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REVIEW ARTICLE

Teacher Competencies for the Implementation of Collaborative Learning in the Classroom: a Framework and Research Review

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Abstract This article describes teacher competencies for implementing collaborative learning in the classroom. Research has shown that the effectiveness of collaborative learning largely depends on the quality of student interaction. We therefore focus on what a *teacher* can do to foster student interaction. First, we present a framework that draws a comprehensive picture of a teacher role we see as germane to fostering student interaction. The framework distinguishes between five teacher competencies that span across all implementation phases of collaborative learning: the ability to plan student interaction, monitor, support, and consolidate this interaction, and finally reflect upon it. Then, we review research on collaborative learning and structure this review along the five teacher competencies presented in the framework. The review targets relevant concepts and pivotal empirical research results about how to foster student interaction. For each competency, we first summarize relevant concepts and empirical results. We then apply the concepts and findings to a classroom situation. These teaching vignettes illustrate the functions of the five teacher competencies in fostering student interaction in collaborative learning. For each vignette, we discuss and highlight specific aspects of the presented teacher role and draw practical implications. Monitoring and supporting in the classroom should be trained in teacher education and facilitated by providing teachers with tools such as a checklist of beneficial student behaviors. These practical implications can inform educational practices and offer new directions for future research regarding promoting collaborative learning.

Keywords Teacher role · Teacher competencies · Collaborative learning · Student interaction · Literature review

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Introduction

In collaborative learning settings, the teacher plays a crucial role in fostering student interaction that is beneficial for learning (Cohen 1994; Gillies et al. 2008; Pauli and Reusser 2000; Van Leeuwen et al. 2013). Collaborative learning is the process of two or more students working together to find a joint solution to the group task at hand (cf. Renkl 2007). They can only accomplish this by sharing their knowledge, for example, definitions of relevant concepts, and thus build common ground and joint knowledge (Roschelle 1992). From a cognitive and metacognitive perspective, the goal of collaborative learning therefore is not the solution itself, but joint knowledge building and each group member's individual learning gains (cf. Renkl 2007). In collaborative learning, students depend on one another because of their unique knowledge and perspective. It is therefore vital that they feel responsible for sharing their knowledge (Roschelle 1992). Collaboration in this sense goes beyond cooperation. Cooperation means that the group task is divided into independent subtasks which are solved individually and then the partial solutions are assembled to form the final solution (Dillenbourg 1999). Cooperation can take place during collaboration, but through joint knowledge construction, collaboration is more than the sum of its parts. In this article, we focus on collaborative learning. We include research on cooperative forms of learning only when it can be extended to collaborative learning.

Meta-analyses have shown that collaborative learning is highly effective and often superior to individual learning in terms of academic achievement and attitudes (Kyndt et al. 2013; see also classic review articles: e.g., Lou et al. 1996; Slavin 1980). Originally, however, research only focused on the conditions under which collaborative learning is effective, such as group composition, group size, learning task (Cohen 1994), reward structure (Slavin 1996), and underlying principles, such as *positive interdependence* and *individual accountability* (Johnson and Johnson 1989; see also Aronson et al. 1978). Meanwhile, the interaction processes that occur during collaboration were being neglected. Today, there is evidence that the effectiveness of collaborative learning largely depends on the quality of student interaction (Dillenbourg and Tchounikine 2007; Kobbe et al. 2007) as well as on the teacher who guides students' collaborative learning (Gillies et al. 2008). Thus, to implement collaborative learning successfully in the classroom, it is critical that the teacher makes fostering beneficial student interaction a priority (cf. Gillies et al. 2008; Pauli and Reusser 2000).

