Table 51. Overall mean and standard deviations for use of concepts of evidence for all classes

Condition	Variable Structure *M*	Variable Structure *SD*	Fair Testing *M*	Fair Testing *SD*	Choosing Values *M*	Choosing Values *SD*	Patterns and Relationships *M*	Patterns and Relationships *SD*	Reliability and Validity *M*	Reliability and Validity *SD*
Before intervention	1.04	.691	.92	.808	.31	.560	.21	.425	.76	.592
After intervention	1.23	.607	1.03	.817	.37	.660	.36	.516	1.06	.485
Effect sizes	.29		.14		.10		.32		.56	

A comparison of the experimental groups with the control group using repeated measures MANOVA was performed for peer feedback statements coded based on concepts of evidence. The results showed an overall main effect for class and time, and more important a time by class interaction (Table 52).

Table 52. Repeated measures MANOVA on class effects over time

Effect	Wilks' Lambda	*F*	df (Error)	*p*
Class	0.618	3.315	35(957.3)	0.001
Time	0.768	13.697	5(227.0)	0.001
Time*Class	0.751	1.927	35(957.3)	0.001

An inspection of univariate tests on time by class using the Greenhouse-Geisser correction indicated that there were significant differences for including fair-testing in peer feedback, F (7, 957.3) = 3.55, $p < .001$ and, use of reliability and validity concepts in peer feedback F (7, 957.3) = 3.08, $p < .005$. The results of this analysis are shown in Table 53.

Table 53. Comparison of time and class effects on feedback levels

Effect	*F*	df	*MS*	*p*
Variable structure	1.027	7	0.357	0.413
Fair-testing	3.549	7	1.395	0.001
Choosing values	1.514	7	0.389	0.163
Patterns and relationships	1.158	7	0.247	0.328
Reliability and validity	3.076	7	0.635	0.004

The analysis of effect size further indicated that although there was much variance across the experimental classes, the students in most experimental classes still used more concepts of evidence in their peer feedback compared to control class (Table 54).

Table 54. Effect size of concepts of evidence used in peer feedback by class

Classes	N	Effect sizes				
		Variable Structure	Fair Testing	Choosing Values	Patterns And Relationships	Reliability And Validity
A	37	0.32	0.03	0.17	0.35	0.24
B	40	0.39	0.72	0.31	0.29	0.85
C	40	0.30	-0.18	0.28	0.60	0.42
D	34	0.37	0.38	-0.10	0.21	1.05
E	21	0.77	0.28	0.14	0.77	0.94
F	19	0.26	-0.61	-0.29	1.08	0.82
G	16	0.09	0.33	-0.83	-0.31	0.63
H (Control)	32	-0.26	-0.19	0.00	0.08	-0.06

Student Perception of Usefulness of Peer Feedback

Most comments showed that students welcomed peer feedback, found peer feedback useful and described some positive aspect of using peer feedback in their work. Three main categories were used for classifying students' perception of peer feedback usefulness—source, function, and presentation. Most students view the source of peer feedback in terms of its trustworthiness, credibility and accuracy. Functional aspects, such as providing corrective or elaborative information, motivation and opportunities for idea sharing and reflection on mistakes, also influence their perception of usefulness of peer feedback. The third category is presentation, as indicated by students' responses on clarity, specificity and being judgemental in peer feedback.

What do students' perceive as most useful in peer feedback?

When commenting on usefulness of peer feedback, a large majority of students considered the functional aspect as important. For example, peer feedback could serve a corrective function, "I would know the reasons of why I did well and why I did not, and from there I can improve my work by following their feedback"; an elaborative function, "Peer feedback gives me ideas that I do not know and this can definitely improve my work"; or a reflective function, "His views, opinions and constructive comments made me think deeper about my work".

Peer feedback was also perceived as useful when it came from a truthful, credible, and accurate source. Students commented that peer feedback which was trustworthy and honest was useful to them. For example:

> I find honest, constructive feedback most helpful.

> It would be on his feedback's truthfulness; if he is not truthful, I will not be able to accept it.

Peer feedback was credible when provided by peers of equal status, which was seen as less critical (compared to teacher feedback), more understanding, and pitched at a level that they can relate to. For example:

> They are able to understand our difficulties and situation better as they have done the same things too. The feedback they give is also less harsh, more encouraging and constructive" or "I find that my peers can relate to me at a more personal level, and give me feedback which is more easily understood than my teachers. I think my peers are able to explain in a simpler way, thus, it is easier to relate to.

Most students perceived accuracy in peer feedback as a prerequisite and highlighted the lack of it as least useful. For example:

> My peer's feedback may not be accurate all the time. This makes it less useful.

What do students' perceive as least useful in peer feedback?

When it came to the least useful peer feedback, most students commented on source and presentation aspects, with *credibility* as the main limitation. Not surprising, students found feedback from peers lacking in reliability (Falchikov & Goldfinch, 2000; Nilson, 2003; Topping, 1998). This took the form of peer's lack of content knowledge, harbouring misconceptions, and explanations that lacked depth or focus. For example:

> It may not be entirely accurate or useful as peers are not really as knowledgeable as a qualified teacher or senior.

Peers may also be perceived to be deficient in assessment skills such as error detection, understanding, and using of criteria as well as translating their evaluations in a constructive and meaningful way. For example:

> They may not really understand what difficulties I might have.

> They don't know how to explain my mistakes to me.

From a social perspective, the intrusion of personal feelings and emotions into the feedback process may have reduced the effect of the feedback. For example:

> The least useful thing is that peer feedback is sometimes biased. This will give me inaccurate information.

> Feedback is least useful when they add their personal feelings in it.

Personal motivation to be involved in the feedback process was another limitation, as peers may have lacked effort in formulating feedback, or they simply did not provide any feedback at all. For example:

> I find it least useful as my peers may not do the feedback seriously.

Presentation of peer feedback was seen as less useful when the feedback was incomprehensible, non-specific, and judgemental or personal. For example:

> My peer's feedback is vague and confuses my understanding of a certain concept.

I may get upset and insulted by their feedback if they are personal.

How do students use peer feedback in their work?

The analysis of written comments on the way students use peer feedback revealed an interesting array of views which can be classified into four main categories— receptive-transmission, processing, holistic, and indifference (Table 55).

Table 55. Student's view of peer feedback in revising their work

Categories	Description	Examples
Receptive-transmission view	Peer feedback provides information on what, where and how to take corrective action. The role of learner is to follow, carry out and remember the corrections, in order not to "repeat the same mistakes again".	"I can use the feedback from my friends to revise on what I need to do better. This also helps me to remember my weak points and avoid making the same mistakes the next time."
Processing view	Peer feedback provides alternative viewpoints, ideas and suggestions that help the learner to make comparison with their own understandings, make decisions on choice of strategies and further corrective actions. The learner may compare peer feedback with other peers or with feedback from the teacher.	"I can use peer feedback to look at things from a different point of view." "My peers gave me a different perspective on my work, enabling me to make comparison and choose the best alternative."
	Peer feedback allows the learner to reflect, monitor and think deeper about their work. The learner is able to initiate his or her own corrective actions and come up with new ways of improving their work.	"I can use her feedback to formulate questions and hence, improve my answers." "I can reflect on my own mistakes...the more mistakes you see, the more you know how to identify what's good and what's not, which is very beneficial to everyone."
Holistic view	Peer feedback serves as a form of motivation, guidance or advice to enhance the learning experience. The learner may adopt a positive attitude towards learning, and strive to change undesirable habits or practices.	"They encourage me and make me more motivated to do my best." "I will try to do what my peers suggested, because this is for my own good."
Indifference view	Peer feedback has little or no effect on the learner. The learner is satisfied with the current work or understanding, and sees no reason to exert effort in using peer feedback. In most cases, the learner failed to recognise the importance of peer feedback.	"Not really useful. I believe in myself." "I don't see how my peer's feedback can improve my work."

Besides showing that students held differing views about using peer feedback, this analysis also illustrates how students perceived peer feedback as not only having a corrective or elaborative function, but that it supports their own calibration by helping them recognise important cues and monitor task engagement. Butler and Winne (1995) suggested that *calibration* involved making accurate associations between cues and achievements, and feedback that focused learners on the relationship of cues' values to performance was seen as essential for self-regulation. For example, "by comparing and contrasting peer feedback with my work, I can then spot my own mistakes more easily". Another example of using peer feedback to enhance calibration was described by a student:

> I failed when I tried to do my titration. My friend gave me feedback on how to make the corrections. After using the feedback received to evaluate myself, I tried to do the titration again. Then, I compared the results before the feedback and after using the feedback to evaluate my own work.

Drawing on Butler and Winne's (1995) findings that students' beliefs and understandings may filter the effects of feedback, the different viewpoints identified in this analysis may indicate that students' perception of how to use peer feedback further influences how peer feedback is interpreted and internalised.

