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How to guide effective student questioning: a review of teacher guidance in primary education

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Although the educational potential of student questions is widely acknowledged, primary school teachers need support to guide them to become effective for learning the curriculum. The aim of this review is to identify which teacher guidance supports effective student questioning. Thirty-six empirical studies on guiding student questioning in primary education were analysed. Four emergent themes for teacher guidance of effective student questioning were identified in the data: first, guiding effective student questioning requires confident teachers, who create a supportive classroom culture for question generation and acknowledge the potential in students' initial questions; second, defining a conceptual focus supports teachers in aligning student questions to curricular goals; third, organising collective responsibility for the question process in the classroom fosters effective student questioning; and fourth, teacher guidance is supported when the process of questioning is visualised on a collective platform.

Introduction

Although the use of questions in education has a long tradition, in this tradition teachers are in control of questioning, whereas students are mainly expected to provide answers (Dillon, 1988). Only since 1990 has evidence accumulated that asking questions is an important (meta-) cognitive strategy for students, which supports active learning and knowledge construction (Graesser & Wisher, 2001; Veenman, 2004). This review focuses on student questioning in primary education, defined as students generating, formulating and answering sincere information seeking (SIS) questions. SIS questions express the genuine interest and intrinsic motivation of students to enquire into a topic (Graesser & Wisher, 2001). We define SIS questions as questions raised by students about a general area of knowledge in order to enlarge their knowledge base or to resolve cognitive conflicts (Van der Meij, 1994; Jirout & Klahr, 2011). This review does not research academic help-seeking questions that request clarification or assistance from their teacher or peers with the aim of resolving problems related to completing academic tasks (Karabenick & Newman, 2006), or text-based questions that focus on the characteristics of text materials, such as the meaning of words, an analysis of grammatical constructions, or the reproduction of text statements, produced on the demand of the teacher (Scardamalia & Bereiter, 1992).

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Student questioning is expected to have multiple educational benefits for both learning and teaching. First, student questioning is claimed to foster intrinsic motivation, for it allows students to set their own learning purposes (Gillespie, 1990; Scardamalia & Bereiter, 1992), which increases the motivation to pursue enquiries (Abrandt-Dahlgren & Öberg, 2001; Wells, 2001). According to the Social Determination Theory of Ryan and Deci (2000) intrinsic motivation for learning will increase if students are allowed more autonomy and are supported in their perceived competence. Student questioning allows both autonomy, by acknowledging the personal need for seeking understanding, and the development of competence, by letting students pursue enquiries of their own interest. Second, student questioning is claimed to support knowledge construction because asking questions is a vital part of information seeking and requires a conscious effort by the learner to identify cognitive conflicts or knowledge gaps in his or her prior knowledge (Ram, 1991; Graesser & McMahen, 1993; Farmer, 2007; Pardo & Bakes, 2015). Finally, student questioning is considered to be an effective metacognitive strategy that helps learners to monitor and self-evaluate their level of understanding (Scardamalia, 2002; Veenman, 2004), and can support forms of higher level thinking such as analysing, reasoning and hypothesising (Graesser *et al.*, 1996). Moreover, student questioning has been found to be a basic heuristic for young children to seek knowledge about the world (Chouinard *et al.*, 2007).

Besides the benefits student questioning seems to have for constructivist learning, research shows that it can support teaching in several ways. Teachers have been found to use student questioning to: (i) diagnose students' level of understanding, (ii) evaluate their students' level of thinking, (iii) enhance enquiry, and (iv) evoke critical reflection (see for an extensive review Chin & Osborne, 2008). Therefore, student questioning is considered to be a potential resource for teaching students to practice self-regulated learning and acquire knowledge about the world.

However, although teachers generally acknowledge the benefits of student questioning for teaching and learning, research shows that teachers make little use of the potential of student questioning (Eshach *et al.*, 2014). Several reasons might be the cause for this. First, teachers are concerned with meeting the demands of formal school curricula (Wells, 2001). Student questioning might disrupt or cause deviations from the smooth deliverance of well-planned lessons (Rop, 2002). Second, teachers often use questions in order to exercise classroom control (Reinsvold & Cochran, 2012). When teachers perceive student questions as a threat to this authority and control, they are inclined to reduce student questioning to a minimum (Chin & Osborne, 2008). Third, while many teachers hold the belief that they ought to know all the answers, few teachers are prepared to put their knowledge to the test through student questioning (Woodward, 1992; Zeegers, 2002). Finally, even if teachers would be willing and self-confident enough to support student questioning, most of them have not had sufficient training in pedagogical repertoires to guide student questioning (Lin *et al.*, 2009).

Facing these challenges, teachers seem to need support that would enable them to guide effective student questioning, defined as aligning student questioning to the requirements of the curriculum, which consist of a set of predetermined learning goals established by the school system, syllabi and/or the teacher. Although many studies pay attention to how teachers can elicit and train student questioning (Chin &

Osborne, 2008), it remains unclear how teachers can align student questioning with curricular goals. What seems to be needed is a comprehensive overview of how teachers can guide effective student questioning. This literature review aims to identify emergent themes put forward by empirical research on teacher guidance of effective student questioning in primary school classrooms. First, we will examine the trends in the literature about student questioning and the process of questioning in more detail in order to determine inclusion criteria and develop a framework of analysis for this review.

Theoretical framework

In the literature two types of studies on student questioning can be distinguished. Most dominant in number are studies that focus on teaching students how to question, based on schema theory, activity theory, or metacognitive theory (Janssen, 2002). Distinctive features of this 'teaching to question' approach are various methods of question training, specific materials (such as question-starters and question-stems), and procedures for eliciting specific types of questions by students [for an extensive review, see Rosenshine *et al.* (1996)]. Another type of study on student questioning, which emerged in the 1990s, focuses on how students can learn from their own questioning. This 'questioning to learn' approach, mostly inspired by the Self Determination Theory and sociolinguistic perspectives on questioning, is aimed at developing an inquisitive stance and emphasises the personal meaning and ownership of student questioning (Carlsen, 1991; Ryan & Deci, 2000). In this approach teachers support classroom dialogue about the process of enquiry and relate student questioning to students' prior experiences, current understanding and personal interests (Kock *et al.*, 2015). The main difference between these approaches seems to be that the 'teaching how to question' approach focuses on developing questioning as a skill, while the 'questioning to learn' approach aims at developing questioning as a stance.

Most studies in the 'teaching how to question' approach seem to be grounded on the assumption that asking a question is a speech act, in which a student tries to convey a sense of curiosity through an utterance. The meaning of the question is then in the intention of the student and the recognition of the hearer of this intention (Henderson & Brown, 1997). From this perspective, teachers who are trying to develop student questioning have to support students in extending their vocabulary and improving their syntax in order to be able to convey their intentions most accurately. Therefore, many of these studies focus on the training aspect, by offering question-stems or question-heuristics to teach students how to formulate their speech act. However, students' original sense of curiosity is hardly ever explored and might even be ignored in this process, potentially leading to mechanically produced questions without personal meaning (Neber, 2008).

By contrast, in the 'questioning to learn' approach student questioning is considered to be a stance, an epistemic attitude that involves perceiving the world from the perspective of wonderment or perplexity (e.g. Cochran-Smith & Lytle, 2009). This wonderment might initially be diffuse and difficult to put into words, but can gradually become more clear and focused when explored and discussed. If teachers perceive the task of guiding student questioning to be first and foremost about exploring and discussing students' sense of wonderment, asking questions is not a technical exercise, but a journey to develop both the focus and the adequate language to frame students' sense of curiosity. Although studies from the 'teaching to question' approach have advanced our knowledge on question generation and formulation, this review focuses on the 'questioning to learn' approach, in order to find out how teachers can guide intrinsically motivated student questioning in way that meets curricular demands.

In order to analyse teachers' guidance of student questioning it is important to examine the process of questioning. In general, questioning can be described as a process that consists of three phases: (1) *generating*, (2) *formulating*, (3) *answering* questions (cf. Ram, 1991; Van der Meij, 1994). In the generating phase the learner becomes aware of the need or possibility to ask a question, triggered internally by a cognitive disequilibrium or externally by events or phenomena evoking a state of perplexity or an inquisitive stance. In the formulating phase, the learner tries to verbalise his or her perplexity by formulating a question (verbal coding) and can choose to express it in a social setting (social editing). In the third phase of answering, the learner consults available resources and processes acquired information in order to construct an answer to his or her question.

In practice, the process of questioning is often more dynamic and iterative than this linear model of generating, formulating and answering questions might suggest. Generating and formulating questions can become an intertwined process (e.g. Wells, 2001). Finding preliminary answers might lead to reformulating questions, for instance (Van der Meij & Dillon, 1994). Initial questions, especially, might need reformulation when students become more aware of their emergent interests and learn to articulate their intentions (Tan & Seah, 2011). Student questioning can become progressive, for as students learn more about a domain they can raise better and more detailed questions (Ram, 1991). The ultimate goal in guiding student questioning is, arguably, that students get involved in a continuous and cyclic process of questioning in which new-found answers are the stepping stones to new questions. This continuing process of generating, formulating and answering questions is referred to as progressive enquiry (e.g. Hakkarainen, 2003).

For the sake of reviewing teacher guidance with respect to student questioning, we use the three main phases of questioning to identify patterns in and among each phase of questioning. The model allows us to analyse and compare teacher guidance in various educational contexts within and between the three phases. The aim is to look for patterns that help teachers to start and maintain an almost continuous process of questioning and answering. Therefore the underlying assumption is that, in order to make student questioning effective, all phases should contribute to meeting curricular goals, but what challenges does this set for teaching?

In the phase of generating questions, the challenge for teachers is to make students aware of the possibility of raising intrinsically motivated questions about curriculum topics. First, teachers would like students to generate authentic SIS questions, based upon students' interests. However, it is not clear how teachers can help students to develop an interest in curriculum topics, which at first glance might not be connected to students' prior experiences and knowledge. Even when succeeding in raising interest, how can teachers prompt student perplexity and promote an inquisitive stance that leads to student questioning with respect to topics in the curriculum? Second, having operationalised question generation as the process of identifying what needs to be learned, teachers need to consider how they can provide a context in which students become aware of what is yet unknown to them (Ram, 1991). However, what teacher guidance can make students aware of what they do not know about the curriculum? Although some scholars suggest only a very limited amount of prior knowledge is necessary for students to raise questions (Chouinard *et al.*, 2007), other scholars emphasise that some exploration of the topic is a prerequisite for generating adequate questions (Markman, 1979; Van der Meij, 1994). Finally, the third challenge in this phase is to motivate students to consider raising their questions, when they have become aware of what needs to be learned. Dillon (1988) and Reinsvold and Cochran (2012) found that primary school students generally raise very few questions in class, while Graessar and Person (1994) reported that students in tutor settings tend to ask many more questions. Therefore, teachers need to find ways to create classroom environments in which students are more inclined to ask questions.