How the teacher fosters beneficial student interaction has been studied through self-assessment and classroom observation. Interestingly, teachers often do not feel competent in implementing collaborative learning successfully in their classrooms (e.g., Gillies and Boyle 2010). Ruys et al. (2011) asked teacher students to self-assess their own skills for implementing collaborative learning and also found that self-reported skills were low. However, these skills did improve over time when teacher students were using collaborative learning in their own classrooms. Van Leeuwen et al. (2013) studied authentic teacher behavior during collaborative learning by looking at the aim of teacher interventions or their means. The aim can be to guide social, affective, cognitive, or metacognitive aspects of student interaction (see De Lièvre et al. 2006). The mean, that is, how the teacher intervenes, can be reminding or suggesting (see Greiffenhagen 2012). While these studies are limited to describing teacher actions and cannot speak to the causal effects of these actions (but perhaps correlating effects), there is ample experimental research on instructional features of collaborative learning that teachers can use to foster beneficial student interaction.

To describe how a teacher can foster beneficial student interaction, we draw upon research conducted in settings with face-to-face interactions, as well as on research investigating computer-supported settings. Research in face-to-face settings has mainly focused on designing optimal conditions for collaboration, that is, how teachers should set up collaborative learning (cf. Green and Green 2010). When authors have addressed the teacher's role after planning, and during the collaboration, it was mainly to warn teachers not to negatively affect the collaboration by interrupting the natural processes taking place (see Haag and Dann 2001; Renkl 2007). One argument made by authors is that the teacher's role should be limited to thorough planning of the collaborative learning setting and being available for students' questions during the collaboration process. However, despite thorough planning, students' cognitive and metacognitive activities often remain shallow (King 2008). This lack of in-depth cognitive activity has detrimental effects on joint knowledge building and individual learning gains. It therefore seems crucial not only to plan student interaction, but also to monitor whether such interaction actually takes place and to support it when needed. Indeed, the benefits of monitoring and supporting student interaction in an adaptive way have been well-researched in *computer-supported collaborative learning* (CSCL; see Dillenbourg 1999) settings (e.g., Rummel and Weinberger 2008; Van Leeuwen et al. 2013). In CSCL settings, collaboration is supported by technological means, in addition to or not by a human teacher.

In this article, we will first present our framework of teacher competencies necessary to successfully implement collaborative learning in the classroom (ICLC) (Kaendler et al. 2013). The ICLC competencies are *planning*, *monitoring*, *supporting*, *consolidating*, and *reflecting* (cf. Artzt and Armour-Thomas 1998; Pauli and Reusser 2000). This framework is then used to structure a research review of features of instructional contexts that promote collaborative learning. The research review provides a thorough description from a research perspective of what a teacher should know and do to successfully implement collaborative learning in the classroom. By framing our research review along the five teacher competencies, we summarize relevant concepts and empirical results of research on collaborative learning in a manner that supports their translation into practice. Finally, we demonstrate how the reviewed research findings can be applied to typical classroom situations with teaching vignettes. These teaching vignettes illustrate the function of the five teacher competencies in fostering student interaction in collaborative learning. Our discussion will highlight how a teacher's monitoring and supporting of student interaction can be facilitated, trained, and assessed. In the next section, we will present the ICLC framework.

ICLC Framework

The implementing collaborative learning in the classroom (ICLC) framework (see Fig. 1) draws a comprehensive picture of a teacher role we see as germane to fostering student interaction because it describes five teacher competencies that span across all implementation phases of collaborative learning. The ICLC framework includes two levels, a teacher and a student level (see Fig. 1). While the framework focuses on the teacher level, the student level is also presented in the framework, as the teacher's goal is to ensure a high quality of student interaction, on which the effectiveness of collaborative learning depends (Dillenbourg et al. 1996; Kobbe et al. 2007; Webb 1989). Teachers' professional knowledge, teacher beliefs (cf. Artzt and Armour-Thomas 1998), and five teacher competencies (see teacher level in Fig. 1) all impact the quality of student interaction.