Another notion that came up when analysing students' views on using peer feedback was that the uncertainty in peer feedback may be seen as an opportunity for peers to engage in discourse involving further clarification, comparisons, and justifications. In other words, *disconfirmation* in peer feedback may be a positive avenue for learning. Most research on peer feedback focused on the need for feedback information to be accurate and detailed (Gielen et al, 2010), and attempted to guide feedback givers by elaborate criteria, and review templates (Prins et al., 2006) ensured that the 'right' feedback was provided. While there was a need to keep feedback 'error free', the possibility of peers using the feedback for further discussion may have been short-changed.

Comments on Instruments and Limitations

The focus of this study was on formulating peer feedback. As such, the focus was on analysing peer feedback responses, that is, the students' written peer feedback in terms of task, process, self-regulation, and self levels. This invariably captured only a slice of the feedback discourse that may occur during the learning process, which further suggests that students' verbal interactions may also have been investigated. In formulating peer feedback, students may have consulted and discussed their ideas and thoughts with other, and it would be interesting to examine the possible mediating effects that peer discussion may have on the peer feedback provided. In relation to feedback discourse, using a pre-designed test report instrument may have provided valid comparison of pre- and post-test responses, but this may also have constrained students in communicating their feedback at different levels. In short, what was observed and analysed was limited by students' ability and willingness to convey that message in writing.

Another possible limitation was the duration of the intervention, which was short given the type of extended coaching required for higher-order skills such as generating self-regulating questions and evaluating peer's work in relation to learning criteria. It would be interesting to see the development of students' peer feedback skills with a longitudinal research design.

CONCLUSION

Summary of Findings

The results of this study indicated that coaching students to formulate peer feedback at task, process, and regulation levels had a significant impact on the quality of feedback students provided on written laboratory reports. The emphasis on interpreting feedback at different levels and on matching feedback to the level in which the report was written during coaching helped students provide more differentiated feedback. Results on pre-test indicated that students predominantly provided task level feedback to their peers, with hardly any feedback at the regulation level. When students were explicitly coached on how to differentiate the feedback at task, process, regulation, and self levels, they were able to formulate more feedback at the regulation level. This was evident in the post-test results and thus, the findings of this study supported the argument for coaching students in formulating more meaningful peer feedback responses.

The qualitative analysis of students' perception about peer feedback usefulness suggests that giving and receiving peer feedback was a potentially enriching experience because it allowed learners to identify their learning gaps, collaborate on error detection and correction, and develop their ability to self-regulate, including monitoring their own mistakes, and initiating their own corrective measures or strategies.

Implication for Teaching and Learning

First, the notion of peer learning through the use of peer feedback does not usually occur without instructional support of some kind. In this study, although students were provided with feedback forms and criteria for evaluating lab reports, there was no guarantee that meaningful peer feedback was provided to enrich the learning experience. This was the case for the control group, which failed to show any change in the students' feedback levels even after practise using the feedback form and criteria. According to research on peer learning (e.g., O'Donnell, 2006; Topping, 1998), students needed to possess the necessary skills to collaborate as well as to engage one another in elaborative cognitive restructuring, rehearsal, or joint deliberative practise. This implies that teachers need to take into consideration students' skills in giving and receiving peer feedback, and how to support these skills before implementing peer feedback in class.

Second, the findings of this study showed that instructional support in the form of a visual graphic organiser with explicit examples may enhance the learning experience of students in formulating feedback to their peers. The graphic organiser provides a common platform for teachers and students to engage in discussing how each feedback level can be formulated, the relation to other levels and the matching of levels (as well as challenge) to the receiver's understanding or response. It is important to note that the criteria for laboratory reports needs to be clearly communicated to the students, in order to facilitate their use of criteria in formulating feedback at the different levels. Explicit examples help students to visualise the link between criteria and the feedback levels generated.

Third, conceptualising feedback in terms of levels (task, process, regulation, and self) provides teachers as well as students with a working definition of what feedback looks like and how it can be interpreted and applied to learning. For example, the notion of feedback at the self level means that students need to interpret the feedback carefully and in relation to the task, and not to take it personally. When students are able to visualise feedback levels as a progression in relation to their work, they may interpret the feedback differently and adopt relevant strategies to improve or revise their work. Feedback at the task level will probably require more basic information while feedback at the regulation level will prompt students to focus on conditional knowledge and strategies to improve their work.

Fourth, the practice of giving and receiving peer feedback at different levels opens up opportunities for formative assessment discourse in the classroom, especially in building students' (as well as teachers) capacity for assessment by drawing attention to evaluating criteria, reviewing learning goals and communicating meaningful feedback.

Implications for Further Research

The significance of this study can be attributed to the following three aspects:

1. Building on a theory of feedback in relation to task, process, and regulation to develop instructional support for peer feedback (i.e., from a dichotomous view to one of progression).
2. Providing further evidence that coaching is a pre-requisite for students to provide quality feedback responses.
3. Developing a coding scheme to characterise the quality of peer feedback in terms of levels.

This study investigated the effects of coaching for peer feedback on secondary students' ability to comment on laboratory report. With the increasingly important role of peer learning and peer assessment, more research is needed to inform quality peer feedback practice in the classroom. The multidimensional nature of feedback suggests that future research can examine peer feedback in a number of different areas.

First, more research can be conducted to address the question of how the formulation of feedback levels can help students to interpret and use feedback to improve their own learning? For a start, research can be conducted to investigate the impact of different feedback levels on students' uptake and revision.

Second, it would be useful to study the different aspects of the coaching process to determine the most useful activities for engaging peers in formulating feedback at the regulation level.

Third, we need to examine whether the effects of coaching are applicable to actual collaborative peer feedback situations. This will probably involve studying the effects of coaching on individual performance, group performance and possible interaction effects.

A fourth suggestion for future research is to examine the impact on teachers in developing feedback levels for instructional intervention and giving feedback to learners.

CHAPTER 6
DISCUSSION AND CONCLUSIONS

INTRODUCTION

The research presented here has examined the effects of prompts and explicit coaching on peer feedback quality by building on the feedback model postulated by Hattie and Timperley (2007). The feedback model postulated two orientations in which the learner can interact with feedback—by focusing on the consequential aspect of feedback (asking the three major questions) and by targeting cognitive and meta-cognitive engagement at three different levels (task, process, and self-regulation). As explicated in the model, effective feedback involves answering three questions—Where am I going? How am I going? Where to next? It follows that a key quality indicator of peer feedback is the consequential impact of feedback, which in this research, is represented by the suggestions for improvement and the uptake for revisions. Another quality indicator developed from the feedback model is the notion of cognitive and meta-cognitive engagement with peer feedback. This perspective draws from the observation that feedback is powerful when it focuses the learner on task, process and self-regulatory skills and knowledge in relation to the learning task.

Building on this feedback model as well as the review of feedback literature, four assertions were derived to frame the empirical research.

1. Peer feedback is meaningful when it is integrated into a cycle of learning.
2. Peer feedback is useful when it provides information to identify where the learner is at, direct attention towards the learning outcome and indicates how best to achieve this outcome.
3. Peer feedback is powerful when it cues the attention of the learner to the learning task, task processing strategies and self-regulation strategies instead of directing attention to the self.
4. Peer feedback levels are viewed as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.

Study One provided a baseline view of the role of peer feedback during a collaborative chemistry investigative task. One key observation from the peer discourse in Study One suggests that peer feedback is an inherent feature of classroom collaborative learning. Students invariably turn to their peers for feedback when carrying out an investigative task and this feedback is usually implicit, unstructured and may positively or negatively influence their learning when they work on the task. In order to harness the power of peer feedback, there is a need to look at ways of providing explicit instructional support that promotes and enhances the way students engage with peer feedback during the learning process.

Study Two investigated assertions 1, 2, and 3 by designing question prompts to scaffold the identification of learning gaps and support the generation of peer feedback with suggestions for improvement. While the prompts helped students provide suggestions that resulted in uptake and revision of their work, they were not sufficient to guide learners in generating feedback that targeted the three different feedback levels.

Study Three examined the use of explicit coaching to support learners in providing peer feedback that was targeted at the task, process, and self-regulation levels. Assertion 4 was found to be productive for developing the notion of peer feedback quality. Recognizing peer feedback as a progression was a key step in helping students engage meaningfully with peer feedback. Being aware of the different levels in which feedback works allowed students to generate more differentiated feedback and facilitated the cognitive and meta-cognitive engagement with the feedback message itself.

This concluding chapter brings together the findings of the three studies to highlight the importance of meaningful engagement with peer feedback and how this can be supported through the use of prompts and explicit coaching. The significant contributions of this research are drawn out in relation to the four assertions.

PEER FEEDBACK AS INTEGRAL TO A LEARNING CYCLE

Assertion one suggests that *peer feedback is most meaningful when it is integrated into a cycle of learning.* This idea of situating peer feedback within a learning context (semi-open investigative task) was developed throughout the research and provided the basis as well as opportunity for peers to engage in a more interactive peer feedback discourse.