In the second phase of questioning, the challenge for teachers seems to be to support students in articulating their interests and sense of perplexity into investigable questions that address both the width and depth of the curriculum. Multiple studies show that many of students' initial questions seem to be both unfocused and uninvestigable (e.g. Biddulph, 1989; Chin & Kayalvizhi, 2002). It seems to be difficult for primary students to phrase questions that focus on their interests and that facilitate feasible investigations, partly because of developing vocabulary and literacy skills (Zeegers, 2002). Therefore, teachers have to find methods to guide students' initial questions so that they take on an investigable form without losing the students' original intent. A second challenge in the formulating phase is to guide student questioning so as to explore the width and depth of the curriculum. Coverage of the width of the curriculum seems to be challenged by the divergent interests of students, owing to personal preferences and the general popularity of certain topics. This diversity in questioning might easily lead to partial knowledge construction for the individual student, and fragmented overviews of (sub-)domains on the collective level of the classroom curriculum (Baram-Tsabari *et al.*, 2006). Attaining more in-depth knowledge is another challenge, for students are not just expected to learn factual knowledge; rather, they are supposed to develop conceptual thinking in which they relate concepts with prior knowledge and different concepts to each other (Graesser & Wisher, 2001). However, unguided student questioning is seldom connected to prior knowledge and seems to be predominantly factual rather than conceptual (De Vries *et al.*, 2008). Therefore, spontaneous student questioning might not meet the requirements for deep learning in terms of conceptual understanding. Key issues for teachers in the formulating phase are therefore to support students in articulating investigable questions and to guide student questioning so that it addresses both the width and the depth of the curriculum.

In the answering phase, the challenge in guiding effective student questioning appears to be to help students find relevant answers and organise an efficient method for the exchange of learning outcomes. Finding answers to their questions can be expected to be an important prerequisite for students to advance their knowledge and to learn the curriculum. However, the exchange of learning outcomes also seems necessary. Individual students will most likely not be able to learn the whole curriculum on the basis of their own questions and answers and therefore need the questions and answers of their fellow students as well. Scardamalia (2002) suggests that answers to individual student questions could be used as building blocks for collective knowledge construction in a community of learners.

Furthermore, to develop more in-depth knowledge of the curriculum, not only should learning outcomes be exchanged, but students should also sustain the enquiry by building upon each other's questions and raising follow-up questions that lead to a deeper conceptual understanding (Scardamalia, 2002). Collaboration in a community of learners seems to be a key issue in the answering phase, but it is not yet clear how teachers can guide collective knowledge construction and sustained enquiry in a way that will meet the demands of the curriculum.

To summarise, although a considerable number of studies have focused on student questioning, their findings have been falling short when it comes to helping teachers to guide student questioning in a way that meets the demands of the formal school curriculum. Key issues for teachers seem to be: (1) to promote students' interest in curriculum topics and prompt students to experience a feeling of perplexity about these topics, (2) to support students in articulating investigable questions and to guide student questioning so as to address the width and depth of the curriculum, and (3) to support a collective enquiry that contributes to effective student questioning.

Important reviews in the literature on student questioning focused on issues such as its potential with respect to teaching and learning science—on teaching question generation strategies, on the role of student questioning in reading comprehension, literature and prose processing, and on the role of student questioning in the information-seeking process (Cornbleth, 1975; Wong 1985; Biddulph *et al.*, 1986; Gillespie, 1990; Woodward, 1992; Rosenshine *et al.*, 1996; Graesser & Wisher, 2001; Janssen, 2002; Farmer, 2007; Chin & Osborne, 2008; Pedrosa de Jesus & Watts, 2012). These reviews have, however, not yet examined how teachers can address the key issues with respect to guiding effective student questioning. To identify emergent themes concerning how to successfully implement effective student questioning in classroom practice, a qualitative description of patterns in teacher guidance is needed. For this purpose, the following research question is raised in this systematic qualitative literature review:

> *RQ*1: Which emergent themes with respect to guiding effective student questioning in primary school classrooms can be derived from the literature?

Method of review

Identification of studies

A data set of articles was collected in three steps. First, we conducted an explorative computer search. To identify studies on student questioning in primary education, a computer-based search was conducted in the following databases: EBSCO (Elton B. Stephens Co.), Google Scholar, JSTOR (Journal Storage), Picarta and ERIC

(Educational Research Information Clearinghouse). In the search query we used combinations of the following terms: student* AND question* AND (guid* OR generat* OR pos* OR ask* OR self-generat* OR self-formulat* OR develop*). In order to augment this search query, fragments of the titles of retrieved articles on student questioning were used as search terms in Google Scholar, which identified citing articles. To reduce the possibility of missing data, references from collected studies and review articles were scanned for relevant publications. In total, 385 possibly relevant studies were collected in this first round.

In the second step, abstracts of all retrievable studies were screened for eligibility criteria for both study and report characteristics. The criteria for study characteristics were: students as questioners, not teachers' questioning; SIS questioning, not academic help-seeking; knowledge-based questioning, not text-based questioning; reporting on teacher guidance or on characteristics of the learning environment that support teachers in guiding student questioning. Report characteristics were: peer-reviewed manuscripts published in scholarly journals and dissertations, published from about 1990 and containing empiric data collected in primary education. Of the 323 retrievable studies, 248 studies were identified as reports on student questioning. These studies were scanned to check if they matched all the eligibility criteria, resulting in a final dataset of 36 studies.

Analysis

The analysis was conducted in two steps. First, an analysis framework and an analysis procedure were developed. The analysis framework initially only consisted of the three phases of questioning. To test the analysis framework, two researchers independently analysed ten studies from the dataset and the outcomes were subsequently compared and discussed. From this preliminary analysis it became clear that the studies reported on teachers' guidance from three perspectives: (1) teacher characteristics such as confidence, stance and attitude; (2) teachers' instructional moves to support student questioning; and (3) teachers' organisation of collaboration and support. To improve the focus of our analysis, the three perspectives on teacher guidance were integrated into our analysis framework, resulting in a three by three matrix to summarise findings from each study. Then an analysis procedure was developed to document systematically for each study, general bibliographical and methodological categories (cf. Cooper, 1998), as well as the findings concerning teacher guidance structured according to the analysis framework. All findings were stored in an Access™ database.

In the second step, summary reports were extracted from the database and subsequently analysed to identify characteristics of teacher guidance within the analysis framework. Every time a new characteristic was identified, an appropriate label was created. For each label a table was made to register in what studies relevant findings had been identified. By labelling all findings from the summary reports both quantitatively and qualitatively, trends, similarities, differences and peculiarities of teacher guidance of effective students became apparent between studies, which allowed the identification of emergent themes for teacher guidance of effective student questioning.

To minimise risk of bias when analysing and interpreting, the strength of evidence in each study was estimated (Table 1). For each study it was established if it was either a single, multiple case, or (quasi-)experimental study. To describe the context of the studies, the focus of studies, the number and grade of participants, the type and duration of the intervention, the type of instruction, the type of student enquiry and the connections to larger research or intervention programmes were recorded. The independence of the research was estimated by identifying the role of teachers as actors or as (co-)researchers. Neither of these categories are indicative of the quality of the studies *per se*, but together they help to put the findings in perspective with respect to the strength of the evidence. Statistical evidence in the studies was rare and of various nature; hence, no meta-analysis could be conducted.

Findings from reviewed studies

As Table 1 shows, the dataset consists of 12 single case studies, 19 multiple case studies, and 5 (quasi-)experimental studies. In 18 studies the researchers were independent and did not participate in the teaching, in 8 studies teachers reported on their own teaching, and 10 studies were conducted by mixed teams of teachers and researchers. The studies address (sometimes multiple) school subjects such as biology (9 studies), literacy (5 studies), numeracy (4 studies), physics (13 studies), and (social) sciences (9 studies). About two-thirds of the studies were conducted in Canada (5) and the USA (18), although studies were also included from countries as diverse as Australia (4), Brazil (1), Ghana (1), Hong Kong (1), New Zealand (2), Russia (1), Singapore (2), Taiwan (2) and the UK (1). The age of the student participants varied between 4 and 13 years old. Most studies (24) report on older primary students (grades 4–6 or even 7), but 14 studies report on younger students (grades 1–3). The types of intervention varied both in form and in duration, ranging from regular lessons to project-based units, lasting from one lesson to multiple years. Teacher guidance of student questioning was predominantly done in a face-to-face setting, although in 10 studies the instruction was also supported by an Electronic Learning Environment (ELO). Students used various strategies to investigate their questions such as: conducting experiments (14 studies); observing the natural environment (2 studies); consulting secondary sources, such as expository texts, experts, the internet, or ELOs (16 studies); discussing literary texts (3 studies) and solving mathematical problems (4 studies).

The next sections present a qualitative synthesis of the findings from the reviewed studies structured according to the analysis framework. First, the influence of teacher characteristics on student questioning is reported. Second, various instructional moves by teachers to support questioning are explored. Third, the (impact of) organisation of collaboration is described.

Teacher characteristics

Twelve studies have shown that teacher characteristics such as self-confidence and positive attitude support an inviting and accepting classroom atmosphere, in which students feel free to raise questions without fear of losing face (Biddulph 1989, 1995;

Table 1. Overview study characteristics

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Aguiar *et al.* (2009)	Multiple case	Teacher	Physics	Types of dialogue	3 classrooms *N* = ?	7–9	Brazil	Regular lessons	11 lessons	Face-to-face	Conducting experiments	Type of question-pattern of interaction
Allmond and Makar (2010)	Quasi-experimental	Teacher	Numeracy	Developing investigable questions	*N* = 66	3	Australia	Unit on *creating questions*	8 lessons 1 month	Face-to-face	Solving math problems	Level of questions (investigative)
Awanta (2013)	Multiple case	Independent	Numeracy	Knowledge construction in classroom discourse	*N* = 48	7	Ghana	Regular lessons	7 weeks	Face-to-face	Solving math problems	Nature of questions (basic- critical)
Baumfield and Mroz (2002)	Multiple case	Independent	Critical literacy	Type of discourse which fosters student questioning in community of enquiry	2 classrooms *N* = ?	2–5	UK	Community of enquiry on narrative texts	29 sessions	Face-to-face	Questioning narrative texts	Question categories Influence text type Benefits to pupils and teachers
Beck (1998)	Single case	Independent	Social science	Teacher's stance on student questioning	1 classroom *N* = ?	4	USA	A *Project-Approach* Science unit	4 weeks	Face-to-face	Consulting internet, experts, expository texts	Type of questions (focus on learning potential)
Biddulph (1989)	Multiple case	Independent	Physics	'Interactive' teaching approach based on student questioning	4 classrooms *N* = ?	1–5	New Zealand	Unit structured by *Interactive approach*	12 lessons	Face-to-face	Conducting experiments	Teachers' & Students' responses to teaching approach
Biddulph (1995)	Multiple case	Independent	Numeracy	Questions about number	*N* = 276	5–6	New Zealand	Student teachers' assignment	4–5 sessions	Face-to-face	Solving math problems	Nature of questions (various categories)
Brown and Campione (1994)	Quasi-Experimental	Independent	Biology	Knowledge building in community of learners	not reported	2–6	USA	Project-based Science units	1 semester (example)	Face-to-face	Consulting internet, experts, expository texts	Knowledge Test Depth of analogy Types of explanations
Busching and Slesinger (1995)	Multiple case	Mixed	Social Science & Critical Literacy	Learning environment to raise 'real' questions	5 classrooms (*N* = 125)	7	USA	Unit on WO2	5 lessons (50 min)	Face-to-face	Discussing literary and expository texts	Nature of questions (focus on function)

Table 1. (Continued)