In line with the definitions provided by Klieme and Leutner (2006), we here define competencies as the ability to perform tasks in a specific situation, for instance a classroom situation, in a flexible and adaptive fashion. The first step in developing competencies is the acquisition of professional knowledge; see the ellipse in Fig. 1. Professional knowledge, in this context, is knowledge about the tasks and how to perform them in general. Thus, while

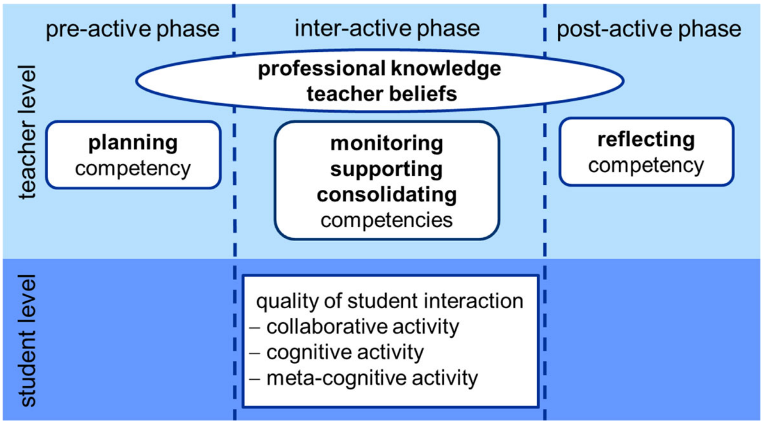

Fig. 1 The ICLC framework

professional knowledge is generic, professional competency is the ability to apply professional knowledge to perform tasks in a specific situation and thus task-specific. Task performance is also influenced by teacher beliefs (see the ellipse in Fig. 1) which are defined as "an integrated system of personalized assumptions about […]" (Artzt and Armour-Thomas 1998, p. 8) their role in the classroom. For example, a teacher might be convinced that his/her own involvement in student interaction has a detrimental effect on students' collaborative learning (cf. Haag and Dann 2001; Renkl 2007) and, thus, avoids supporting his/her students during their interaction.

The ICLC framework is based on the metacognitive framework of teacher practice by Artzt and Armour-Thomas (1998) that describes teaching in analogy to the cognitive process of solving a problem in three phases: a pre-active phase, an inter-active phase, and a post-active phase (cf. Jackson 1968). With regard to collaborative learning, the pre-active phase includes the teacher's preparation of the lesson and the introduction of the collaborative learning setting to the whole class before students start working in groups. During the inter-active phase, students find solutions to the problem at hand, which are eventually reviewed with the whole class. Finally, the post-active phase takes place after the teaching lesson, when the teacher reflects on the previous phases.

In order to master the different phases of this complex teaching situation, five ICLC competencies are needed for planning the lesson, monitoring and supporting student interaction, consolidating groups' work, and reflecting (cf. Artzt and Armour-Thomas 1998; Pauli and Reusser 2000). Each of these five competencies has been researched in contexts other than collaborative learning as well. For example, Baer et al. (2011) studied the development of the planning competency during the time practical experience is gained. Monitoring student interaction is one form of teachers' *professional vision* (Sherin 2001), which focuses only on crucial aspects of the classroom situation. Supporting students, particularly in an adaptive fashion, is regarded as a key aspect of professional teaching (Seidel and Shavelson 2007; Van de Pol et al. 2013). Knowledge consolidation in the classroom is generally seen as an essential characteristic of high quality teaching (cf. Helmke 2009). How to assess and promote reflecting upon one's own teaching has also been studied in research on teacher education (e.g., Sparks-Langer et al. 1990; Zeichner and Liston 1987). Although these competencies are crucial in teacher practice in general, they have not yet been considered to be associated with one another or identified for collaborative learning. We here integrate them into a framework in order to systematically describe the teacher's role in a collaborative learning setting. Next, we provide a brief overview of each competency.

The teacher's tasks that have to be carried out in planning a collaborative learning scenario in the pre-active phase are seen as follows: First, the teacher defines the learning goal(s) and identifies characteristics of the present classroom situation in which collaborative learning should be implemented. Characteristics may include task features, the students' prior knowledge of the lesson content, and their experience with collaborative learning. Based on these characteristics, an appropriate *macro-script* (cf. Dillenbourg and Hong 2008) is selected which structures the collaboration in advance to maximize the likelihood of beneficial student interaction taking place. In addition to the macro-script, the task instructions and the learning material must be designed. Finally, a method for composing groups must be selected.