In Study One, the students' communicative approach was identified as predominantly interactive in nature, while moving between authoritative and dialogic modes of discourse. The semi-open nature of the investigative task, which required students to plan and implement the experiment, generated a learning context that fostered collaborative discourse and allowed students to engage with the peer feedback, as observed in the IRF interaction patterns. It can be seen from the findings of Study One that peer feedback moves occurred through the negotiation of meaning when students engaged in planning and implementing the investigation. Discursive feedback moves involving scaffolding and elaborations helped students to build ideas as well as discount ideas. Here, the findings suggested that providing an engaging learning context was important, but insufficient, to ensure that students were able to leverage on peer feedback to enhance the quality of their discussion. Research that examined ways of helping students to engage in specific dialogic strategies for collective thinking concurred on this point (Mercer & Littleton, 2007; Rojas-Drummond & Mercer, 2003). In other words, to bring about meaningful peer feedback discourse, instructional support for ways of talking is warranted.

To further develop this notion of a learning cycle, feedback from peers should be thought of as an on-going activity and not just at the end of the learning process. In Study Two, the two peer feedback cycles could be seen as providing opportunities for peers to engage with giving and receiving immediate written comments to each other regarding what they did well, what they failed to do well, and suggestions that would help to improve their work. It involved creating a meaningful context for peer feedback whereby students could see giving and/or receiving feedback as part of the learning task, in this case, from planning to *reviewing* and revising the plan, and then from implementing to *evaluating* and finally completing the full report on the investigation. Situated in this learning context, students engaged with peer feedback in a recurring and purposeful way, and uptake of feedback for revision was enhanced. Providing opportunities for peers to engage with the feedback for revision or further negotiation of meaning recognises the importance of acting on the peer feedback provided (Gibbs & Simpson, 2004; Gielen et al., 2010).

In Study Three, analysis of students' written perception of usefulness of peer feedback demonstrated that students were encouraged to make choices about using the peer feedback received for revision of their work. Here, students saw peer feedback as an alternative viewpoint, or as a different approach to the task, rather than searching for the 'right' answers. This dissatisfaction with their own work provided the impetus for exploring other viewpoints and make informed comparisons. In other words, students recognised the value of peer feedback as a response for their own work and this created a context in the form of a reader-writer relationship that promoted purposeful use of peer feedback (Hyland & Hyland, 2006, p. 2).

IDENTIFY WHERE YOU ARE, KNOW WHERE YOU ARE GOING AND HOW BEST TO GET THERE

Although peers may engage in giving and receiving feedback during the learning cycle, in most instances, the peer feedback provided may be lacking in quality if unsupported. This can be seen in the case of Study Two, where students in the control group (without prompts) continued to formulate feedback that was lacking in suggestions for improvement in both feedback cycles. This research has argued for the need for instructional support in peer feedback. In particular to draw the link between effective support and peer feedback one needs to consider the nature and quality of feedback generated by the students to their peers. Adopting Hattie and Timperley's (2007) feedback model, this study developed two interrelated notions of peer feedback quality—the identification of a learning gap with suggestions for improvement, and provision of differentiated feedback to help focus the learner on task, process, and self-regulation levels of understanding.

Assertion 2 suggested that *peer feedback is useful when it provides information to identify where the learner is at, directs attention towards the learning outcome and indicates how best to achieve this outcome.* To be effective, peer feedback should cue learners to identify the learning gap and provide suggestions for improvement. In supporting this notion of peer feedback, question prompts were designed in Study Two to scaffold the formulation of peer feedback with reference to the task criteria. The use of criteria in formulating peer feedback allowed students to see their performance against those learning goals. This might improve the process of identifying the learning gap, while at the same time clarifying the learning goals. The findings of Study Two showed that peer feedback formulated with the use of question prompts was more focused, structured, and informative than feedback without the question prompts. Prompts, as a form of instructional support, were seen as effective in scaffolding the process of formulating peer feedback by directing the attention of students to what they did/did not do well and provided suggestions to revise their work. This study further showed that prompts elicited more peer feedback with suggestions for revision, which led to uptake of these suggestions by the students. While previous research focused on the effects of peer feedback types on learning outcomes (Dochy et al., 1999; Falchikov & Goldfinch, 2000), this study has pointed to the link between prompts and supporting peer feedback quality. This is an important contribution because it demonstrates that question prompts which direct students' attention to identifying the learning gap and providing improvement suggestions can serve as effective supports to students in formulating productive peer feedback.

The finding that prompts are an effective support for peer feedback is similar to that of previous research, which found that superficial processing of learning strategies by the learner can be overcome by using cognitive/meta-cognitive prompts that act as "strategy activators" (Berthold et al., 2007; Davis & Linn, 2000; Lin & Lehman, 1999). In Study Two, the prompts cued the students to draw comparisons between the learning criteria and the work done (peer's written report) by evaluating what was or was not done well. At the same time, students have to come up with suggestions for improvement which required them to think of possible ways of 'closing' the gap by revising their partner's work. In short, the prompts explicitly guided the students in identifying the learning gap and then invoking revision actions.

Students in the prompted condition were found to have a greater uptake of suggestions for improving their reports as compared to the unprompted condition. One possible explanation is that students saw the *relevance* in the feedback as they shared a common goal of task completion (through reciprocal peer feedback). McCrudden, Schraw, and Kambe (2005) described 'relevance' as the extent to which text segments are germane to a reader's goals and the 'relevance effect' as the facilitative effect of relevance on learning. The relevance effect occurs when text segments match the 'particular goals, purpose, task, or learning outcome' and the reader is able to engage in information search and construct meaning representations in a goal-directed manner (McCrudden, Schraw, & Hartley, 2006). Here, the prompted evaluation and feedback process was a type of relevance manipulation, where there is purposeful reading of the work done and based on the evaluation criteria; (McCrudden & Schraw, 2007; Wilson & Sperber, 2004). By articulating the criteria in relation to the work done in the form of feedback to their peers, students established a standard for their work (Orsmond, Merry, & Reiling, 2002). It appears that when students saw the relevance of criteria to their own learning goal, they were more willing to interpret and use peer feedback, leading to uptake of suggestions for revision.

ENGAGING PEER FEEDBACK

In assertion 3, *peer feedback is seen as powerful when it cues the attention of the learner to the learning task, task processing strategies, and self-regulation strategies instead of directing attention to the self.* This extends the quality concept for peer feedback to include the notion of cognitive/ meta-cognitive engagement and is akin to the quality indicator of 'depth of feedback'. In other words, besides identifying a learning gap, peer feedback at the three levels relates this learning gap to the learner's cognitive and meta-cognitive learning process and outcomes.

To find out if learners can be supported to formulate feedback at the three levels, Study Three was designed to give one group of students explicit coaching using a graphic organizer with feedback levels, while another group of students was not provided with instructional support on the feedback levels. The graphic organizer was designed with question prompts that guided students in identifying the current level of work done by their peers in relation to the criteria, and then they generated feedback that would *match* or *challenge* that level of understanding. The findings indicated that students who were taught to identify and give feedback at the three levels formulated more feedback at the self-regulation levels compared to students who were not given any instruction on feedback levels. This suggests that students can be taught to formulate peer feedback of greater depth by scaffolding their use of knowledge of cognition (declarative, procedural, and conditional knowledge) as well as their monitoring process when giving feedback to their peers. Building on previous research on training peer feedback skills (Min, 2005; Sluijsmans et al., 2002; Van Steendam et al., 2010), the findings extended the notion of peer feedback quality by demonstrating a means of evaluating the quality of peer feedback as a progression from task to self-regulation levels.

The conceptualization of peer feedback as information at task, process, and self-regulation levels and incorporating it in the empirical Studies of Two and Three helped to operationalise the feedback model (Hattie & Timperley, 2007) within a classroom context. The development of a coding scheme as well as a graphic organizer for peer feedback information led to the refinement of what feedback looked like at each level of engagement. From a methodological perspective, the coding scheme provided a useful way to analyse peer feedback responses. When viewed from a theoretical perspective, the feedback levels incorporated both cognitive and meta-cognitive dimensions into a learning progression that enabled learners to be aware of their own cognitive processes and to engage in co-regulation, or self-regulation, with respect to the learning task.

The findings of this research have helped to shape the development of ideas in relation to task, process and self-regulation feedback levels as first postulated by Hattie & Timperley (2007). Task level feedback was first conceived as basic task information. Further clarification led to a refinement of the definition to knowledge of correct response. The repeated iterations and re-reading of the peer feedback statements then resulted in adopting *declarative* knowledge as task level information (see Table 56).

Table 56. Developing the notion of peer feedback at task, process and self-regulation levels

Main category	Definition in Study One	Definition in Study Two	Definition in Study Three
Task-level	Following given information to carry out the task.	Provides information about the correctness of the learner's responses. Also informs the learner of the correct answer, but without suggesting how to revise the response. May provide indication of error/incorrect response or location of mistakes.	Provides declarative knowledge or information about the correctness of the learner's responses. Also informs the learner of the correct answer, but without suggesting how to revise the response.
Process-level	Adopting strategies to engage the task.	Provides strategies/cues/hints/ examples for error detection, information search or steps to revise report. May suggest explanation or justification for correct/incorrect response and reason for the use of a particular search strategy or revision approach.	Provides procedural knowledge or strategies and examples for error detection, information search, or steps to carry out revision of work done.