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Chin and Kayalvizhi (2002)	Single case	Mixed	Science	Questions for open science investigations	$N = 39$	6	Singapore	I: invited to ask questions II: modelling questions	I: 8 weeks II: 3 × 1 hour	Face-to-face	Consulting internet, experts, expository texts	Topics of interest Typology of investigable questions
Chouinard *et al*. (2007)	Experi-mental	Independent	Biology	Information requesting mechanism	$N = 67$	K–1	USA	I: Walking the Zoo II: Problem-solving task	I: 1 session II: 1 session	Face-to-face	Observing real objects, toys and images	I: Impact stimulus on questioning II: effect questions on problem-solving
Commeyras (1995)	Single case	Mixed	Critical literacy	Encourage student-centred questions	$N = 20$	2	USA	7th lesson in series of 18	1 lesson	Face-to-face	Discussing literary texts	Intention & meaning of questions
Di Teodoro *et al*. (2011)	Multiple case	Teacher	Numeracy	Integration of meaningful mathematical questions in teaching	4 classrooms $N = ?$	2–3	Canada	Lessons on three literature-based mathematical problems	Several lessons in the course of a year (?)	Face-to-face	Solving math problems	Levels of questions Teacher's self-report
Diaz (2011)	Multiple case	Independent	Physics/ Biology	Student-centered questioning & argumentation	3 classrooms $N = 60–75?$	5	USA	Units structured by *Science Writing Heuristc*	3 semesters	Face-to-face	Conducting experiments	Level of questions (Bloom) Level of argumentation
Hakkarainen (2003)	Single case	Independent	Biology	Progressive Enquiry in computer supported classroom	$N = 28$	5–6	Canada	*Computer Supported Intentional Learning Environment*	1 academic year	Face-to-face & online	Consulting internet, ELO, expository texts	Level of explanations Level of student questions
Harris *et al*. (2011)	Multiple case	Independent	Biology	Classroom discourse to elicit and develop students' questions	3 teachers	5	USA	Unit on Isopods	12 weeks	Face-to-face & online	Consulting internet, experts, expository texts	Student assessment? Instructional moves
Hume (2001)	Single case	Teacher	Physics	Developing knowledge-building community	$N = 24$	6–7	USA	Unit on Light and Colour	4 weeks	Face-to-face	Conducting experiments Informational texts	Classroom interaction Development of Questions Student engagement

Table 1. (Continued)

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Hung *et al.* (2014)	Single case	Independent	Biology	Developing student questioning ability in field enquiry	$N = 43$	5–6	Taiwan	Unit on Ecology of Wetlands—including 3 fieldtrips	4 months	Face-to-face & online	Observing wetlands Consulting ELO, internet & expository texts by mobile device	Autonomous questioning Assistance to others questioning Autonomous question correcting Assistance to others question correcting
Keys (1998)	Multiple case	Mixed	Physics	Generative model of teaching science (Harlen & Osborne, 1985)	2 classrooms $N = ?$	6	USA	Investigative units	3 × 4 weeks (= 3 × 15 hours)	Face-to-face	Conducting experiments	Reasoning strategies for question generation Teacher's roles
Lai and Law (2013)	Multiple case	Independent	Social science	Questioning and quality of knowledge construction	$N = 86$	6/10	Hong Kong	Knowledge Forum (CSILE)	6 × 3 × 50 min 6 weeks	Face-to-face & online	Consulting ELO, internet, experts, expository texts	Level of questions Levels of explanations
Lehrer *et al.* (2000)	Multiple case	Mixed	Biology	Design tools for fostering enquiry1	1 classroom $N = ?$	1/3–5	USA	Units on *decomposition & plant growth*	1 year	Face-to-face	Conducting experiments	Development of enquiry
Lin *et al.* (2009)	Quasi- experimental	Independent	Physics	Change of classroom learning environment by enquiry-based activities and student questioning	$N = 92$	5	Taiwan	Enquiry activities in Science Lessons	4 hours each week During 1 year	Face-to-face	Conducting experiments	Enquiry activities Questioning skills What is Happening in the Classroom? (WIHIC) test
MacKenzie (2001)	Single case	Independent	Science	Effect of teacher's stance on learning community	$N = 125$	7	USA	Mind Games in science lessons: Enquiry activities on hypothetical situations	1 year	Face-to-face	Consulting internet, experts, expository texts	Description of classroom activities and discourse

Table 1. (Continued)

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Martinello (1998)	Single case	Mixed	Social science	Co-enquire with children cognitive apprenticeship	$N = 10$	2/5/7	USA	Summer group	3 hours for 10 weeks	Face-to-face	Consulting internet, experts, expository texts	Description of student questions & enquiry activities
Ness (2013)	Single case	Mixed	Literacy	Addressing students' (disregarded) spontaneous questioning	1 classroom $N = ?$	3	USA	Student centred small group sessions to address questions	Twice a week for several(?) weeks	Face-to-face	Consulting expository texts	Description of student questions & enquiry activities Answers
Penuel *et al.* (2004)	Multiple case	Mixed	Science	Design of a socio-technical system to support enhanced student questioning	2 teachers in design phase 75 teachers in test phase	5	USA	Using handheld computers and Boomerang software in various subjects in science education	Several sessions	Face-to-face & online	Not reported	Teacher and student use and experience
Scardamalia and Bereiter (1992)	Quasi- Experi-mental	Independent	Biology/ Science	Educational potential of students' questions	2 classrooms $N = 50$	5–6	Canada	Units of enquiry in CSILE and informal question-generating sessions	1 session	Face-to-face & online	Not reported	Educational value of questions Student rating of questions
Simpson (1996)	Single case	Teacher	Literacy	Developing critical literacy by student questioning	1 classroom $N = ?$	6/7	Australia	Reading circles	Not reported	Face-to-face	Discussing literary texts	Student questions Teacher's role
Tan and Seah (2011)	Multiple case	Independent	Biology	Questioning behaviour of students engaging in enquiry science using Knowledge Forum	$N = 138$	4	Singapore	Knowledge Forum (CSILE)	April–October	Face-to-face & online	Consulting ELO, internet, expository texts	Types of questions (Ideational functions) Nature of enquiry task

Table 1. (Continued)

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Van Tassel (2001)	Single case	Teacher	Physics	Knowledge building by student questioning in science	$N = 20$	1–2	USA	Unit of solids, liquids and gasses	2 semesters	Face-to-face	Conducting experiments	Transcripts of discourse, student's questions & teacher's considerations
Van Zee *et al.* (2001)	Multiple case	Mixed	Physics	Types of science conversation that encourage student questioning	5 classrooms	1–6	USA	Guided discussions, student generated enquiry & peer collaboration on science topics	Many months(?)	Face-to-face	Conducting experiments	Factors that stimulate student questioning in science conversation
Virgin (2015)	Case study	Teacher	Social Science	Big Ideas as focus for instruction and teaching with and for student questioning	Not reported	6–7	USA	Not reported	3 year	Face-to-face & online	Consulting internet, expository texts	Procedures to elicit student questioning & connect student questioning to curriculum
Weizman *et al.* (2008)	Case study	Teacher	Chemistry & Physics	Functionality of Driving Question Board for organising and focusing student questioning	Two examples for classrooms	7	USA	Project-based Science units	Not reported	Face-to-face	Conducting experiments	Sample Driving Board Questions Sample interview responses
Zeegers (2002)	Multiple case	Independent	Physics	Praxis of primary teachers who encouraged student questioning in science	3 classrooms	4–7	Australia	Project-based Science units Some cases *cooperative learning*	5–8 weeks	Face-to-face	Conducting experiments	Teaching strategies Teacher's views Factors for generating & using questions
Zhang *et al.* (2007)	Multiple case	Independent	Physics	Online science discourse aimed at knowledge building	$N = 22$	4	Canada	Knowledge Forum (CSILE)	4 months	Face-to-face & online	Conducting experiments Consulting ELO, internet, expository texts	Enquiry threads Idea improvement Knowledge gains (individual & collective)

Table 1. (Continued)

Study	Type of study	Researcher	Subject	Focus of study	Student participants	Grade	Country	Intervention	Duration	Instruction	Student enquiry	Reported outcomes
Zhang *et al.* (2009)	Multiple case	Independent	Physics	Effect of various forms of student collaboration on knowledge building	$N = 22$	4	Canada	Knowledge Forum (CSILE)	3 years	Face-to-face & online	Conducting experiments Consulting internet, expository texts	Awareness of contributions, complementary contributions, distributed engagement.
Zuckerman *et al.* (1998)	Multiple case	Mixed	Physics	Science curriculum build on student enquiry	$N = 120$	1–4	Russia	Davydov styled curricula for science and math	Twice a week 3 years	Face-to-face	Conducting experiments	Descriptions of enquiry activities; Tests of symbolic representations

Beck, 1998; Lehrer *et al.*, 2000; Hume, 2001; MacKenzie, 2001; Van Zee *et al.*, 2001; Baumfield & Mroz, 2002; Zeegers, 2002; Zhang *et al.*, 2007; Aguiar *et al.*, 2009). Teacher confidence has been found to pave the way for letting go of too much control over the process of questioning (Biddulph, 1989; Zuckerman *et al.*, 1998; Van Tassel, 2001). When feeling confident, teachers are able to allow for unexpected and unclear student questioning. Van Zee *et al.* (2001) found that confident teachers are willing and able to cope with unexpected and potentially threatening student questions. Hume (2001) observed that her confidence in students' agency and her willingness to empower students has helped her to let students struggle to make sense of what they are thinking. Keys (1998) found that teachers' confidence was reflected in their decision to allow grade six students to explore inappropriate lines of enquiry, with the aim of letting students experience the true nature of scientific investigation, rather than providing the students with correct procedures that are not fully understood. Both Diaz (2011) and Zeegers (2002) have shown that teachers' level of confidence in student questioning seems more related to the level of domain knowledge than to teaching experience. For instance, both authors found a significant correlation between the level of a teacher's conceptual domain knowledge and the amount of student questioning in classroom discussions. Furthermore, Zeegers points out that, in addition to domain knowledge, a thorough understanding of scientific procedures contributes to a teacher's confidence.

Nine studies reported that a positive stance of the teacher supports student questioning. Seven studies found that when teachers acknowledge and appreciate all student questions, students become more willing to raise questions. For instance, Beck (1998) describes a fourth-grade teacher who explicitly acknowledges the potential for learning of each of her students' questions, even when the questions appear naïve or unclear. This teacher succeeds in establishing a classroom culture in which asking and discussing questions is the norm. Similarly, Zeegers (2002) observed a teacher who focused on the articulation of wonderment, deliberately disregarding the phrasing or practicality of initial student questions, which resulted in greater student confidence with respect to raising questions. Also, Simpson (1996) found that when grade 6 students are encouraged to write down all questions, even those that seem to be trivial, students feel more at ease raising their questions. Brown and Campione (1994) and Van Tassel (2001) note that when teachers value student questions as serious attempts to construct knowledge, this stance positively influences students' willingness to ask questions. Two studies have explicitly shown that teachers need to set specific norms in order to establish a supportive classroom culture. MacKenzie (2001) observed a teacher that first ensured that all her grade 7 students knew her strict norms about mutual respect, before engaging in student questioning. Hume (2001) reported that she instructed her grade 7 students to allow for multiple perspectives when emotional responses on questions about the assumed causal relationship between eye colour and sight fuelled classroom discussion.

Based on the data the following general picture emerges about the effects of teachers' confidence, stance and attitude on effective student questioning. The review's findings suggest that confident teachers, having extensive content and procedural knowledge, can create a positive classroom culture for student questioning by valuing all student questions and by modelling their own questioning behaviour.

Teacher's instructional moves

All the studies in the dataset show that teachers use a variety of instructional moves (Table 2), which in this study is defined as a teacher's actions meant to guide student questioning by means of speech and activities (cf. Harris *et al.*, 2011). Instructional moves vary between the provision of opportunities for exploration and discussion to strategies to prompt and develop questions, and from the organisation of enquiries and exchanges of findings to support for student to reflect on their sense of perplexity, their questions and their findings. This section reports on how teachers use instructional moves to guide the generation, formulation and answering of student questions.