During the inter-active phase, students work together in groups, preferably following the given macro-script while finding solutions to the problem at hand. This is where the teacher's monitoring and supporting competencies are required. Even though the teacher has planned the collaborative learning scenario thoroughly by structuring collaborative learning through a macro-script, students often fulfill the prescribed activities in a narrow manner (King 2008). Consequently, in the inter-active phase, while monitoring, the teacher pays attention to the student interactions taking place. The teacher can observe if students are actively engaged (Johnson and Johnson 1998), asking targeted questions, giving explanations to each other (Webb 1989), and making the group aware of any mistakes (Bannert 2003).

Monitoring is a prerequisite for the supporting competency. Based on the observation of the student interactions, the teacher decides in which groups, how and when to intervene. For example, occasionally reminding students to contribute to the group work may be necessary. CSCL research on this so-called *micro-scripting* (cf. Dillenbourg and Crivelli 2009) investigates different kinds of prompts that should be given, depending on the situation. A prompt might be used, for example, when the collaboration comes to a critical moment such as students offering insufficient explanations or if there is a lack of question asking between the students in one group.

The different steps to be carried out while monitoring and supporting student interaction in the inter-active phase are summarized and presented in the *collaboration management cycle* by Soller et al. (2005). This cycle describes the whole process of collaboration management in four steps. In the first and second steps, data of the ongoing interaction are collected and summarized into indicators or dimensions regarding the quality of interaction. The goal of these first two steps is the construction of a current model of interaction. The third step serves to diagnose difficulties during the interaction by comparing the current state of the interaction with a desired interaction model, which represents beneficial students' behaviors for knowledge construction. Differences between the current state and the desired state indicate primarily the need for support, but also show how to support students in an adaptive fashion in the last (fourth) step of the collaboration management cycle.

The next ICLC competency required in the inter-active phase is consolidating the groups' results after the group work phase is done. The teacher's task is to ensure learning gain by compiling and acknowledging each group's solution to the problem that the students have been working on. When consolidating the groups' results, the teacher, for instance, compares and differentiates between the different and sometimes suboptimal or wrong solutions, while focusing on important aspects of the concepts to be learned (see Kapur and Bielaczyc 2012). Another method of consolidating the groups' work could be a final discussion with the whole class (see Lampert 1990).

The final competency is reflecting. Here, we concentrate on the self-reflection process taking place after teaching. The teacher analyzes the whole implementation process that took place. Students' behaviors during interactions are considered again and possible explanations for them are sought out. The success of the collaborative learning setting is evaluated based on the intended learning goals and intended learning activities. The learning gain can be investigated on three levels: individual learning gain, knowledge of the group as a whole, and learning progress of the entire class (cf. Dillenbourg et al. 2011). Potential other categories of outcomes might include students' motivation, their epistemological beliefs, perceptions toward the subject, or attitudes toward collaborative learning (cf. Kyndt et al. 2013). For the purposes of this article, we chose to focus on academic achievement, an outcome variable with positive effects in many studies of collaborative learning (cf. Kyndt et al. 2013).

In line with the collaboration management cycle, the effects of the teacher's supportive intervention should also be evaluated. Reflecting on the whole implementation process helps to develop alternative strategies for the next implementation of collaborative learning in the classroom. Consequently, the fourth step of this management cycle does not represent a final step (Soller et al. 2005). Instead, the fourth step ties back into the first step of data collection and analysis.

In summary, the ICLC framework is comprised of five competencies for successfully implementing collaborative learning in the classroom. We outlined the corresponding teacher's tasks necessary in the planning, monitoring, supporting, and consolidating, and reflecting upon phases that took place. The ICLC framework serves as a structure for our literature review.