Main category	Definition in Study One	Definition in Study Two	Definition in Study Three
Self-regulation level	Monitoring and self-evaluating task progress.	Provides reflective or probing questions that guide the learner in self-evaluation, seeking additional information, or monitoring of learning progress.	Provides conditional knowledge, usually in the form of reflective or probing questions, which guides the learner on when, where and why in selecting or employing task and process level knowledge and strategies. Peer feedback at this level helps to identify the demands of the specific learning situation and directs attention to strategies that are most appropriate for that situation.

The notions of process level and self-regulation level feedback were also deliberated and elaborated in light of the research findings (see Table 56). Process level feedback shifted from the use of strategies to incorporate a wider notion of *procedural* knowledge. While self-regulation level feedback was initially defined as self-monitoring or self-evaluation, this proved difficult as a coding scheme for peer feedback, which mostly consisted of statements that were directed at a peer rather than to oneself. The research findings indicated that peer feedback which involves monitoring and thinking about one's actions and ideas may take the form of reflective or probing questions. This led to the notion of *conditional* knowledge, which was evident from feedback questions asking a peer to focus attention on 'when' and 'why' to adopt or use a strategy or approach. By viewing self-regulation level as conditional knowledge, peer feedback takes on a meta-cognitive role. This is a significant contribution as it provided not only a functional coding scheme but also allowing students to understand, recognise and engage meta-cognitively with peer feedback.

PROGRESSIVE VIEW OF PEER FEEDBACK

The 'mechanism' of formulating peer feedback at a higher level may be attributed to students' awareness of a learning progression in terms of feedback levels and their ability to visualize the feedback levels when writing the feedback in relation to the learning task. Assertion 4 suggests that learners and teachers need to *recognize peer feedback levels as a learning progression, with information that moves the learner from basic task understanding to self-regulatory skills.* This means that for feedback to be effective, it must match the learner's current level of understanding and provide sufficient challenge so that the learner will put in effort to move to the next level. The level of cognitive and meta-cognitive engagement of the learner with the feedback is seen as crucial for interpreting and using feedback meaningfully.

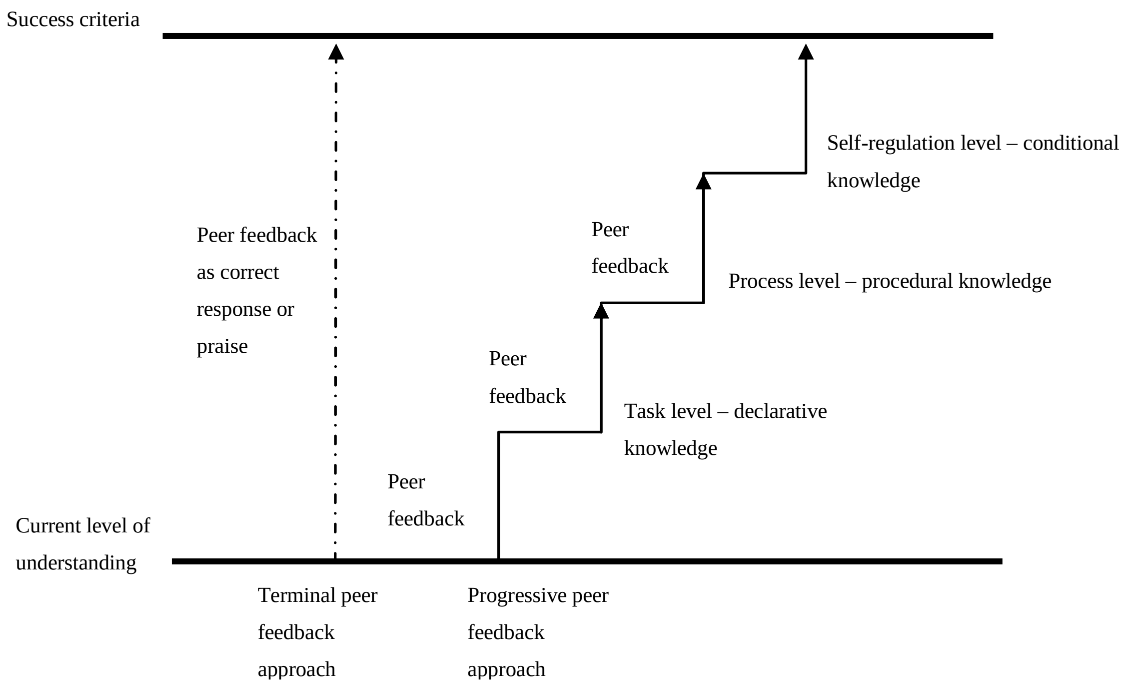

Figure 13. Comparison of peer feedback as a terminal activity and a learning progression

To develop this notion of feedback as progressive information, students were coached to identify what knowledge was required for each level and how to generate feedback that was targeted at that level of understanding. Prompting and coaching were seen as instructional support for cognitive and/or meta-cognitive engagement with the peer feedback. In contrast, the unprompted or untrained students seemed to adopt a 'terminal' feedback approach where the solution or right answer was provided and praise was used to reinforce the notion of a correct response. The progressive peer feedback and terminal feedback approaches are illustrated in Figure 13.

The terminal peer feedback approach assumes that students are capable of drawing inferences or making judgments based on the corrective information and then decide on the corrective action to move from their current state of understanding to meet the success criteria. While it may seem probable for higher-ability students to come up with their own revision strategy, this will not likely be the case for lower-ability students. Conversely, the progressive peer feedback approach provides students with a mental picture that breaks down the feedback into concrete steps, allowing students to focus on a specific area to work on. This organization of learning and feedback may be seen as reducing the demand on the student's cognitive resources, enabling them to draw connections and identify the learning gaps and take corrective action. The notion of reducing cognitive load by using a graphic organizer with hierarchical feedback levels is supported by research which demonstrated that visual/spatial displays facilitate *computational offloading* in learners by making explicit the complex relationship inherent in the learning task (Cheng, Lowe, & Scaife, 2001; McCrudden, Schraw, Lehman, & Poliquin, 2007; Vekiri, 2002). For example, the findings of an investigation involving readers who studied adjunct displays (causal diagrams and lists), or read a text, showed that adjunct displays improved comprehension of causal relationships by explicitly representing a text's causal structure (McCrudden, Schraw, & Lehman, 2009). The authors suggested that adjunct display made relevant information salient to the learner, reduced cognitive effort, provided an integrated retrieval structure, and reduced the burden on working memory.

PEERS AS FEEDBACK RESOURCE

As can be seen from the three studies in this research, peer feedback during an investigative task is an interactive process, involving clarifying, elaborating, evaluating, justifying, and revising ideas, viewpoints or suggestions between students and their peers. The combination of the learning context and feedback cycles serves as a useful platform for engaging in feedback dialogue and provides opportunities to discuss their work and discover others' interpretations of them. While the reciprocal nature of the peer feedback task ensures that there is structure and scope for feedback exchange and interpretation, prompting and explicit coaching further supported and enhanced the process of collaborative cognitive engagement.

Although evidence from students' questionnaire and interviews indicated a positive view of giving and receiving peer feedback during investigative task, some students expressed reservations about the usefulness of peer feedback. The findings of Studies Two and Three showed that students' main concerns stemmed from the need for feedback information to be *credible* and this credibility was perceived to fall on a continuum that depended on *authority* and *affectivity*. The notion of authority has been deliberated in studies such as the differential opportunities in participation as a function of status characteristics (Cohen & Lotan, 1995; Cohen, Lotan, Scarloss, & Arellano, 1999) or the influence of authority on a peer's conceptual development (De Lisi, 2002). On one hand, students perceived their peer's feedback as less useful because they were seen as less experienced, less knowledgeable, and lacking in interactive skills such as giving clear explanations or providing rich elaborations when compared with the teacher's feedback. On the other hand, feedback from peers was perceived as relevant as their peers had encountered similar problems or experiences in relation to the learning task. Peer feedback was also seen as less threatening, more informal, and given in a language that peers could relate to.

Another issue regarding perception of peer feedback is the intrusion of feelings during peer learning. Villamil and de Guerrero (1996) argued that a crucial aspect of peer interactions was 'affectivity', which includes "camaraderie, empathy and concern for not hurting each other's feelings" (p. 65). The findings in Studies Two and Three showed that students regarded their peer's feedback as less useful because of affectivity—the feedback information might not be a critical evaluation of their work so as not to 'hurt' their friends or 'jeopardize' the friendship. Conversely, the trust in the friendship might facilitate the sharing of ideas and mediate the receiving of critical feedback.

These findings on the perception of peer feedback indicate that collaborative learning involving peer feedback is a form of social engagement that is situated in the wider context of sociocultural beliefs and practices. How students perceive the nature and quality of feedback will invariably influence the way they understand peer feedback and construct meaning in the feedback process. In essence, students, as well as teachers, need to recognize the differences between peer feedback collaborative discourse structures, and their daily conversations in the classroom. For example, as Study One has shown, interactive/dialogic discourse involves peer feedback moves that help to scaffold and elaborate on ideas. The instructional support in this research can be seen as a way forward. Visualizing peer feedback in terms of progressive levels entails a view that peers play a role in creating a 'shared learning space'. In this learning space, students need to recognize that peer feedback is about the negotiation of ideas and making connections from different viewpoints, rather than the commonly held notion of ‘receptive transmission’ of knowledge. An open and non-judgmental environment ensures that students feel confident in identifying learning gaps, acknowledging the discrepancy in their current level of understanding, actively seeking ways of addressing this ‘dissatisfaction’, and using information targeted at the different levels to progress in their learning.