Guiding question generation. Eight case studies suggest that teachers need to provide students with the time and opportunity to become acquainted with the relevant topic. Biddulph (1995) observes that children in grades 5–6 find it difficult to raise questions about mathematics unless they have some idea of the concept under consideration. Biddulph (1989) also reports that students need adequate time initially to explore phenomena and events before generating scientific questions. A similar observation was made by Martinello (1998), who notes that students' real interests only surface in the third or fourth week of co-enquiry, even when they are allowed to choose a topic of their own interest. Hume (2001) found that when grade 7 students explore a scientific topic for a longer period of time, their sense of puzzlement deepens. Similarly, Busching and Slesinger (1995) report that grade 7 students explain that it is hard to ask questions about a social science subject when just starting reading about it, because 'You [aren't] in to it yet' (p. 346). Lehrer *et al.* (2000) show that grade 1 and students in grades 3–5 generate more and more interesting questions when they can build upon their knowledge and experience about the natural phenomenon under investigation. Van Tassel (2001) observes that student questions were more valuable and had taken on personal meaning after the initial exposure to the topic. However, a remarkably contrasting finding was identified by Scardamalia and Bereiter (1992). They report that when teachers instruct grades 5–6 students to explore prior knowledge and reference materials to raise questions, students predominantly ask 'basic information' questions aimed at fact seeking. In an experimental condition in which students were invited to ask questions spontaneously, without exploring their prior knowledge first, students asked significantly more educationally valuable 'wonderment questions', seeking relations and explanations. As a possible explanation, it is suggested that when teachers explicitly avoid the suggestion that questions need to be investigated, students feel more free to articulate their real wonderments and do not select beforehand which questions might be easy to answer.

All studies, except Ness (2013) and Diaz (2011), report that teachers use prompting strategies to elicit interest from students and stir a sense of perplexity about the topic. Four types of prompting strategies used by teachers become apparent from the dataset: activate prior knowledge, explore literature, organise exploratory hands-on activities and present questions or problem-solving tasks.

First, four studies show that teachers prompt questioning by activating students prior knowledge about the relevant topic. Lehrer *et al.* (2000) found that a teacher

Table 2. Findings on teacher's instructional moves

		Generating questions				Formulating questions					Answering questions		
		Prompt perplexity				Divergent phase		Convergent phase			Guide knowledge construction		
Study	Grades	Prior knowledge	Literature	Exploratory activity	Question or task	Share	Write	Clarify	Categorise	Model	Individual	Collective	Progressive
Aguiar *et al.* (2009)	7–9	X	–	X	–	X	–	–	–	–	–	–	–
Allmond and Makar (2010)	3	–	–	X	–	X	X	X	X	–	–	–	–
Awanta (2013)	7	–	–	–	X	X	X	–	–	–	–	–	–
Baumfield and Mroz (2002)	2–5	–	X	–	–	X	X	X	X	X	–	–	–
Beck (1998)	4	X	–	–	X	X	X	X	X	–	X	X	–
Biddulph (1989)	1–5	–	–	X	–	X	X	X	–	X	X	–	–
Biddulph (1995)	5–6	–	–	–	–	X	–	–	–	–	–	–	–
Brown and Campione (1994)	2–6	–	X	–	–	X	X	X	X	–	X	X	–
Busching and Slesinger (1995)	7	–	X	–	X	X	–	X		X	–	–	X
Chin and Kayalvizhi (2002)	6	–	–	–	X	X	X	X	–	X	–	–	–

Table 2. (Continued)

		Generating questions				Formulating questions					Answering questions		
		Prompt perplexity				Divergent phase		Convergent phase			Guide knowledge construction		
Study	Grades	Prior knowledge	Literature	Exploratory activity	Question or task	Share	Write	Clarify	Categorise	Model	Individual	Collective	Progressive
Chouinard *et al*. (2007)	K–1	–	–	X	–	–	–	–	–	–	–	–	X
Commeyras (1995)	2	–	X	–	X	X	–	X	–	–	–	–	–
Di Teodoro *et al*. (2011)	2–3	–	X	–	X	X	X	–	X	–	–	X	–
Diaz (2011)	5	–	–	–	–	X	X	–	–	–	–	–	–
Hakkarainen (2003)	5–6	–	–	–	X	X	X	X	–	–	X	X	X
Harris *et al*. (2011)	5	–	–	–	X	X	X	X	–	X	X	X	–
Hume (2001)	6–7	–	–	X	–	X	X	X	–	–	–	X	X
Hung *et al*. (2014)	5–6	–	–	X	–	X	X	X	X	–	X	X	–
Keys (1998)	6	–	–	X	–	X	X	X	–	–	X	–	–
Lai and Law (2013)	6/10	–	–	–	X	X	X	–	–	–	–	–	–
Lehrer *et al*. (2000)	1/3–5	X	–	X	–	X	X	X	X	X	X	X	X
Lin *et al*. (2009)	5	–	–	X	–	X	X	–	–	–	–	X	–
MacKenzie (2001)	7	–	–	–	X	X	–	–	–	–	–	–	–

Table 2. (Continued)

		Generating questions				Formulating questions					Answering questions		
		Prompt perplexity				Divergent phase		Convergent phase			Guide knowledge construction		
Study	Grades	Prior knowledge	Literature	Exploratory activity	Question or task	Share	Write	Clarify	Categorise	Model	Individual	Collective	Progressive
Martinello (1998)	2/5/7	–	–	–	X	X	X	X	–	X	X	–	X
Ness (2013)	3	–	–	–	–	X	X	–	–	–	X	–	–
Penuel *et al.* (2004)	5	–	–	–	X	X	X	–	X	–	–	–	–
Scardamalia and Bereiter (1992)	5–6	–	–	–	X	X	X	–	–	–	–	–	–
Simpson (1996)	6/7	–	X	–	X	X	X	X	–	–	–	–	–
Tan and Seah (2011)	4	–	–	–	X	X	X	–	–	–	X	X	–
Van Tassel (2001)	1–2	X	–	X	–	X	X	X	X	–	X	X	X
Van Zee *et al.* (2001)	1–6	–	–	–	X	X	X	X	–	–	–	–	X
Virgin (2015)	6–7	–	–	–	X	X	X	–	–	–	–	X	–
Weizman *et al.* (2008)	7	–	–	–	X	X	X	–	X	–	–	X	–
Zeegers (2002)	4–7	–	–	X	–	X	X	X	X		X	X	X
Zhang *et al.* (2007)	4	–	–	–	X	X	X	X	–	–	–	X	–

Table 2. (Continued)

		Generating questions				Formulating questions					Answering questions		
		Prompt perplexity				Divergent phase		Convergent phase			Guide knowledge construction		
Study	Grades	Prior knowledge	Literature	Exploratory activity	Question or task	Share	Write	Clarify	Categorise	Model	Individual	Collective	Progressive
Zhang *et al.* (2009)	4	–	–	–	X	X	X	X	–	–	–	X	–
Zuckerman *et al.* (1998)	1–4	–	–	X	–	X	X	X	–	–	X	–	–
Total		4	6	13	21	35	30	22	11	7	14	16	9

began a science unit with an extended conversation about what grade 1 students already knew about the topic. Van Tassel (2001) describes how she activates her grade 1 and grade 2 students' prior knowledge by asking them to explain their personal understanding of an issue to each other in small group discussions. She reports that these discussions make the students both aware of their prior knowledge and of gaps in their knowledge. Beck (1998) shows that a teacher can make grade 4 students aware of their background knowledge about the government by asking students to discuss their own experiences in making difficult choices and decisions. Aguiar *et al.* (2009) report that in grade 7, student questioning tends to emerge when teachers link the topic to student interests and experiences—for example, by providing examples that have had high exposure in the media.

A second strategy teachers use to prompt student questioning, found in five studies, is to explore and discuss literature. Baumfield and Mroz (2002) found that teachers can evoke spontaneous student questioning in grades 2–5 when they choose texts with an intriguing twist or puzzle in them. Busching and Slesinger (1995) observe that students with limited prior knowledge can be prompted by a storybook about the experiences of a young girl in World War II. Brown and Campione (1994) report that both an informational text and a play can serve as starting points for a biology unit on endangered species in grades 5–6. Simpson (1996) shows that teachers easily engage students in raising questions about picture books when these student questions are used to guide other groups in discussing the books. Commeyras (1995) found that discussing the biography of Harriet Tubman elicits lively discussions and questions about the lives of slaves among students in grade 2. Di Teodoro *et al.* (2011) report how storybooks can be used to introduce and discuss mathematical problems in grades 1–2.

A third teacher strategy for eliciting perplexity was found in 13 studies and reports on how teachers organise exploratory (hands-on) activities in which students can observe, collect and compare data. Keys (1998) reports that teacher-led science experiments aroused both interest and curiosity in grade 6 students. Biddulph (1989), Hume (2001), Van Tassel (2001), Zeegers (2002), Aguiar *et al.* (2009) and Lin *et al.* (2009) show that both younger and older primary students, are prompted not only to explore but also to raise questions about effects and explanations by various hands-on science experiments using and testing materials. Collecting and comparing data from the real world, either during field trips in the wetlands in grades 5–6 (Hung *et al.*, 2014) or by observing changing patterns in rainfall on the roof of the class in grade 6 (Keys, 1998), or observing differences in rates of decomposition between tomatoes and pumpkins in grades 1–2 (Lehrer *et al.*, 2000), or by visiting the Zoo (Chouinard *et al.*, 2007), prompted student questioning about natural phenomena. Comparing maps of islands to explore patterns of erosion has also been reported to be an effective strategy for evoking wonderment and curiosity (Zuckerman *et al.*, 1998). Hume (2001) reports that exploratory activities by the whole class supports a shared understanding of the topic, introduces a common language for discussing the topic and raises students' interests.

Finally, 11 studies point to the use of various types of questions or problem-solving tasks as a prompting strategy. The most basic application of this strategy is simply to invite students to share their wonderments—as reported by Scardamalia and Bereiter

(1992), Busching and Slesinger (1995), Simpson (1996), Beck (1998), Martinello (1998), Van Zee *et al.* (2001), Harris *et al.* (2011) and Awanta (2013)—by asking questions such as 'What would you most like to know about . . .?'; 'Is there anything you would like to find out about . . .?' Hakkarainen (2003) found that a simple prompt: 'I need to understand' to be the most effective scaffold for student questioning in an online discussion forum called 'Computer Supported Intentional Learning System' (CSILE). More complex teacher questioning techniques are also reported to be effective for prompting student questioning. MacKenzie (2001) shows that a teacher's imaginative questions, such as 'What if the sun becomes a supernova?' (p. 146), can elicit student wonderment. Weizman *et al.* (2008) found teachers who prompted their students with 'driving questions', that is, open-ended questions in everyday language that contextualised physics content to students' personal interests, such as, for example 'When can I believe my eyes?' (p. 35). Zhang *et al.* (2007, 2009), Tan and Seah (2011), and Lai and Law (2013) note that enquiries on Knowledge Forum, an online discussion forum, starts with 'seed-questions' such as 'Can technology solve the problem of global warming?' Virgin (2015) describes how he prompts student questioning on the historical period of Reconstruction in the USA by using statements such as: 'The Civil War didn't change much' (p. 99). Tan and Seah (2011) found that the type of task set by a teacher on Knowledge Forum influences the types of student questions that are elicited. They find that a fact-seeking task predominantly generates fact-seeking questions, while a problem-solving task generates the greatest number and greatest variety of questions.