Our initial search strategy was to search the databases *PsycINFO*, *EconLit*, *ERIC*, *FRANCIS*, and *Teacher Reference Center* with various combinations of keywords such as collaboration, cooperation, group, team, and learning, as well as with keywords describing the competencies. We focused on peer-reviewed journal articles that described collaborative learning in schools and university settings. In our literature review, we included experimental studies or case studies, as well as meta-analyses or research reviews on face-to-face collaborative learning and CSCL. The review aims to provide a thorough research-based description of which collaborative learning principles and concepts a teacher should know in order to understand when and why student interaction is constructive, and how to ensure beneficial student interaction.

The upcoming sections correspond to the five teacher competencies for implementing collaborative learning in the classroom. For each competency, we review relevant concepts and key empirical research results. We then apply the findings of our review to a classroom situation. These teaching vignettes illustrate the teacher competencies' functions in fostering student interaction in collaborative learning.

Pre-active Phase: Planning

In the section, we first introduce collaboration principles and concepts a teacher should know in order to effectively plan a collaborative learning setting; see also Fig. 2. These relevant principles and concepts are then illustrated by the teaching vignette.

Collaboration Principles: Individual Accountability and Positive Interdependence

Since the success of collaborative learning depends on the quality of student interaction (Dillenbourg and Tchounikine 2007; Kobbe et al. 2007), student interaction should be a major consideration when planning collaborative learning (Lowyck and Pöysä 2001; Dillenbourg and Tchounikine 2007; Hämäläinen and Vähäsantanen 2011). In order to ensure that students are motivated to collaborate and are able to build common knowledge, Johnson et al. (1998b) suggest implementing two principles: individual accountability and positive interdependence.

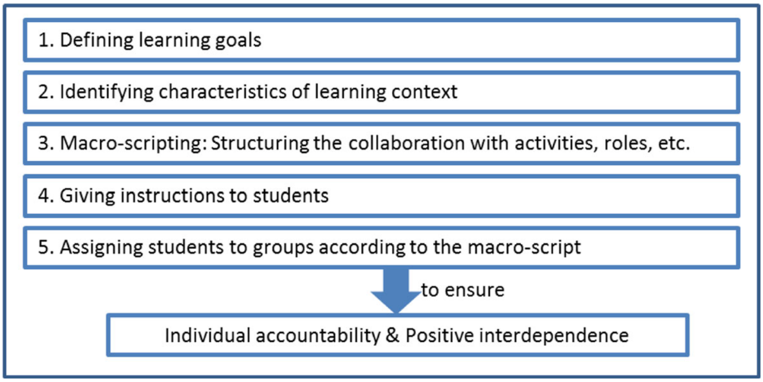

Fig. 2 Key strategies for planning collaborative learning

Individual accountability is the responsibility of each group member to make contributions that help to solve the problem at hand or, in an even broader sense, to reach the group's goal (Johnson et al. 1998a). Each group member can be held responsible for making contributions as well as the group as a whole can be held responsible for the contribution of its group members. Positive interdependence is when each group member can only succeed when all other group members succeed as well (Johnson et al. 1998a). These two principles not only make sure that students are motivated to learn, but also help students learn. For example, when individual accountability and positive interdependence are present, individual students may make use of specific cognitive or metacognitive activities, such as predicting, question asking, explaining, or checking for mistakes (cf. Isotani et al. 2013). In the following section, the design and implementation of these learning activities will be described.

Design Principle: Macro-scripting

Students often do not show beneficial collaborative learning activities by themselves (Salomon and Globerson 1989). Consequently, instruction and guidance are often required to involve them in successful collaborative learning. One method of structuring student interaction is through collaboration scripts (Hämäläinen and Häkkinen 2010), also known as macro-scripts (cf. Dillenbourg and Hong 2008). Macro-scripts provide the conditions for beneficial interactions by prescribing different phases and interaction patterns for the collaboration, as well as distributing different roles to groups or group members. The focus is thereby laid on the facilitation of the knowledge building process instead of the group product (Dillenbourg and Tchounikine 2007; Kobbe et al. 2007). Macro-scripts are regarded as an important design principle in implementing collaborative learning settings (Kobbe et al. 2007; Hämäläinen and Vähäsantanen 2011).