IMPLICATIONS FOR TEACHING AND LEARNING

Peer Feedback Quality as a Learning Progression

This research builds on and expands the concept of ‘quality’ in peer feedback, to include the notion of progression. A learning progression describes the stages of a learner’s understanding based on hierarchical representation of criteria. In contrast to a dichotomous view of peer feedback quality, conceptualising peer feedback as a progression suggests that feedback information can be given in a hierarchical and sequential manner, involving task, process, and self-regulation levels of understanding. It also recognises the view that student learning can be surface or deep, and instruction can help students to move from surface to deep learning approaches.

Coaching students to examine the progression of feedback in relation to the learner’s current level of understanding provides opportunities for students to visualise the steps required to achieve the success outcome. As a giver of peer feedback, instructional prompts and a graphic organiser help students to identify the learning gap by drawing inferences between the criteria and the work done, and suggesting a systematic approach to generating progressive feedback. As a receiver of peer feedback, students have a mental picture of a learning progression to encode, interpret, and apply peer feedback in a meaningful way.

Supporting Quality Peer Feedback for Learning

The findings in this research contribute to the understanding of peer feedback by providing evidence that instructional support is needed to scaffold the peer feedback process. Peer feedback instructional intervention that considers the context, cueing, coaching, and collaboration of peers are central to developing students in giving peer feedback that is progressive and meaningful. Furthermore, by making the direct relationship between peer feedback and learning progression explicit, students have a mental map of what progress looks like, and how to make personal judgement on moving from one level to the next. The advantage of coaching students on understanding a learning progression can be extended to *self-assessment*, where students can use graphic organisers with feedback levels to evaluate their own work and take corrective actions.

Creating Peer Feedback Opportunities in the Laboratory

This research also contributes to collaborative learning in the chemistry laboratory by addressing the need to create opportunities for students to engage in meaningful peer feedback discourse. While supporting and developing peer feedback skills and strategies are important, teachers and educators should also realise that students need to be provided with a feedback "space", where errors or mistakes are seen as learning points, and peer feedback goes beyond a corrective function to one which promotes critical discourse (*regulatory* function). This implies that we need to see peer feedback as negotiating meaning and connecting ideas, rather than providing the "right" answers. Instead of having peer feedback sessions that focus solely on marking and providing confirmatory responses, students should be encouraged to discuss the feedback, ask further questions for clarification and share alternative viewpoints. This notion is very much akin to what Hodson (2009) claimed in moving towards "critical scientific literacy"—a measure of intellectual independence and personal autonomy on scientific matters. Peer feedback, with elements of feedback levels, can be seen as an instructional strategy to promote active critical engagement with scientific text and issues. Here, the advantage is seen as providing opportunities to explore and use the language of science in interpreting, evaluating, justifying, and reviewing the written science reports of their peers and then finding ways of clearly communicating that feedback. The line of argument here is that giving and/or receiving peer feedback mirrors the important practice of 'peer reviewing' in the scientific community and thus, facilitates the inclusion of ideas related to the nature of science, such as "scientific knowledge is tentative" and "scientific knowledge is openly negotiated in the scientific community" (see Hodson, 2009, p. 87).

IMPLICATIONS FOR FUTURE RESEARCH

This research has investigated the effects of prompting and coaching on peer feedback to improve secondary students' ability to comment on laboratory reports. With the increasing emphasis on peer learning and peer assessment activities, more research is needed to inform quality peer feedback practice in the classroom. The multidimensional nature of feedback suggests that future research should examine peer feedback in a number of different areas.

First, further research could be conducted to find out how feedback levels can facilitate individual learning. To address this, a research question might be "To what extent can the formulation of feedback levels help students to interpret and use feedback to improve their own learning?" An investigation of this nature may help to shed light on the impact of different feedback levels on students' uptake and revision in a particular content domain.

Second, the relationship between learning progression and peer feedback needs to be explored further. While it is clear from these studies that explicit coaching of students, informed by this notion of progressive feedback, has a positive impact on the generation of peer feedback, it also raises some interesting questions, for example, "What is considered as progression in a particular learning context—knowledge structures, task-related strategy use or peer feedback skills?" and "How does the nature of this progression impact on the giving and/or receiving of peer feedback?"

Third, research has suggested that building student assessment capability is an important aim of education (e.g., Boud, 1995; Topping, 1998; Gibbs, 1999; Bloxham & West, 2004; Falchikov, 2005). An advice paper to the New Zealand Ministry of Education, asserted:

> All our young people should be educated in ways that develop their capability to assess their own learning. Students who have developed their assessment capabilities are able and motivated to access, interpret, and use information from quality assessments in ways that affirm or further their learning. (section 3.1)

(Absolum, Flockton, Hattie, Hipkins & Reid, 2009)

The paper further elaborates the need for a learning progression to help students be aware of what progress entails and to make judgements based on these criteria.

> As active participants in their own learning, students also need to know what progress looks like. However, descriptions and examples of progress that can support their judgments are not as readily available as might be hoped...Given the shortage of good examples of progressions (whether local or international), exactly what making progress means for different areas of the curriculum needs to be determined through research and the professional deliberations of teachers and school leaders. (section 6.3)
>
> (Absolum et al., 2009)

It follows that research which situates peer feedback within a learning progression may lead to a better understanding of how students develop, interpret, and construct meaning with progress criteria and examples.

From the students' perspective, peer feedback is as much about exchange of reliable information as it is about social interaction. This act of communication is invariably situated within a sociocultural context that both facilitates and constrains the way students generate and respond to feedback (Goldstein & Conrad, 1990; de Guerrero & Villamil, 1994; Nelson & Carson, 1998). As students engage in negotiating and making choices about how to use peer feedback, they are also constantly involved in enacting and constructing particular social identities and relationships in the classroom. A fourth suggestion for future research is to examine whether the effects of coaching can be applicable in actual collaborative peer feedback situations. This would probably involve studying the effects of coaching on individual performance, group performance and possible interaction effects. As students become more familiar with the peer feedback approaches, does 'co-regulation' using the feedback information occur?

Fourth, there are practical constraints on classroom intervention studies that suggest caution in interpreting the results. The short timeframe for intervention implies that further research is necessary to explore and investigate the effects of prompts and coaching by incorporating longitudinal experimental designs. As the participants came from different countries—New Zealand and Singapore, future research can also explore the mediating effects of sociocultural factors that may influence the way peers interact, construct, and interpret peer feedback (de Guerrero & Villamil, 1994; Nelson & Carson, 1998).

CONCLUDING COMMENTS

This research emphasises the importance of supporting peer feedback that focuses not only on the consequential impact of using feedback but also on helping students in developing a wider conception of peer feedback quality. The findings of this research contribute to our understanding of the impact of prompting and explicit coaching as effective approaches to prepare students to be better feedback providers. Indeed, the influence of peers as feedback resource is immense, and future research in this area will help to enrich our knowledge and understanding of supporting meaningful and engaging peer feedback for learning.

As Graham Nuthall (2007, p. 93) wrote, "...much of the knowledge students acquire comes from their peers, and when it does, it comes wrapped inside their social relationships". To foster learning, there is a need to be aware of the influence of the peer culture, to be involved with the peer culture and to develop a culture of mutual respect and co-operation that brings learners together as a learning community.

Supporting effective peer feedback provides a way forward in this direction.

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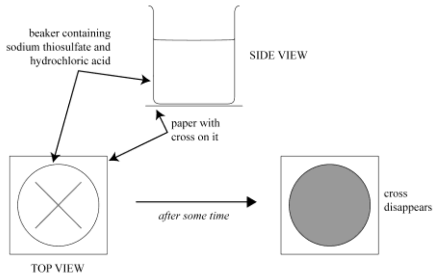
APPENDIX 1

PRE/POST CONCEPT TEST ON RATE OF REACTION

Name: …………………………………. Class: ………………….. Date: …………..

You should answer ALL the questions in this booklet. You are advised to spend ***20 minutes*** *answering the questions in this booklet.*

A class was investigating rates of reaction using the reaction between sodium thiosulfate and hydrochloric acid. A pale yellow solid forms during the reaction. Over time, a cross on a piece of paper under the beaker gradually disappears when viewed from above.



The students record the **time taken in seconds for the cross to disappear**.

The experiment uses five different concentrations of sodium thiosulfate solution (**A, B, C, D** and **E**). The starting concentration of the hydrochloric acid is the same for all five solutions. All the experiments are carried out at **20 °C**. The table shows the average results of the class.

Sodium thiosulfate concentration	Time taken for cross to disappear (s)
A	142
B	55
C	124
D	63
E	13

(a) Refer to the table above.

(i) Which is the most concentrated solution of sodium thiosulfate?