Having prompted students' perplexity in various ways, three studies suggest that teachers should also support students in reflecting on their perplexity from a curriculum perspective. Keys (1998) notes that when teachers ask students to explain relations between prompted observations to the scientific topic, students seem to be able to relate their own personal experiences to the exploration of science ideas. Similarly, Van Tassel (2001) reports helping students to relate their observations to their prior knowledge and experiences by asking them to formulate preliminary explanations. Zuckerman *et al.* (1998) found that teachers help students to find patterns in their observations by making graphical representations of the main features and characteristics of the phenomenon under study.

Next, with respect to helping students reflect on their sense of perplexity, eight studies show how teachers connect student interest to key concepts in the curriculum. Zuckerman *et al.* (1998), Zhang *et al.* (2007, 2009), Diaz (2011) and Virgin (2015) report that teachers use key concepts or Big Ideas, which capture the most essential characteristics of the subject under study, to connect student questions to curricular goals. Beck (1998) shows an example of how a teacher was able to raise the interest in the key concept of 'government' by relating this concept to students' previous experiences with making choices and decisions. Brown and Campione (1994) found that a skilled teacher appropriates the spontaneous interest of the students for endangered species and encourages students to consider underlying key concepts such as metabolic states, survival and reproduction. Zhang *et al.* (2007, 2009) report about a teacher who organises 'rise-above' discussions with students to reflect on their developing understanding of the key concepts under study. Virgin (2015) presents narrative evidence that when teachers generate a conceptual focus, student questions go deeper with respect to, for example, a key concept such as 'change' in American History. In order to be able to do this, Baumfield and Mroz (2002) observe that teachers need in-depth knowledge of both the curriculum content and students' interests and prior knowledge.

Guiding question formulation. Whereas in the generating phase teachers' guidance is aimed at raising wonderment and exploring a topic, in the formulating phase teachers' guidance aims at helping students actually formulate and pose their questions. In total, 35 studies show that teachers first guide the student question formulation process through a divergent phase by organising opportunities for students to articulate and share their questions (Table 2). Teachers organise various forms of classroom discussions in order for students to become aware of the range of questions they have formulated and share ideas. However, explicit planning for question formulation might sometimes be necessary, as found by Zeegers (2002), who observes that a teacher needs to allocate time for questions during scientific hands-on experiments because students are so immersed in the task that they forget to think about their questions.

In 31 studies teachers requested that students record their questions (Table 2), either on paper or digitally in e-learning environments, such as Boomerang, CSILE, Knowledge Forum, and Ubiquitous Problem Based Learning System (UPBLS). Hume (2001) explains why she, as a teacher, asks her students to write down questions. A written question is asynchronously available, accessible for everyone to read and to react to, and therefore affords more involvement from students and more opportunities for further examination and reflection. However, not all teachers choose to record questions immediately. Van Zee *et al.* (2001) report that a grades 1–2 teacher first allows students to discuss their wonderings and questions and waits to record questions, because this might disturb spontaneity and emergence of other student questions.

Contrasting findings have been reported on the quality of the students' initial questions. As regards to coverage of the curriculum, Biddulph (1989) and Beck (1998), found that the majority of initial student questions tend to be connected to curriculum content. Hakkarainen (2003) and Zhang *et al.* (2007) show that student questioning on Knowledge Forum covers all the required topics of the curriculum and even elaborates on some of the topics in the higher grades. Hakkarainen and Zhang *et al.* find student questions more exploratory than fact seeking, which they interpret as students seeking a deep understanding and thorough explanations of the phenomena under study. However, other studies report initial student questions to be naïve (Biddulph, 1989; Zuckerman *et al.*, 1998; Chin & Kayalvizhi, 2002; Zeegers, 2002), not investigable (Hume, 2001; Van Tassel, 2001), lacking in purpose (Allmond & Makar, 2010), and in general aimed at fact seeking rather than being exploratory in nature (Martinello, 1998; Lai & Law, 2013).

Twenty-five studies show that teachers organise a convergent phase once students have formulated their initial questions (Table 2). In this phase teachers help students to further develop their questions and prepare them to investigate the topic. Six studies discuss why teachers support the development of students' questions. Martinello

(1998) shows that students from various grades (1–5) need teacher support before they can articulate what they want to discover and that their initial questions do not reflect their true interests. Similarly, Allmond and Makar (2010) found that grade 3 students are not always able to frame their questions to their intent, because they are still developing their language and literacy skills. Beck (1998) shows how a teacher needs to explore together with grade 4 students 'the question within the question' to find what is really meant or sought after, thus clarifying the meaning and intention of questions. However, Busching and Slesinger (1995) and Commeyras (1995) suggest that teachers should be aware of their own prejudices when interpreting the intent of a student's question. Teachers should be especially sensitive to the fact that their understanding of the meaning of a question might not match the student's intent, according to Commeyras. Simpson (1996) notes similarly that teacher concerns about following the curriculum might restrain teachers in recognising what the students are wondering about.

Four teacher strategies for developing questions have been identified: clarifying questions, categorising questions, developing criteria for questions and modelling questions. The most reported teacher strategy is to clarify the meaning, intent and assumptions imbedded in students' questions (22 studies, Table 2). This support seems to require teachers that are good listeners and who can also ask students regarding what is not being communicated. Besides carefully listening, teachers can take various instructional actions to clarify the questions. Hakkarainen (2003), Harris *et al.* (2011), Hume, (2001), Lehrer *et al.* (2000), Van Zee *et al.* (2001), Zeegers (2002) and Zhang (2007, 2009) report that teachers can simply ask students to clarify what they mean. Hume (2001) and Biddulph (1989) found that teachers also discuss the assumptions underlying the questions with their students. Martinello (1998) and Keys (1998) observed teachers guiding their students to consciously explore their topic from different perspectives, thus helping students to identify factors most salient to the investigation. Biddulph (1989) and Harris *et al.* (2011) report that asking students to suggest possible answers makes them aware of the underlying intent and assumptions of their questions. However, Van Tassel (2001) emphasises that teachers should be prepared that to interpret the meaning of questions is not a clear-cut and straightforward process, but '. . . involves lot of messing around with ideas and fumbling for words and clarity' (p. 53).

A second teacher strategy for developing student's questioning capabilities, found in 11 studies (Table 2), is to make the students aware of the quality of questions by categorising them. Lehrer *et al.* (2000) report that teachers help students in grades 3–5 evaluate their questions by writing them on index cards and asking students to arrange and rearrange them into categories. In the subsequent classroom discussion, the values and consequences of different types of questions are explored. Similarly, Allmond and Makar (2010) observe teachers that instruct grade 3 students to sort their own questions for investigability and subsequently ask them to justify their choices. Van Tassel (2001) reports that her grade 2 students categorise their questions in groups before selecting ones to enquire into. Weizman *et al.* (2008) find that a teacher instructs grade 7 students to categorise their questions in order to connect them to the key concepts and to become aware of the variety in the type and level of questions. Hung *et al.* (2014) and Penuel *et al.* (2004) report that teachers instruct their students to categorise their own questions using a generic rubric for question quality as a reference.

Four studies show a third strategy used to support student questioning in which teachers develop and discuss quality criteria for questions together with students. Zuckerman *et al.* (1998) found teachers that involve all students in discussing the investigability of initial naïve questions and thus help students to reformulate questions along lines that can be investigated. Both Allmond and Makar (2010) and Lehrer *et al.* (2000) observed how teachers help their students to develop criteria for good questions by discussing aspects such as the interest in expected outcomes, to what extent the questions are researchable, and considerations of evidence. Di Teodoro *et al.* (2011) report that a team of teachers for grades 1–2 initially set out to derive the criteria for 'deeper' vs 'superficial' questioning themselves by sorting out student questions. However, the teachers realised this was also a valuable learning experience for their students and decided to involve them in discussing the question criteria. Di Teodoro *et al.* found this strategy to be highly supportive of students and note that the percentage of 'deeper' student questions rose from 16% to 70% in the cases they investigated.

A fourth strategy for teachers to develop student questioning is modelling, as reported in six studies (Table 2). Some teachers provide students with example questions. Busching and Slesinger (1995) show how a teacher shares her own questions to support student questioning. Other teachers model the vocabulary and syntax of questioning. Lehrer *et al.* (2000) report how a teacher models modes of conversation for discussing the quality of questions. Allmond and Makar (2010) report how a teacher models the syntax of statistical questions by exploring and discussing the effects of ambiguous words on subsequent enquiry. Zeegers (2002) observes teachers who model types of questions that are investigable by emphasising scientific vocabulary such as *effect*, *compare*, *explain*, *evidence*. Martinello (1998) found that teachers support question development by modelling the syntax of 'I wonder' questions. Finally, there are teachers who model their own thinking to conceptually elevate student questions. For instance, Harris *et al.* (2011) report that the teachers who were most successful in developing student questioning use re-voicing and think-aloud strategies as ways to explain and clarify their own understanding and to engage students in refining their own questions.

Although in many studies teachers apply strategies to develop questions, three studies emphasise that teachers should also be aware that the quality of student questioning is not dependent on its form, but rather on its function within the context. Both Busching and Slesinger (1995) and Di Teodoro *et al.* (2011) find that some questions, which appear to be 'on the surface', actually stimulate deeper thinking. They also observe that 'surface' questions often lay the factual foundation for creating deeper questions. Simpson (1996) reports that all students' questions, regardless of type or quality, elicit interested responses from fellow students and lead to educationally valuable classroom discussions. Simpson concludes that the development of understanding seems not to be dependent on the quality of the question but on the discussion that follows.

Guiding answering questions. Twenty-four studies in the dataset (Table 2) report on teacher guidance in the answering phase, although in all cases this is originally not the focus of study. The evidence is therefore mostly indirect and no effects have been reported. Teacher guidance in the answering phase addresses two main issues: (1) to guide students' questions to an answer, and (2) to exchange learning outcomes in order to develop a collective understanding among the students.

In the process of guiding students to answer their questions, teachers provide several forms of practical support. First, teachers support students in finding the most appropriate method of enquiry. Lehrer *et al.* (2000) reports that teachers discuss with students in grades 3–5 which tasks and tools the questions call for, taking the prior knowledge of the students into account. Van Tassel (2001) describes how she asks her grade 2 students how to proceed in order to get answers. The students tend to suggest various authoritative resources, such as books, experts and the internet, but never come up with the idea of constructing knowledge themselves by conducting experiments until prompted by the teacher. Harris *et al.* (2011) observed that teachers prepare grade 5 students for investigation by asking them procedural questions concerning planning and conducting experiments.

Second, teachers support students in locating the relevant resources. Both Beck (1998) and Tan and Seah (2011) report that teachers need to support grade 4 students in identifying relevant information on the internet, because students tend to include interesting but irrelevant information. Furthermore, teachers can provide support by offering appropriate resources to their students. Ness (2013) found that a teacher was able to get grade 3 students answer their 'parking lot questions' by matching them with appropriate informational texts. Busching and Slesinger (1995) offer their grade 7 students a variety of expository and literary texts as starters for their enquiries. Brown and Campione (1994), Beck (1998) and Martinello (1998) organised things so that their grade 1–6 students could consult external experts by inviting them as guest speakers or by contacting them by e-mail or phone.