Internal Versus External Scripts

Fischer et al. (2013) differentiated *internal scripts* from the above-mentioned *external scripts.* Internal scripts of collaborative learning are defined as individuals' cognitive structures that refer to procedures and acts in collaborative situations. Internal scripts are developed and restructured in collaborative learning situations. When considering scripts, the teacher should consider students' prior experiences with collaborative learning, that is, their internal scripts of collaborative learning which also influence the effectiveness of the external macro-scripts. The teacher's goal in this case would be to prevent *overscripting* (Dillenbourg 2002), namely the interference of the students' internal scripts with the external scripts given by the teacher. If the students' internal scripts are sufficiently developed, the teacher should avoid highly structured external scripts, which may have unfavorable effects on students' self-regulations (Fischer et al. 2013).

Social Versus Epistemic Scripts

External macro-scripts given by the teacher can be further characterized as *social scripts* (cf. Weinberger et al. 2005) or *epistemic scripts* (cf. Weinberger et al. 2005). While social scripts structure how students should collaborate, epistemic scripts structure the learning content itself (Brooks and Dansereau 1983). Epistemic scripts thus are also sometimes called *content schemes* (cf. Ertl et al. 2005). Social scripts can structure the collaboration, for example, by prescribing cognitive and metacognitive activities or roles, such as question asking, explanation giving, or monitoring one's own understanding, as well as different phases, such as individual and collaborative phases. An epistemic script can, for example, provide external representations such as a table that has to be completed by the learners or present guiding questions that have to be considered. Epistemic scripts therefore help learners to notice the relevant concepts or to differentiate between important and less important aspects of the topic at hand (cf. Ertl et al. 2005).

Multiple studies have examined the effectiveness of social scripts and epistemic scripts (e.g., Ertl et al. 2005; Kopp and Mandl 2011; Mäkitalo et al. 2005; Stegmann et al. 2007; Weinberger et al. 2005) for collaboration outcomes and individual domain-general or domain-specific learning gains. In essence, the combination of both, social scripts and epistemic scripts, promotes learning best on a collaborative as well as on an individual level (Ertl et al. 2005; Kopp and Mandl 2011). The design of effective epistemic scripts vastly depends on the respective domain and the corresponding pedagogical content knowledge. The design of social scripts is less dependent on the domain. Therefore, for the purposes of this article, we will focus on social scripts in the following.

Components of a Social Script: Students' Characteristics

When designing a social script, the teacher should consider student characteristics such as their prior knowledge of the subject area or problem at hand (e.g., Webb 1989) and their familiarity with how to collaborate with each other, so-called internal scripts. These are individuals' cognitive structures that refer to procedures and acts in collaborative situations (Fischer et al. 2013). Depending on the learners' internal scripts and domain-specific knowledge levels, the teacher can vary the structure of the social script (cf. Fischer et al. 2013), such as the amount of instructions given and activities prescribed by the macro-script. As an example for adapting to prior knowledge of the domain, considering the *expertise reversal effect* (cf. Kalyuga et al. 2003), the teacher should provide high-ability learners with low-structured scripts and vice versa.

Components of a Social Script: Activities, Roles, and Resources

Activities that are described by social scripts can be, for example, discussing a topic, asking a question, giving an explanation, or finding an argument. Group members may take different roles (e.g., question asker or explainer) and switch between them during the collaboration.

Assigning different but specific roles or responsibilities to group members (Slavin 1990) promotes individual accountability and positive interdependence. Resources for collaboration may be found in books, work sheets, and websites, as well as by using tools like computers, calculators, and other technical devices. Those resources are given to different group members in order to stimulate positive interdependence.

Components of a Social Script: Group Task(s)

The group task(s) selected for the lesson should promote shared knowledge building and thus require that students depend on each other and feel responsible to share their knowledge. For example, a so-called *conjunctive task* (Steiner 1972) demands that all group members contribute equally, so the group result depends on even the weakest group member. For example, every group member may be required to give a correct answer to a question before the whole group is finished. High-ability group members are expected to share their knowledge with low-ability students by explaining the concepts to be learned. Ultimately, low-ability group members are also able to solve the problem on their own because the high-ability students shared their knowledge with them.