Circle your answer. **A B C D E** [1]

(ii) Justify your answer to (a) (i).

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….[1]

(b) State why the reaction will eventually stop.

……………………………………………………………………………………………………[1]

(c) (i) What factor affecting reaction rate is being investigated in this experiment?

…………………………………………………………………………………………………….[1]

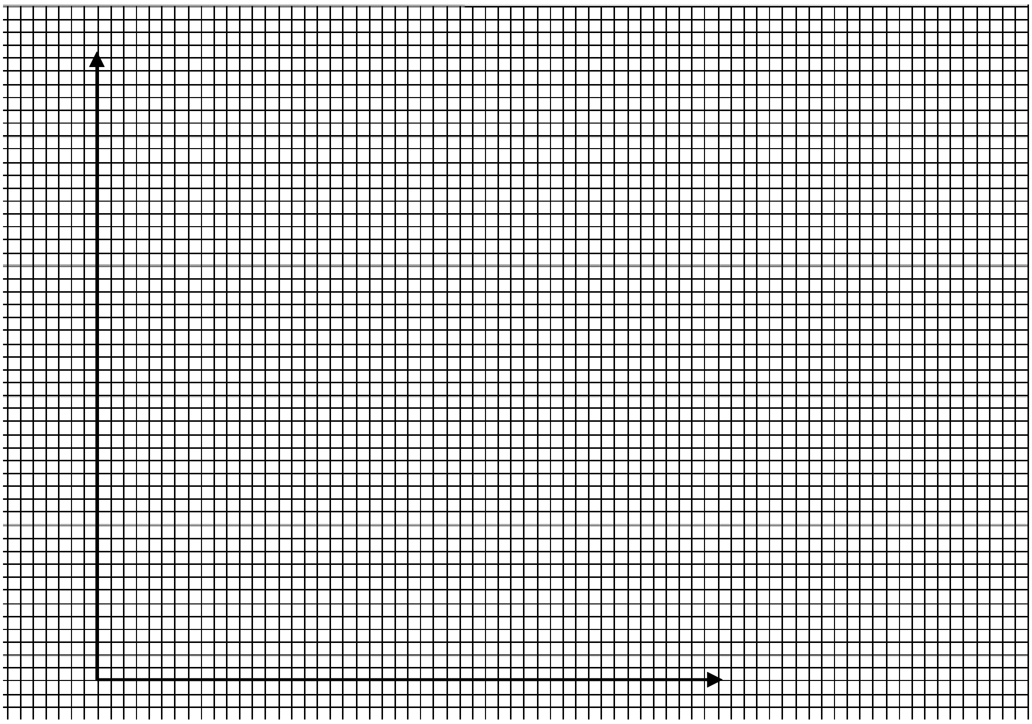
(ii) Justify your answer to (c) (i).

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….[1]

(d) (i) Using the grid shown below, **sketch** a graph you would expect from this experiment.

(**Label your axes**) [1]



(ii) Explain the shape of your graph.

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(iii) Explain the change in reaction rate that occurs, with reference to the collisions of particles.

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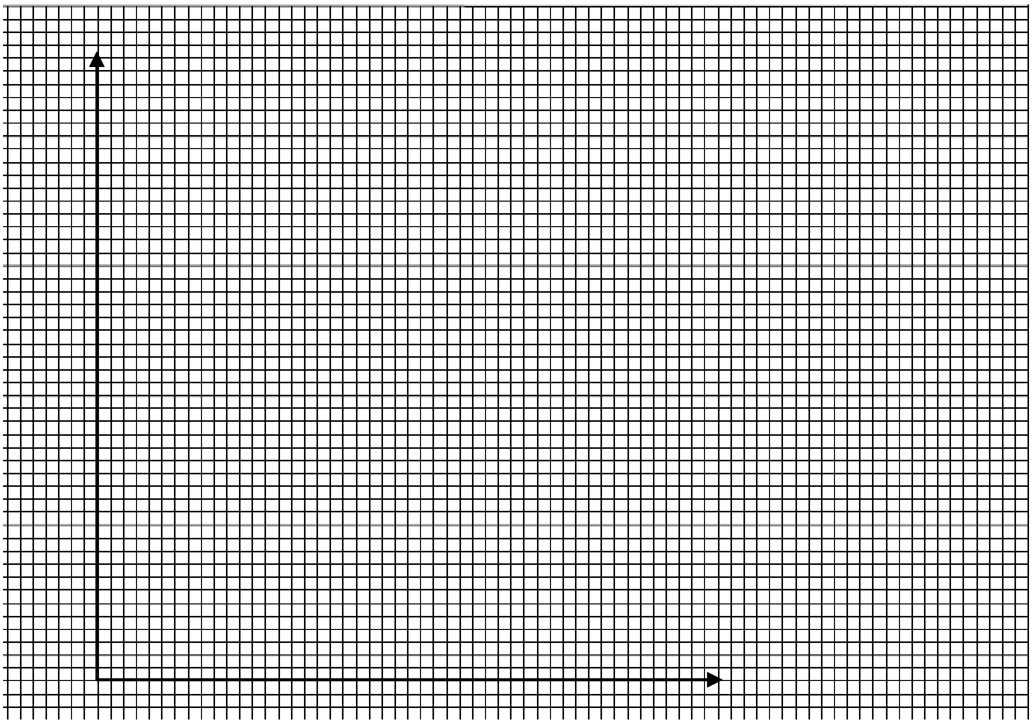
……[2]

(e) The investigation is repeated keeping the concentration of sodium thiosulfate solution and concentration of hydrochloric acid the same for all five solutions. The experiments are carried out at 20 ℃, 30 ℃, 40 ℃, 50 ℃ and 60 ℃.

(i) Using the grid shown below, **sketch** a graph you would expect from this experiment.

(**Label your axes**) [1]



(ii) Explain the shape of your graph.

……….

……[2]

(iii) Explain the change in reaction rate that occurs, with reference to the collisions of particles.

……….

……[2]

(f) Two brands of de-scaler are shown below.

Sunbeam De-scaler	**Apex De-scaler**
Normal tap water contains minerals such as limestone that can build up in your kettle. Regular use of the **Sunbeam** liquid de-scaler will remove this scale (limestone) and restore the efficiency of your appliance.	Normal tap water contains minerals such as limestone that can build up in your kettle. Regular use of the **Apex** liquid de-scaler will remove this scale (limestone) and restore the efficiency of your appliance.

Which brand would take less time to remove limestone found in a kettle? Explain your answer as fully as you can in terms of particles.

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APPENDIX 2

RATE OF REACTION INVESTIGATIVE TASK

Rate of reaction investigative task

Name:………………………………………………………….. Class:……………. Date:……………………

Objective

The purpose of this exercise is to promote meaningful peer discussion during practical through the use of a peer feedback form.

Background of investigative task

Sodium thiosulfate solution reacts with dilute hydrochloric acid to produce sulfur, sulfur dioxide gas, sodium chloride and water.

$$Na_2S_2O_3\,(aq) + 2HCl\,(aq) \longrightarrow S\,(s) + SO_2\,(g) + 2NaCl\,(aq) + H_2O\,(l)$$

As the reaction proceeds, the reaction mixture becomes cloudy due to the formation of a dispersed precipitate of sulfur. The rate at which the reaction mixture becomes cloudy indicates the rate of reaction – the faster the reaction, the faster the reaction mixture goes cloudy. The rate of this reaction can be measured by timing how long it takes before the cloudiness obscures a cross drawn on a sheet of paper placed under the reaction beaker.

Purpose of investigation

To investigate the ways in which an increase in temperature and in the concentration of reactants affects the rate of a reaction.

Instructions to participant

- In this exercise, you and your partner will each design and carry out an investigation on one of the factors (either temperature or concentration) that affects the rate of a reaction. For each student, kindly choose one factor to investigate.
- The table below shows the duration as well as the activities for you to follow.

Lesson	Activity	Purpose	Duration
1	Pre-test	Concept test on rate of reaction	20 mins
	Trial and planning	Carry out the trial experiment by following the instructions provided. Write a draft plan for your investigation.	30 mins
2	Peer feedback	Exchange your draft plan with your partner. Use the peer feedback form to give feedback to your partner.	15 mins
	Revise plan	Read the peer feedback from your partner, discuss and revise/make changes to your plan.	15 mins
	Implement plan	Carry out your experiment and collect the data.	20 mins
3	Evaluation and writing report	Plot your graph and write the full report.	20 mins
	Peer feedback	Exchange your draft plan with your partner. Use the peer feedback form to give feedback to your partner.	15 mins
	Revise report	Read the peer feedback from your partner, discuss and revise/make changes to your report.	15 mins
4	Post-test	Concept test on rate of reaction	20 mins
	Questionnaire	Student questionnaire	30 mins

For student investigating the **concentration** of a reactant:

Apparatus (per student)

0.1 M sodium thiosulfate solution (200 mL)	Measuring cylinder, 50 mL (1)	Stop watch (1)
2.0 M hydrochloric acid (200 mL)	Measuring cylinder, 10 mL (1)	Disposable pipette (2)
Distilled water (1)	Thermometer (1)	Paper with cross (1)
Beakers, 100 mL (3)	Glass rod stirrer (1)	Safety goggles (1)

Trial and planning:

(a) Carry out the following trial reaction and record your observations. Use the trial to **draft a plan** to investigate the effect of the concentration of hydrochloric acid on the rate of the reaction.