Third, teachers help students to design or conduct experiments and help to organise and visualise data and findings. Van Tassel (2001) reports how she models the skills of observing, recording, discussing and reflecting on experiments for her grade 2 students. Zuckerman *et al.* (1998) observed how teachers model experiments that investigate erosion using trays of sand, clay, water and wind. Likewise, Keys (1998) found how teachers help students to test ideas by discussing how to set up experiments with insulating materials. Even when having conducted experiments, teacher guidance might still be needed, as reported by Martinello (1998) and Lehrer *et al.* (2000), who have found that teachers need to help students to organise the data they have collected.

Teachers have also been observed offering students conceptual support. Teachers can probe students' understanding by asking clarification, elaboration, or justification questions, as reported by Keys (1998) and Zhang *et al.* (2007). Lehrer *et al.* (2000) observed that teachers help students in grades 1–2 to deepen their understanding of answers by discussing and developing consensual criteria for what counts as convincing evidence. Hakkarainen (2003) found the teachers request that their grade 4 students explicate exploratory relations between biological phenomena in order to develop understanding of their findings. Teachers also bring in new ideas and prompts to consider deeper principles. Brown and Campione (1994) show how a teacher encourages students in grades 5–6 to consider deeper principles of metabolic rate, survival and reproductive strategies, when exploring the topic of endangered species. Zhang *et al.* (2009) found that a teacher can bring in important new ideas, emergent in Knowledge Forum, to a grade 4 student's attention with the aim of deepening an enquiry. Virgin (2015) reports that teachers connect all grade 7 student questions to key historical concepts. By revisiting these key concepts in different historical periods, teachers help students acquire knowledge about these concepts across multiple contexts.

Having guided students to answer their questions, teachers face the challenge of guiding the process aimed at reaching a shared understanding among all the students. In 16 studies, which report about guiding the building of collective knowledge (Table 2), three types of instructional moves are identified: discussing knowledge advances, interconnecting findings and exchanges of distributed expertise. In three studies teachers initiated a meta-discourse about knowledge advances. Hume (2001) facilitated metacognitive reflection on the knowledge building process during classroom discussion by asking students to summarise their findings in a 'progress update'. Keys (1998) similarly observed that teachers reflect with their students on the progress of their findings. Zhang *et al.* (2009) report that the teacher they followed initiate discussions about 'What are our knowledge advances' and collectively reviews the students' input on Knowledge Forum.

Another instructional move for teachers to guide collective knowledge building is to interconnect questions and answers. Harris *et al.* (2011) show that during discussions teachers relate the findings of some students to those of others, highlighting the scientific ideas the answers may have in common. Similarly, Tan and Seah (2011) report that the teacher they followed helps students to rise above their own findings by summarising their understanding of the topic, emphasising differences and similarities, making patterns in various answers explicit and reasoning together to find coherent scientific explanations.

A third type of instructional move to guide collective knowledge construction is to organise exchanges of distributed expertise. Brown and Campione (1994), Hume (2001) and Van Tassel (2001) have found that through questioning, students can become experts in a subtopic. Brown and Campione (1994), Beck (1998), Zeegers (2002) and Lin *et al.* (2009) show that in many classrooms teachers ask their students to share their expertise with their classmates. Hakkarainen (2003), Zhang *et al.* (2007, 2009), Tan and Seah (2011) and Hung *et al.* (2014), show that e-learning environments such as CSILE, Knowledge Forum, or UBPLS support students in continuously exchanging questions, ideas and findings.

Eight studies suggest that questioning should not stop when students find their answers. In these studies, progressive enquiry was observed in which questions evolved gradually from fact seeking to more exploratory meaning seeking. Busching and Slesinger (1998) report a gradual development of grade 7 student questioning from unfocused information-seeking questions about World War II to more focused exploratory questions, the latter not only aimed at understanding but also reflecting moral, psychological and historical wonderment. Zeegers (2002) observed a forward spiralling process in which the investigation of students' questions seemed to lead to further questions and new investigations. Lehrer *et al.* (2000) and Van Tassel (2001) found that some of the most absorbing questions only arise in grades 2–5 as a by-product of enquiries into other questions. Martinello (1998) describes how the duration of involvement with a topic deepens questioning behaviour, and reports that over time more student questions emerge that explore anomalies and analogies, or that have an evaluative nature. Zuckerman *et al.* (1998) also report that when students find answers to their self-formulated questions, this frequently raises new questions, for the new information makes students aware of new problems and cognitive discrepancies. Chouinard *et al.* (2007) report that the order of questions of children seems to be similar to that of adults. Both first build a base of knowledge by asking descriptive questions and then gradually seek deeper or more causal information. Hakkarainen (2003) reports that the exchange of questions and answers between students in grades 5–6 in CSILE is identified by experts in the field as progressive enquiry, in which students improve their working theories on the functions of the human body. These findings suggest that guiding students to progressive enquiry seems to be beneficial for both developing questioning capabilities and deepening knowledge construction.

Teachers use various instructional moves to support progressive enquiry. Lehrer *et al.* (2000) show that teachers facilitate students in grades 1–2 and grades 3–5 to continuously revisit knowledge, questions, inscriptions and data in order to take new and more challenging steps, sending the message that work conducted is not work completed. Martinello (1998) reports that teachers can support progressive enquiry by seeking questions rather than answers in the dialogue with the students. Hume (2001) and Zeegers (2002) describe how teachers organise students so that they share and challenge each other's findings, in order to support the idea that student investigations lead to further questions and new investigations. Hakkarainen (2003) reports that a teacher can facilitate progressive enquiry by suggesting new conceptual perspectives to students in grades 5–6. For example, when students are focusing on exploring the number of different brain cells the teacher suggests: 'I was wondering if you were going to consider how the cells differ in functions?' (Hakkarainen, 2003, p. 1081). Furthermore, Van Zee *et al.* (2001), Hakkarainen (2003) and Zhang *et al.* (2009) found that teachers support progressive enquiry by highlighting new-found information and thereby bringing it to the attention of all students. These findings suggest that when teachers make students aware that findings are just tentative conclusions, new questions and lines of enquiry can be evoked.

We conclude that teachers can use a wide variety of instructional moves to support student questioning in the three phases of questioning. Teachers can prompt relevant student questioning by various instructional moves, such as activating prior knowledge, exploring and discussing literature, hands-on experiments and questions, or problem-solving tasks. Some studies suggest teachers should not only raise student interest, but should also connect student's sense of perplexity to key concepts from the curriculum. After generating questions, teachers often organise convergent activities to record and develop student questioning. Teachers can guide students so that they reformulate their initial questions by clarifying their intentions and meaning, seeking and applying criteria for investigability and modelling questioning behaviour. However, an important prerequisite for mediating questions seems to be that teachers recognise the potential in all student questions for learning the curriculum. Teacher guidance in the answering phase is aimed at the construction of both individual and collective knowledge. By giving both practical and conceptual support, such as finding the method of enquiry, locating resources, designing experiments, developing criteria for evidence, offering new perspectives and explicating relations, teachers can guide students in a way that enables them to answer their individual questions. An awareness of the progressive nature of enquiry helps teachers to deepen enquiries and to realise a chain of enquiry in which student questioning evolves.

Organising peer collaboration

Thirty-four studies show that teachers organise peer collaboration to enhance their instructional moves (Table 3). Several forms of peer collaboration with various aims have been identified in the data. Teachers organise whole and small group discussions aimed at opening perspectives, sharing ideas, exchanging and modelling questions, seeking and planning investigations, presenting findings and reflecting together on the meaning of their findings. This section elaborates on the reported support and limitations of peer collaboration for guiding effective student questioning.

Peer collaboration is reported in 10 studies to support the generation of questions. Biddulph (1989), Keys (1998), Lehrer *et al.* (2000), Hume (2001), Chin and Kayalvizhi (2002), Baumfield and Mroz (2002), Allmond and Makar (2010) and Virgin (2015) all report that questions emerge more easily during small or whole group discussions. Biddulph (1989) observed how a few students can ignite student questioning in multiple classroom discussions in grades 1–5 and calls this pattern a 'ripple-effect'. Similarly, Zuckerman *et al.* (1998) report that when some grade 4 students take initiative to ask questions, other students gradually join in and elaborate upon these questions. Awanta (2013) also shows that when some grade 7 students share their critical questions this inspires their peers to join in and hypothesise, predict, seek and generate questions for things that puzzle them. Allmond and Makar (2010) found that grade 3 students are initially reluctant to write questions individually, but when students work with a partner or in a small group they engage in substantive conversations about their questions.

Next, with respect to question generation, nine studies report how the process of question formulation is supported by peer collaboration. Lehrer *et al.* (2000) and Weizman *et al.* (2008) found that classroom discussions help students in grades 1–5 and grade 7 to become familiar with the range and variety of questions, as well as help to learn to consider additional ways of questioning. Busching and Slesinger (1995) report that grade 7 students benefit from discussing questions because students show each other examples of questions. Lehrer *et al.* (2000) and Di Teodoro *et al.* (2011) show that in grades 1–2 students can build on each other's ideas when refining questions, especially when the teacher models appropriate criteria for evaluating listed questions. Baumfield and Mroz (2002), Hakkarainen (2003). Allmond and Makar (2010) and Hung *et al.* (2014) report that students can give peer feedback on both the content and wording of each other's questions working in small groups. Chin and Kayalvizhi (2002) and Baumfield and Mroz (2002) found that discussing questions

Table 3. Findings on Peer Collaboration and Visual Tools

		Peer collaboration		Visual support		
Study	Grades	Whole class	Small group	Simple tools	Advanced tools	Complex tools
Aguiar *et al.* (2009)	7–9	X	X	–	–	–
Allmond and Makar (2010)	3	X	X	–	–	–
Awanta (2013)	7	X	–	–	–	–
Baumfield and Mroz (2002)	2–5	X	X	–	–	–
Beck (1998)	4	X	X	X	–	
Biddulph (1989)	1–5	X	X	X	–	–
Biddulph (1995)	5–6	–	X	–	–	–
Brown and Campione (1994)	2–6	X	X	X	–	–
Busching and Slesinger (1995)	7	X	X	X	–	–
Chin and Kayalvizhi (2002)	6	–	X	–	–	–
Chouinard *et al.* (2007)	K–1	–	–	–	–	–
Commeyras (1995)	2	X	–	–	–	–
Di Teodoro *et al.* (2011)	2–3	X	–	–	X	–
Diaz (2011)	5	–	–	–	–	–
Hakkarainen (2003)	5 – 6	–	X	–	–	X
Harris *et al.* (2011)	5	X	X	–	–	–
Hume (2001)	6–7	X	X	–	–	X
Hung *et al.* (2014)	5–6	–	X	–	X	–
Keys (1998)	6	X	X	X	–	–
Lai and Law (2013)	6/10	X	X	–	–	X
Lehrer *et al.* (2000)	1/3–5	X	X	–	X	–
Lin *et al.* (2009)	5	–	X	–	–	–
MacKenzie (2001)	7	X	–	–	–	–
Martinello (1998)	2/5/7	–	X	–	X	–
Ness (2013)	3	–	X	X	–	–
Penuel *et al.* (2004)	5	X	–	–	X	–
Scardamalia and Bereiter (1992)	5–6	–	–	–	–	–
Simpson (1996)	6/7	X	–	–	–	–
Tan and Seah (2011)	4	X	X	–	–	X
Van Tassel (2001)	1–2	X	X	X	–	–
Van Zee *et al.* (2001)	1–6	X	X	X	–	–
Virgin (2015)	6–7	–	X	X	–	–
Weizman *et al.* (2008)	7	X	X	–	X	–
Zeegers (2002)	4–7	X	X	–	–	–
Zhang *et al.* (2007)	4	X	X	–	–	X
Zhang *et al.* (2009)	4	X	X	–	–	X
Zuckerman *et al.* (1998)	1–4	X	–	X	X	–
Total		26	27	10	7	6

in small groups removes misunderstandings and tangential questions and leads to more precise questions.