Collaborative learning is particularly useful for conceptual learning (cf. Mullins et al. 2011), such as defining or applying mathematical concepts. To promote conceptual learning, the teacher should use tasks that provoke productive activities, such as question asking and explanation giving, cognitive conflict solving, and exchanging ideas and information (Hämäläinen and Vähäsantanen 2011). Teachers should also use authentic problems such as determining the best soccer player based on the player's success in the last season. Due to their complexity, authentic problems require many students to solve them (cf. Kirschner et al. 2004; see also Gros 2001). Their complexity also promotes cognitive conflicts, clashes of conflicting attitudes held by the group members, and elaborations of contributions. They also prompt building common ground, because students need to clarify their definitions of concepts, which can lead to the construction of joint knowledge. Finally, the teacher should clearly explain the meaning of the collaboration task by pointing out how students will benefit from completing the task. This will lead to students' stronger engagements in the collaborative process (Arvaja et al. 2000) and foster individual accountability.

Mechanisms of a Social Script: Group Formation

Group formation can be determined by the number of participants per group or also by the composition of the group in terms of the students' point of view or knowledge level. Composing groups can be difficult while designing a collaborative learning scenario (Hämäläinen and Vähäsantanen 2011). The question is whether to compose homogeneous or heterogeneous groups (cf. Gros 2001). When the goal is to stimulate critical reflection of the learning content, the teacher should compose groups that are heterogeneous in attitudes and perspectives. Such heterogeneous groups can promote effective reasoning strategies. In this case, teachers may be concerned that high-ability students in heterogeneous groups are not being challenged enough and that low-ability students may behave in a rather passive way. However, research findings showed that the achievement level of low-ability students improved in heterogeneous groups and that the achievement level of high-ability students also increased, or at least reached the same level as high-ability group members in homogenous groups (Dillenbourg 1999; Wiedmann et al. 2012). A closer look at the effects of group composition shows that explanation giving does not occur as frequently when group members differ strongly in their ability level or when only low-ability students work together in a group (Webb 1991).

Selecting an Appropriate Macro-script

A consensus exists that the starting point of instructional design is the identification of learning objectives and characteristics of the learning context (e.g., students' individual skills and task affordances; Hämäläinen and Vähäsantanen 2011). Based on these considerations, an appropriate macro-script can be selected (Dillenbourg and Hong 2008). Typical learning goals include stimulating students' prior knowledge, mutual teaching of new concepts, and establishing newly acquired knowledge (Renkl and Beisiegel 2003). Depending on the intended learning goal, the teacher splits the learning content at hand (cf. jigsaw script; Aronson et al. 1978) or defines different roles (the SWISH principle; Dillenbourg and Jermann 2006). With respect to learning objectives and intended learning activities, three script classes can be differentiated: jigsaw schema, reciprocal schema, and conflict schema (Dillenbourg and Jermann 2006). The *jigsaw script* promotes knowledge building through exchanging information (Aronson et al. 1978). *Reciprocal teaching* fosters question asking and explanation giving (Palincsar and Brown 1984). Finally, *structured academic controversy* promotes solving sociocognitive conflicts as well as reaching an agreement (Johnson and Johnson 1994).

Teaching Vignette: a Planning Example

In this section, we apply the concepts and findings that we reviewed above to a classroom situation. This teaching vignette continues across all the competencies and illustrates their function in fostering student interaction in collaborative learning. We start with the illustration of a teacher's planning competency.

Imagine a teacher preparing a mathematics lesson for a unit on fractions. The class has 15 girls and 12 boys, all of whom are about 12 years old. In the previous two lessons, the students learned about the concepts of a numerator and a denominator. They also were shown different types of representations for fractions, such as a drawing of a pizza or a cake, a number line, or decimal numbers. These students, in this example, have experience in collaborative learning because they have to learn collaboratively in groups once a week. The teacher therefore can assume good internal scripts for collaborative learning, namely, that the students know the procedure of collaborative learning and what they have to consider while collaboratively working on a group task.