Put the paper with cross under a beaker. Measure 40 mL of hydrochloric acid and pour it into the beaker. Add 10 mL of water and stir the mixture. Measure 20 mL of sodium thiosulfate solution and pour it into the beaker with stirring. Start the stop watch immediately. Time how long it takes for the cross to disappear when viewed from above the beaker. Other suitable solutions can be made by using various volumes of hydrochloric acid, and 20 mL sodium thiosulfate solution, and making up the total volume of the mixture to 70 mL by adding water.

(b) **Give feedback on your partner's** draft plan using the feedback form. **Read and discuss on the feedback** received with your partner. **Revise your draft plan**.

Implementation and evaluation:

(a) Carry out the investigation and write **a full draft report**.

(b) **Give feedback on your partner's** full draft report using the feedback form. **Read and discuss on the feedback** received with your partner. **Revise your draft report**.

For student investigating the **temperature** of the reaction mixture:

Apparatus (per student)

0.1 M sodium thiosulfate solution (200mL)	Stop watch (1)	Disposable pipette (2)
2.0 M hydrochloric acid (200mL)	Measuring cylinder, 50 mL (1)	Paper with cross (1)
Distilled water (1)	Measuring cylinder, 10 mL (1)	Safety goggles (1)
Beakers, 250 mL (3)	Thermometer (1)	Glass rod stirrer (1)
Bunsen burner (1),Tripod stand (1), Gauze mat (1)	Lighter (1)	Cloth/Tongs (1)

Trial and planning:

(a) Carry out the following trial reaction and record your observations. Use the trial to **draft a plan** to investigate the effect of the **temperature** of the reaction mixture on the rate of the reaction.

Measure 20 mL of sodium thiosulfate solution and pour it into the beaker. Add 40 mL of water and stir the mixture. Set up the Bunsen burner and heat the solution gently to 40°C. Remove it from the source of heat, place it on top of the cross, and immediately add 10 mL of hydrochloric acid. Start the stop watch. Time how long it takes for the cross to disappear when viewed from above the beaker.

(b) **Give feedback on your partner's** draft plan using the feedback form. **Read and discuss on the feedback** received with your partner. **Revise your draft plan**.

Implementation and evaluation:

(a) Carry out the investigation and write **a full draft report**.

(b) **Give feedback on your partner's** full draft report using the feedback form. **Read and discuss on the feedback** received with your partner. **Revise your draft report**.

APPENDIX 3

PEER FEEDBACK FORM (PROMPTED)

Name (of student giving feedback):	**Class:**

Instructions:

Read carefully through your peer's work. Provide constructive feedback by suggesting areas where your peer has done well, not done so well and how best to improve. Always give further explanation to support and clarify your point of view. Return this form back to your peer. Allow time for your peer to read your comments then discuss the feedback provided with your peer.

Things to note when giving feedback:

1. Be supportive and show genuine concern.
2. Focus on the work done by your peer rather than being personal.
3. Provide feedback that is descriptive rather than judgemental.
4. Give lots of explanations to help your peer understand what and how to go about making improvements.
5. Be open to different viewpoints and build on each other's strengths.
6. Actively participate in feedback discussion with your peer.

Success criteria and peer feedback

Planning an investigation – Purpose and method of investigation

Understanding the concepts

Success criteria:

- ☐ Predict changes in reaction rate as a result of a change in factors
- ☐ Give a reason to support your prediction (in terms of both frequency and effectiveness of particle collisions)

What did he/she do well? Give explanations to support your feedback.
What didn't he/she do as well? Give explanations to support your feedback.
How can he/she improve on the current piece of work? Give explanations to support your feedback.
Maybe you could….because...

Understanding the procedures

Success criteria:

- ☐ Identify key variables – independent variable (the variable that is to be changed); dependent variable (the variable that will be measured) and controlled variables (relevant variables that will need to be kept the same)
- ☐ Describe a step-by-step method clearly (with a focus on fair testing)

What did he/she do well? Give explanations to support your feedback.
What didn't he/she do as well? Give explanations to support your feedback.
How can he/she improve on the current piece of work? Give explanations to support your feedback.
Maybe you could….because...

Implementing an investigation – Collect and record data; analyse and evaluate results

Understanding the concepts

Success criteria:

- ☐ Identify patterns or trend in results
- ☐ Explain the pattern or trend
- ☐ Interpret the graph / results based on scientific knowledge

What did he/she do well? Give explanations to support your feedback.
What didn't he/she do as well? Give explanations to support your feedback.
How can he/she improve on the current piece of work? Give explanations to support your feedback.
Maybe you could….because...

Understanding the procedures

Success criteria:

- ☐ Ensure accurate (e.g. to the nearest mL) and reliable (e.g. a suitable interval of readings) measurement
- ☐ Organise, record and represent data/observations in a systematic format (e.g. graph with best fit line)
- ☐ Extract relevant data to support and justify conclusions
- ☐ Discuss reliability and limitation of data and procedures

What did he/she do well? Give explanations to support your feedback.
What didn't he/she do as well? Give explanations to support your feedback.
How can he/she improve on the current piece of work? Give explanations to support your feedback.
Maybe you could….because...

APPENDIX 4

STUDENT PERCEPTION QUESTIONNAIRE

Name:.. Class:....................
Date:................................

<u>Instructions:</u>

This questionnaire contains statements about peer feedback practices that could take place in your laboratory class. There are two parts to answer on every question or statement:

- The first question is how **important** you consider the statement to be when you are receiving/giving peer feedback.
- The second question asks you to rank how **effective** you consider your peer's feedback (during practical sessions / group work) was in meeting that aspect of the peer feedback.

Please circle the appropriate number on the five-point scale:

1 **<u>Not</u>** important or effective
2 **<u>Somewhat</u>** important or effective
3 important or effective
4 **<u>Very</u>** important or effective
5 **<u>Extremely</u>** important or effective

No.	Peer feedback practice	**Not** important/ effective	**Somewhat** important /effective	important /effective	**Very** important /effective	**Extremely** important /effective
1a	How important is it that peer feedback directs you towards specific mistakes?	1	2	3	4	5
1b	How effective was your peer's feedback in directing you towards specific mistakes?	1	2	3	4	5
2a	How important is it that peer feedback indicates the quality of your work?	1	2	3	4	5
2b	How effective was your peer's feedback in indicating the quality of your work?	1	2	3	4	5
3a	How important is it that peer feedback suggests how to improve your work?	1	2	3	4	5
3b	How effective was your peer's feedback in suggesting on how to improve your work?	1	2	3	4	5
4a	How important are success criteria (learning objectives) to help you think deeper about the feedback content?	1	2	3	4	5
4b	How effective were the success criteria (learning objectives) in helping you to think deeper about the feedback content?	1	2	3	4	5
5a	How important is it that peer feedback clarifies your doubts about the task?	1	2	3	4	5
5b	How effective was your peer's feedback in clarifying your doubts about the task?	1	2	3	4	5
6a	How important is it that peer feedback clarifies your doubts about your understanding of concepts?	1	2	3	4	5
6b	How effective was your peer's feedback in clarifying your doubts about your understanding of concepts?	1	2	3	4	5
7a	How important is it that peer feedback clarifies your doubts about your understanding of procedures?	1	2	3	4	5
7b	How effective was your peer's feedback in clarifying your doubts about your understanding of procedures?	1	2	3	4	5
8a	How important is it that peer feedback helps you to correct your mistakes?	1	2	3	4	5
8b	How effective was your peer's feedback in helping you to correct your mistakes?	1	2	3	4	5
9a	How important is it that peer feedback helps you to elaborate on your ideas?	1	2	3	4	5
9b	How effective was your peer's feedback in helping you to elaborate on your ideas?	1	2	3	4	5
10a	How important is it that peer feedback provides explanations on how to improve your work?	1	2	3	4	5
10b	How effective was your peer's feedback in providing explanations on how to improve your work?	1	2	3	4	5
11a	How important is it that peer feedback provides justifications on how to improve your work?	1	2	3	4	5
11b	How effective was your peer's feedback in providing justifications on how to improve your work?	1	2	3	4	5
12a	How important is it that peer feedback helps you to learn concepts better?	1	2	3	4	5
12b	How effective was your peer's feedback in helping you to learn concepts better?	1	2	3	4	5
13a	How important is it that peer feedback helps you to learn practical procedures better?	1	2	3	4	5