Seven studies show that peer collaboration supports planning and conducting investigations. Brown and Campione (1994), Beck (1998), Keys (1998) and Zeegers (2002) found that teachers organise small independent research groups, in which students in grades 4–7 collaboratively plan and conduct investigations, and support each other in collecting and interpreting data. Similarly, Lehrer *et al.* (2000) and Van Tassel (2001) report that small groups of students in grades 1–2 choose their questions and subsequently collaboratively seek methods for investigation. Harris *et al.* (2011) found that students help each other determine steps for setting up experiments and reason together through benefits and drawbacks of following particular steps. Busching and Slesinger (1995) report that students benefit from each other by sharing experiences and knowledge produced in subsequent enquiries.

Six studies show how teachers organise peer collaboration in order to exchange findings. Some teachers opt for exchanges involving the whole class. Di Teodoro *et al.* (2001) found that teachers organise Math Congresses for students to discuss questions and explore their findings. Lai and Law (2013) show that students report every first 10 minutes of each lesson, on progress from each small group, showcasing their work and sharing important new findings or ideas. Zhang *et al.* (2009) found that a teacher can regularly review with students' work in progress on Knowledge Forum, where they can interact with each other, contributing questions and knowledge and ideas related to different subtopics. Other teachers alternate small group and whole class exchanges. Virgin (2015) reports that teachers group their students on the basis of similar or different questions, and hence organise an exchange of the findings. Brown and Campione (1994) report that students regroup regularly in reciprocal teaching seminars in which each student is an expert in one subtopic holding one-fifth of the information of the whole curriculum theme. Harris *et al.* (2011) report how a teacher alternates whole class and small group discussions for three consecutive rounds to compare a scientific definition of the concept 'habitat' with students' own knowledge and ideas about this concept.

Eight studies found that peer discussions about questions or findings support student reflection and argumentation. Van Tassel (2001) observed that grade 2 students learn to explicate their own views when discussing their questions in small groups. Biddulph (1989), Lehrer *et al.* (2000) and Allmond and Makar (2010), report that negotiating questions in small groups opens up new and different perspectives and supports students in learning to think critically and purposefully. Van Zee *et al.* (2001) show that reflection is prompted when students compare and discuss their findings. Beck (1998) observes that a full airing of the various theories forces students to think through their ideas and provides both an interest in the question and a context for an answer. Harris *et al.* (2011) and MacKenzie (2001) found that an exchange of findings is most supportive when teachers encourage students to articulate to their peers constructive criticisms, suggestions, questions, or approval. Another strategy to prompt reflection and argumentation, reported by Harris *et al.*, is asking students to predict their answers and invite their peers to ask clarification questions about predictions and justify why a prediction should be considered true or false.

Seven studies report on some of the limitations of peer collaboration for guiding student questioning. Three studies suggest teachers need to take group dynamics into account when organising peer collaboration. Zeegers (2002) reports that grade 7 students, who are not accustomed to exchanging ideas in classroom discussions, might be reluctant to share their questions with the whole class. Similarly, Simpson (1996) reports grade 6 students feel more safe sharing ideas and questions in small groups first, rather than directly in discussions involving the whole class. Another potential drawback of peer collaboration has been reported by Baumfield and Mroz (2002), who found that students tend to select the questions for which a consensus can most easily be found and that more complex questions are often dismissed.

Another limitation of peer collaboration is that teachers experience guiding small group work as demanding. Keys (1998) reports that even with three professionals in the classroom, guiding several small groups in their scientific investigations is a considerable challenge. Beck (1998) and Zeegers (2002) both observed that guiding student questioning puts a heavy demand on a teacher's time and capacities. Moreover, Zhang *et al.* (2009) found that students who work on Knowledge Forum in fixed small groups are very dependent on the teacher's organisational and communicative skills in building collective knowledge.

To overcome these drawbacks several studies suggest flexible grouping. Four studies show how teachers organise flexible forms of peer collaboration by making students collectively responsible for generating, formulating and answering their questions. Brown and Campione (1994) describe how teachers support the development of a community of learners by, on the one hand, allowing students in grades 5–6 to develop individual expertise by researching subtopics and, on the other hand, by organising regular small group meetings in which students exchange their expertise about these subtopics with their peers. In this community, teachers hold all students responsible for the mastery of the whole theme, not just for their subtopic. Hume (2001) reports that she explicitly makes students responsible for both researching questions and exchanging answers. She invites students to take responsibility for all questions they are interested in and encourages them to exchange questions, ideas and findings. As a result, most students sign up for several questions—often different questions than the ones they generated themselves—and students collaborate in several investigations in various groupings. Hume observes that students show a collective willingness to contribute to knowledge construction because of this shared responsibility. Zhang *et al.* (2007, 2009) similarly show that inviting students to contribute to all lines of enquiry results in opportunistic flexible grouping. This means that students group and regroup depending on their interests and emergent needs. This form of opportunistic peer support seems to make students feel responsible for each other's work. This responsibility is, for instance, reflected in one student's proposal that all questions have to be 'approved' by the rest of the class in order to ensure their contributions to common goals, before investigations can proceed. Zhang *et al.* (2009) found that flexible grouping is more effective than fixed small groups with respect to the degree of participation in each other's questions, the spread of knowledge to class members, the coherence of network structures, and the extent of student independence from teacher support. Similarly, Harris *et al.* (2011) found that teachers who are the most successful in terms of student knowledge gains in assessments organise things so that there is a shared responsibility for advancing collective knowledge among their students.

However, a shared conceptual focus might be a necessary prerequisite before teachers can make students collectively responsible for their questioning. Although Biddulph (1989) reports that diversity in student questioning accommodates students of different ability, and Tan and Seah (2011) found that a variety of questioning makes it possible to explore a curriculum topic from multiple perspectives, Zeegers (2002) observed that varied levels of conceptual understanding also might obstruct peer collaboration. Zeegers found in multiple classrooms that when students do not have a common shared basic understanding of the topic, they find it hard to support each other in generating, formulating and answering questions. It might therefore be no coincidence that Brown and Campione (1994) and Hume (2001) first establish a common language and understanding in the classroom community by organising exploratory activities and classroom discussions. Moreover, Zhang *et al.* (2009) report that a 'central view', a key concept central to the curriculum topic, supports opportunistic collaboration, because it gives a shared purpose and direction to collective student enquiry.

In summary, organising peer collaboration can support the guidance of student questioning and has been found to have positive effects on all three phases of questioning. The retrieved studies suggest that the most successful teachers support collective knowledge construction by discussing knowledge advances, interconnecting findings and organising exchanges of distributed expertise. Although peer collaboration can support effective student questioning, teachers need to create a safe classroom environment for students in which questioning is the norm. A potential risk in peer collaboration is that working in small fixed groups might lead to students retaining their dependency on the teacher's assistance. In contrast, there is evidence that organising things so that students have a shared responsibility for collective knowledge advances, while having a shared conceptual focus, seems highly effective for guiding student questioning.

To further support collective responsibility, many studies mention the use of visual tools. In 23 studies, teachers organised forms of visual support to guide student questioning (Table 3). When comparing their function for guiding student questioning, three types of visual tools emerge. Simple visual tools have mainly the function to support the sharing of questions and/or findings. More advanced visual tools do not only support sharing questions and/or findings, but are also used to organise and refine questions or transform findings into graphical representations. The most complex visual tools have multiple functions, in addition to sharing, organising and refining questions and sharing and transforming findings, they also provide a flexible structure for elaborating knowledge construction, allowing for emergent questioning and lines of enquiry, as well as for organising peer support and feedback.

Ten studies show that teachers use simple visual tools to guide student questioning (Table 3). In six studies teachers used simple visual tools to support the exchange of questions. Van Zee *et al.* (2001) found that a teacher requests that her grade 1 students record their questions with the aim to remember, to share and to compare them and possibly to try to find some answers. Zuckerman *et al.* (1998) describe how students in grades 3–4 record upcoming questions during enquiries on a poster called 'Our unresolved Questions' in order to share them with the class and to remember them for later. Brown and Campione (1994) report that students in grade 5–6 write their questions on 'post-its' and place them on a bulletin board. By categorising their questions students are able to identify relevant subtopics for further investigation. Busching and Slesinger (1995) observed that a chart of student questions on the classroom wall tends to grow over time, depicting the development in student questions. Before starting their final enquiry projects, students select the most important questions in a classroom discussion from this chart. Biddulph (1989) found that when teachers obtain and record students' questions in public, a stimulus is given to other students to consider aspects that they may not have thought of yet. Van Tassel (2001) describes how teachers brainstorm with grade 2 students about the topic 'Air' and organise their questions on a poster. When exploring the topic further by conducting classroom experiments, student observations are again recorded on a chart, with the aim of visualising these new understandings. However, although teachers seek to make students understand the relation between their observations and the principles of air, these relations are not visualised. The findings suggest that simple visual tools might help students to remember, share and compare their questions.

Four studies report how teachers use simple visual tools to support the exchange of findings. Beck (1998) describes how grade 4 students, as experts in their subtopic, are required to create a piece of writing, something artistic and a diagram to share their findings with the whole group. Keys (1998) also observed how grade 6 student groups make colourful posters to summarise the investigations that they present to the class. In both cases, the effects of these tools on the distribution of knowledge were not reported. Virgin (2015) reports that facilitating online environments such as Google Drive or Schoolology are used to support grade 7 students and get them to interact with each other and the teachers when investigating Big Ideas in History. Information on perceived support, however, was not reported. Ness (2013) found that grade 3 students eagerly research their own questions that are posted on a 'Parking Lot' poster, because they cannot be addressed during class. When students identify some of the answers, they suggest that their findings should be placed on a 'Free Way' poster. Simple visual tools are used for exchange of findings, but it is unclear to what extent they contribute to building collective student knowledge.

The use of advanced visual tools has been reported in 10 studies (Table 3). Four studies show how teachers use them for the development and refinement of student questions. Di Teodoro *et al.* (2011) observed how students in grades 1–2 place their questions on a T-chart, which is a graphic organiser on which students list and examine two facets of a topic, to distinguish between 'surface' and 'deeper' questions. By discussing with students the T-chart, teachers identify criteria for 'deeper' and 'surface' questions. Teachers visualise these criteria on a poster called 'Diving deep for treasure', showing the analogy of an anchored ship, which helps both teachers and students to more easily identify the goals of questioning. The pre- and post-comparison of questions shows that students ask significantly more 'deeper' questions. Hung *et al.* (2014) report on the 'Ubiquitous Problem Based Learning System' (UPBLS) a software application for handheld devices. Hung *et al.* show that UPBLS can be used for collecting, sharing and refining students' questions during and after field trips, but UPBLS also provides an online discussion forum, an e-library and tools for collecting environmental data. Students work in small groups and improve their own questions and those of their peers by giving peer feedback in UBPLS, using scoring rubrics for questioning ability as reference. Tests show that both novice grade 5 and experienced grade 6 students improve their questioning abilities significantly. Penuel *et al.* (2004) describe 'Boomerang', an software application for handheld devices by which students can share their questions by beaming them to peer devices or to the teacher's computer. Boomerang can also be used to categorise questions by using a generic question rubric. The students' motivation to use the application is reported to be high, but the effects on questioning ability have not been reported. Weizman *et al.* (2008) describe the use of a 'Driving Question Board' (DQB) in a grade 7 science class, a large poster board that presents the central 'driving' question and is surrounded by sub-questions that address the various subtopics of the unit. At the start of unit, the DQB was jointly constructed in a classroom discussion and the teacher's driving- and sub-questions were, in turn, surrounded by student questions. During lessons teachers can use DQB for various purposes, such as scaffolding practice of question-asking by categorising, refining or deleting questions, connecting activities to the driving question, relating student questions to specific content topics, and sharing and organising the findings. Both students and teachers report that the DQB has supported them in keeping a conceptual focus and connecting findings and activities to the questions.

Three studies show how teachers can use advanced visual tools to organise and transform student findings. Martinello (1998) observed how teachers introduce students to different types of graphic organisers and ways of visually displaying data, such as time-lines, charts, diagrams, graphs and Venn diagrams. These graphics help students in grades 2–7 to find meaningful patterns in their data and answers to their questions. Guided viewing of the graphics supports students and helps them to find their next questions, as the guided viewing makes them aware of gaps in their knowledge. Lehrer *et al.* (2000) show that the teacher encourages students in grades 1–2 to move 'beyond observation toward inscription' (p. 83). Students use graphical representations to record, describe, and analyse their data, in forms such as strips of paper representing the length of a stem in order to compare the growth of plants. A discussion of these graphical representations and other types of data displays, such as charts, tables and Venn diagrams, inspires students to engage with many of the most interesting questions because they become aware of the emerging properties of the phenomenon under study. Zuckerman *et al.* (1998) also report about teachers helping students to design their own visual representations or models of the phenomenon being studied. By discussing differences and similarities between these representations, teachers guide students and help them identify important features or properties which can be further investigated in experiments. Advanced visual tools seem to support teachers when they seek to improve the quality of questions, to organise exchange of questions and findings, to challenge students about their thinking and to raise new questions.

Six studies report on complex visual tools (Table 3). In five out of these six studies, teachers use either 'Knowledge Forum' (KF) or its predecessor 'Computer Supported Intentional Learning Environment' (CSILE) (Hakkarainen, 2003; Zhang *et al.*, 2007, 2009; Tan & Seah, 2011; Lai & Law, 2013). KF and CSILE are electronic learning environments consisting of a communal database in which students can share their questions, theories, and findings as 'notes'. These notes are digital objects that are accessible for everyone to give comments in response to, ask for clarification, or suggest refinements, but which can only be altered by the author. All five studies report that students in grades 4–6 students can record and share new resources and discoveries in KF/CSILE and sustain the online discourse in order to advance community understanding.

Besides offering a platform for sharing questions and findings, KF and CSILE also provide an adaptable structure for emergent ideas and developments. Zhang *et al.* (2007, 2009) show that the teacher can initiate the unit in KF with one central 'view' about 'light' in which grade 4 students record their questions and theories. In the third week, when students realise that this single view becomes too 'messy', students propose creating more views about focal themes such as shadows, colours and reflections, to accommodate the various emergent lines of enquiry. Then all the notes are reorganised in the new views and the views are mutually hyperlinked for easy navigation in KF. When students make further progress in their investigations, they start to realise that each enquiry involves various sub-issues. To represent the evolving goals, students create subsections within each view. Zhang *et al.* found that KF supports elaborate and flexible knowledge construction and is adaptable to new emergent questions and ideas.

KF and CSILE are also reported to support students' sense of collective responsibility. Hakkarainen (2003) shows that peer and teacher feedback on student notes in CSILE allows students in grades 5–6 students to refine their questions and develop progressive enquiries. Zhang *et al.* (2007, 2009) found that KF allows for opportunistic collaboration in which all students are free to explore any problem from any view in the database. Working with views in KF helps to align all student contributions to the central conceptual focus and makes the structure of the collaboration fluid. Because students do not work in fixed groups connected to one subtopic, but in small groups that form and reform based on evolving needs, students have been reported to take responsibility for the overall growth of the database.

Hume (2001) describes another complex visual tool: the 'Knowledge Wall (KW)'. The KW is a 22 feet long chalkboard in the classroom on which her grade 7 students can post questions, theories and answers written on sticky-notes. Students are free to join any line of enquiry and many students are active in several investigations. Hume observes that students not only share findings, they also challenge each other's questions and answers by posting peer feedback and thereby deepening the enquiry. Students have been reported to show a strong sense of collective responsibility for the KW, which becomes apparent when Hume suggests making a summary of the notes. This proposal is met with fierce resistance from students until the teacher clarifies that it is not her intention to end the enquiry but only to give a 'progress update'. Although the KW is reportedly useful for organising the exchange and development of student questioning, keeping track of responses to earlier input and the availability of space for contributions are found to be issues that become problematic as the enquiry progresses.

In summary, teachers used visual tools to support student questioning in 50% of the studies. The visual tools used varied both in functionality and in form. While simple representations can be used for guiding the generation and formulation of questions and the exchange of answers, more advanced and complex tools also support reflection on the process of questioning and make possible the construction of collective knowledge. The visual tools also vary between traditional forms of graphical representations, such as posters, charts and diagrams, and digitally enhanced visual tools, such as ELOs and mobile apps. Although all visual tools are reported to support teacher guidance of student questioning to some extent, complex visual tools have been found to allow for more student autonomy and to support teachers in realising progressive enquiries.

Discussion

Previous research has shown that student questioning has potential for teaching and learning in primary education, but teachers seem to find it difficult to implement effective student questioning in their classrooms (e.g. Biddulph, 1989; Wells, 2001; Rop 2002; Zeegers, 2002). Effective student questioning was defined as the alignment of student questioning to the requirements of the curriculum. Although a substantial number of studies on student questioning were retrieved, we were not able to find a systematic review of teacher guidance with respect to effective student questioning. The aim of this review, therefore, was to derive emergent themes that come out of the empirical research on teacher guidance of effective student questioning in primary classrooms and the central research question 'Which emergent themes for guiding effective student questioning in primary classrooms can be derived from the literature?' was addressed.

To analyse the retrieved studies, a three-step model of generating, formulating and answering student questions was used, as well as three perspectives on teacher guidance: teacher characteristics, teachers' instructional moves and organising support by peer collaboration. In the theoretical framework, several challenges for guiding effective student questioning were identified in each phase of questioning. In the generating phase the challenges seemed to be to promote students' interest in curriculum topics, to prompt students to feel a sense of perplexity about these topics and to enhance their inquisitive stance. In the formulating phase teachers were challenged to support students in articulating investigable questions and to guide student questioning to address the width and depth of the curriculum. Finally, in the answering phase, teachers faced the challenge of supporting the construction of collective knowledge and evoking progressive enquiries that contribute to effective student questioning.

From this review it can be concluded that four emergent themes in teacher guidance contribute to addressing these challenges. First, effective student questioning requires confident teachers, who create a supportive classroom culture for question generation and acknowledge the potential in students' initial questions. The focus in teacher guidance should be on supporting students' inquisitive stance. When teachers establish a safe and welcoming classroom environment for raising initial questions, students seem to gradually develop the skill to formulate their interests into authentic investigable questions. By taking into account the dynamic nature of questioning and regarding the initial questions as steps in the curriculum, some teachers and students succeed in making enquiries progressive. Then, the dynamic nature of questioning arises in all its strengths, because the process of questioning and answering becomes truly cyclical. Second, providing a conceptual focus supports students and helps them raise relevant but also authentic questions about the topic at hand. Such a conceptual focus could be a core curriculum, a curriculum consisting of a limited number of key concepts that represent the major ideas and perspectives on the topic. A core curriculum allows both the freedom for divergent questioning that addresses the width of the curriculum and the structure to develop questioning that gets at the depth of the curriculum. A conceptual focus also makes it possible for answers to converge into a kind of collective building of knowledge. Third, teachers and students should be encouraged to take collective responsibility for the effectiveness of student questioning. Peer collaboration helps teachers and students to generate a diversity of questions, to value the potential of questions, to support discussion and mediation, and to assume a collective responsibility that fosters progressive enquiry. Fourth, visualising the questioning process helps in guiding all phases of student questioning. Teachers can use visual tools to help students become aware of their prior knowledge and interests. Visual tools can also support students in organising their new-found knowledge and making them aware of new questions. By visualising the cyclical process of questioning and answering it becomes possible to create a collective workspace in which students and teachers can discuss and record progressive enquiry. Hence, in answer to our research question, four emergent themes for guiding effective student questioning in primary classrooms have been identified: (i) acknowledge the potential in all questions, (ii) define the conceptual focus in the core curriculum, (iii) organise collective responsibility, and (iv) visualise progressive enquiry.

To correctly interpret our conclusions, we would like to point out some of the assumptions that guided the choices with respect to methodology. This review aimed to identify emergent themes in the literature that might support teachers in guiding effective student questioning in enquiry-oriented classrooms in primary education. Although the goals of the review might be considered aggregative, setting out to determine 'what works for teachers', its methodology is mainly configurative, identifying patterns in teacher guidance (cf. Gough *et al.*, 2012). Therefore, when selecting studies for this review, similarity of methodology was not a criterion, but relevance to the topic and empirical evidence of classroom experience were. The resulting heterogeneity of the selected studies offers the opportunity to compare teacher guidance in multiple contexts and under varying circumstances, which enhances the review's ecological validity for teachers and instructional designers. However, the heterogeneity among the studies, such as the goals of studies, the educational settings, the types of interventions and the statistical evidence, does not allow for aggregative analysis and therefore no quantative effects of teacher guidance are reported.

Furthermore, we would like to point out some limitations of our study with respect to the data collection and analysis. Having selected a body of studies from the 'questioning to learn' approach on student questioning, a certain bias in retrieved studies should be accounted for when interpreting the results. Studies from this approach are oriented toward developing questioning as a stance and pay less attention to developing questioning as a skill. Furthermore, we only selected 36 studies on the guidance of student questioning in primary education published since 1990. We did not take into account another 78 peer reviewed empirical studies that took place in secondary and tertiary education, for the focus in this review was on primary education. Moreover, we did not include another 33 studies about aspects of student questioning published before 1990 and 36 studies from the 'learning to question' paradigm that have been published since 1990. Reviews of these bodies of literature may have offered new perspectives on the emergent themes identified in this review.

Finally, another methodological limitation of this review is that over 85% of the dataset are single-case or multiple-case studies. Although naturalistic settings contribute to the ecological validity of the findings, their contextual variation also raises the issue of the transferability of the outcomes. However, in all these studies the teachers were attempting to guide one or more phases of student questioning in classroom contexts and similar patterns of guidance were identified between different subjects, grades, countries, modes of instruction and foci of study. The only truly discriminating factor identified between studies seemed to be the length of the intervention. Only in interventions lasting 3 months or longer were forms of progressive enquiry reported.

To extend our knowledge of teacher guidance of student questioning we would like to suggest some opportunities for future reviews and research. Future reviews might adopt a more aggregative methodology and search for the empirical effects of teacher guidance in one or several of the emergent themes identified in this review. Furthermore, because it seems likely that students might need to develop both an inquisitive stance and questioning skills, future reviews might also consider the interplay between findings in this review and in reviews on the 'teaching to question' approach. Further research based on the identified emergent themes might further enhance our understanding of how to guide effective student questioning. Specific questions for future research might be: 'How can teachers be supported in recognising and guiding the potential in all student questions?', 'What are the most effective ways to organise peer support for student questioning?' and 'How can visual tools be effectively used to support teachers in their guidance of student questioning?'

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