13b	How effective was your peer's feedback in helping you to learn practical procedures?	1	2	3	4	5
14a	How important is it that peer feedback helps you to revise your work?	1	2	3	4	5
14b	How effective was your peer's feedback in helping you to revise your work?	1	2	3	4	5
15a	How important is it that peer feedback helps you to monitor your thinking about your strategies (e.g. problem-solving) and actions during the task?	1	2	3	4	5
15b	How effective was your peer's feedback in helping you to monitor your thinking about your strategies and actions during the task?	1	2	3	4	5
16a	How important is it that peer feedback meets your learning goals?	1	2	3	4	5
16b	How effective was your peer's feedback in meeting your learning goals?	1	2	3	4	5
17a	How important is it that peer feedback motivates you to learn better?	1	2	3	4	5
17b	How effective was your peer's feedback in motivating you to learn better?	1	2	3	4	5
18a	How important is it that peer feedback recognises your effort in the work done?	1	2	3	4	5
18b	How effective was your peer's feedback in recognising your effort in the work done?	1	2	3	4	5
19a	How important is it that peer feedback is timely?	1	2	3	4	5
19b	How effective was the timing of your peer's feedback provided?	1	2	3	4	5
20a	How important are guiding questions to help you formulate peer feedback?	1	2	3	4	5
20b	How effective were guiding questions (when provided) in helping you to formulate feedback?	1	2	3	4	5
21a	How important are guiding questions to help you think deeper about the feedback content?	1	2	3	4	5
21b	How effective were the guiding questions (when provided) in helping you to think deeper about the feedback content?	1	2	3	4	5
22a	How important are peer discussions to help you understand the received peer feedback?	1	2	3	4	5
22b	How effective were the peer discussions in helping you to understand the received peer feedback?	1	2	3	4	5
23a	How important are peer discussions on the feedback to elaborate and extend your ideas, concepts or knowledge about the topic?	1	2	3	4	5
23b	How effective were the peer discussions on the feedback in elaborating and extending your ideas, concepts or knowledge about the topic?	1	2	3	4	5
24a	How important is reflection on the received peer feedback to help you improve your work?	1	2	3	4	5
24b	How effective was reflection on the received peer feedback in helping you to improve your work?	1	2	3	4	5
25a	How important are guiding questions to help you reflect on the received peer feedback?	1	2	3	4	5
25b	How effective were the guiding questions (when provided) in helping you to reflect on the received peer feedback?	1	2	3	4	5

APPENDIX 5

STUDENT INTERVIEW QUESTIONS

Qn no.	Interview questions
1	Briefly, tell me in your own words, what would you say ‘peer feedback’ means?
2	How useful is the peer feedback form in helping you give written feedback to your friend?
3	What aspect/part of the peer feedback form do you find useful?
4	What problems/issues do you face when using the peer feedback form?
5	Take a look at the comments in your peer feedback form, tell me
a)	how do you use a particular feedback?
b)	why is that feedback chosen instead of others?
c)	is discussing with a peer important for your choice and use of feedback? Why?
d)	does understanding of the concepts on rate of reaction affect the way you give feedback?
e)	does understanding of the experimental procedures affect the way you give feedback?
f)	is the criteria useful?
6	Overall, what is your opinion about giving peer feedback using the feedback form during practical?
7	Lastly, do you feel you would like more opportunities for using a peer feedback form to give/receive peer feedback in practical?

APPENDIX 6

PRE/POST-TEST

Name: ……………………………( ) Class: ………………….. Date: …………..

<u>Instructions:</u>

Read the background information. Use the criteria & peer feedback form to give feedback to the student.

<u>Effects of acid rain on snail shells</u>

A student carried out an experiment to investigate the ways in which acid rain can affect the thickness of snail shells. Snail shells consist mainly of calcium carbonate, which is arranged in the form of layers called aragonite and calcite. On the very outside of the shell, there may be a thin, coarse 'skin' that covers the relatively thick calcium carbonate layers. The proportions of each of these layers vary between species, as well as between individuals of the same species.

The student collected empty snail shells found in a garden and reacted them to hydrochloric acid at different temperatures for a fixed time. The change in mass of the shells gives an indication of the rate of the reaction or how fast is the reaction at that particular temperature. The student's report of this experiment is shown below.

Student report on investigative task
1. Student's prediction: How does changing the temperature affect the rate of reaction of the snail shells in acid? I predict that the higher the temperature, the faster the rate of reaction of the acid on the snail shell and therefore, resulting in a change in mass of the shell. This is due to the reaction of the hydrochloric acid with the calcium carbonate present in the snail shells.
Read the student's prediction and give your feedback below: **What did he/she do well and why?**   **What didn't he/she do as well and why? How can he/she improve on the current piece of work?**

2. Student's method of investigation:

1. Collect 5 empty shells.
2. Prepare the shells by washing and drying.
3. Gather all equipment and weigh each of the 5 shells collected.
4. Put one shell in a beaker and add 50 mL of 0.1 mol dm^{-3} of hydrochloric acid. Then, put the beaker in a cold water bath at 5 ºC.
5. Remove the shell from the acid after 5 minutes.
6. Dry and weigh the shell again.
7. Repeat using another shell at 20 ºC, 30 ºC, 40 ºC and 60 ºC.
8. Carry out a control using 50 mL of water instead of the acid.

Read the student's written step-by-step method and give your feedback below:
What did he/she do well and why?

What didn't he/she do as well and why? How can he/she improve on the current piece of work?

3. Student's data collection and analysis

Table of results:

Measured temperature of water bath/ ºC	Initial mass of shell/g	Mass after 5 min in acid/g	Change in mass/g	Decrease in mass/%
5	2.32	2.18	0.14	6.0
22	2.40	1.93	0.47	19.6
30	2.28	1.83	0.45	19.7
45	2.43	1.13	1.30	53.5
60	2.23	0.00	2.23	100.0

As the temperature increases, the rate of reaction was faster. This is seen as a bigger loss in mass of the shell within the same timing of 5 minutes.

This result matched my prediction.

Read the student's table of data and written analysis. Give your feedback below:
What did he/she do well and why?

What didn't he/she do as well and why? How can he/she improve on the current piece of work?

4. Student's conclusion and evaluation of results

There is a trend in my results. The trend shows that as the temperature of hydrochloric acid increases, the rate of reaction becomes faster. The hotter the acid, the faster it will react with the calcium carbonate in the shells and therefore, the percentage of the decrease in mass of the shell gets bigger.

One source of error could be the weighing of the shells. Sometimes it was obvious that bits had dropped off, either in the beaker or while the remains were being rinsed before weighing, but it was quite impossible to collect up all the fragments, making the recorded mass less than it should have been.

One limitation of this experiment is that the snail shells may come from different species and so may have different amount of calcium carbonate in their shells.

Read the student's conclusion and evaluation. Give your feedback below:
What did he/she do well and why?

What didn't he/she do as well and why? How can he/she improve on the current piece of work?

APPENDIX 7

SCORING KEY FOR CONCEPT TEST

Scoring key to Concept Test on Rate of Reaction

Question		Scoring points	Marks awarded	Remarks
(a)	**(i)**	E	1m	
	(ii)	Shortest time for cross to disappear means fastest rate of reaction which is the result of highest concentration of sodium thiosulfate.	1m	Accept *more sulfur ppt produced due to high reactant concentration*
(b)	**(i)**	When all the hydrochloric acid has completely reacted	1m	Accept *one of the reactant has completely reacted*
(c)	**(i)**	Concentration of sodium thiosulfate	1m	
	(ii)	The concentration of sodium thiosulfate is changed while keeping the concentration of HCL and temperature constant	1m	
(d)	**(i)**	time for cross to disappear vs [$Na_2S_2O_3$]	1m	Accept *rate of reaction (reciprocal of the time taken) vs [$Na_2S_2O_3$]*
	(ii)	The graph shows that time for cross to disappear is inversely proportional to the concentration of $Na_2S_2O_3$. As the concentration of $Na_2S_2O_3$ increases, the time taken for cross to disappear decreases. This means that the rate of reaction increases as the concentration of $Na_2S_2O_3$ increases.	1m 1m	
	(iii)	With higher concentration of one or more reactant particles, there are **more frequent collisions between particles** and, as a result, products are formed more rapidly/the time taken for sulfur ppt to form decreases. Therefore, **the rate of reaction increases.**	1m 1m	
(e)	**(i)**	time for cross to disappear vs temperature	1m	Accept *rate of reaction (reciprocal of the time taken) vs temperature*
	(ii)	The graph shows that time for cross to disappear is inversely proportional to temperature of reaction mixture. As the temperature increases, the time taken for cross to disappear decreases. This means that the rate of reaction increases.	1m 1m	
	(iii)	At higher temperatures reacting particles have **higher kinetic energy**. **They collide with each other more frequently**. A higher proportion of particles have sufficient energy for bonds to break and new products to form when they collide.	1m 1m	Accept more *particles have energy equal or greater than activation energy/ moving faster*
(f)		Apex descaler; Higher concentration; More particles/more collisions; Chance of collision increase/more successful collisions; Increase rate of reaction	1m 1m 1m 1m 1m	
		TOTAL	20m	

NCEA Chemistry (Year 12)

Unit Standard 6325 - Investigate factors that affect the rate of a chemical reaction
Performance criteria
2.1 Predictions identify changes in reaction rate resulting from a change in factors.
2.2 Reaction rates resulting from a change in factors are explained in terms of both frequency and/or effectiveness of particle collisions.