The teacher thinks about the learning goals intended for the lesson for the day. She decides that students should consolidate the knowledge of the previous lessons and learn the new concept of a common denominator. A typical task to discover this concept could entail comparing several different fractions and putting them in ascending order. This concrete task proves to be an explorative and conceptual task.

To fulfill the intended learning goals, the teacher chooses an appropriate social macro-script that prescribes activities for students and different phases to structure collaborative learning, and thus fosters beneficial student interactions. She decides on the jigsaw script because discovering a new concept requires exchanging different points of view, which are realized by different expert roles. Next, she adapts the jigsaw script to the characteristics of the current classroom situation such as students' prior knowledge about fractions and the concrete task. In doing so, she modifies the original version of the jigsaw script by adding an individual learning phase in which students' prior knowledge about fractions is stimulated. In relation to the concrete task, the learning content is divided and allocated to three different expert groups. The formation of these three expert groups, namely experts for fractions represented as decimal numbers, for fractions represented as pizza drawings, and lastly for fractions represented on a number line, ensures individual accountability. To further enhance individual accountability, each expert group receives its own set of three fractions to work with.

In the beginning of the individual phase, every student individually makes representations of three fractions and finds the right ascending order. This individual phase takes about 10 min.

In the next phase, expert groups made up of three experts who were assigned the same type of representation for fractions are formed to compare and check the individual solutions and eventually correct them. The teacher decides to let the students choose themselves with whom they want to work but also makes sure that not only the low-ability students are working together in a group. This phase seeks to enhance the solidification of the previous lessons through cognitive activities such as explaining and question asking and the metacognitive activities of finding errors and correcting them. This phase, in which the individual solutions are exchanged, takes about 15 min.

For the last phase, new groups of three experts for different types of representations are formed. There is one expert for fractions represented as decimal numbers, another for fractions represented as pizza drawings, and a third for fractions represented on a number line. In this phase, every student has to explain his/her type of representation for fractions and the order of his/her fractions to the other group members. Finally, they have to find the right ascending order of all nine fractions. This task should make students aware of difficulties in comparing fractions with different denominators and help them to discover that first finding a common denominator for all fractions helps to compare them. The last task is to collaboratively define and write down this rule. The last phase is the most intensive one and takes about 40 min. This phase should stimulate information exchange, explanation giving, question asking, reasoning for different solution paths to compare fractions, and critical checking of ideas and the final solution.

Our teacher here also uses an epistemic script which structures the learning content, and thus helps to facilitate the problem-solving process. She decides that the students have to answer a guiding question while finding the right order of fractions. An example guiding question is “What is the difference between numerator and denominator?”. Further, the epistemic script requires a table which has to be completed by the three different representations of every fraction. This table should help to give an overview of the represented fractions and thus to better point out the differences between the fractions.

As the students in this situation are familiar with collaborative learning, the teacher decides to just explain the important aspects of the social macro-script such as the different phases and the different group formations, as well as the crucial learning activities in the different phases. She decides that a low-structured macro-script, that is, one with little instructions on how to collaborate effectively, is adequate for her students’ well-elaborated internal scripts of collaborative learning and thus prevents overscripting.

Conclusion

This example shows that the teacher has to stimulate his/her own theoretical knowledge about the two principles, individual accountability and positive interdependence, and about macro-scripts when planning a collaborative learning setting. The components of a macro-script, learning goals, students’ and task characteristics, as well as activities, are all considered when selecting and adapting a macro-script to the current classroom situation. This is in line with the issue of flexibility of macro-scripts elaborated by Dillenbourg and Tchounikine (2007). Flexibility means the degree to which the macro-script can be changed or adapted to the actual classroom situation by the teacher. When considering how to modify the macro-script in light of the current classroom situation, the teacher should be aware of intrinsic versus extrinsic constraints. The teacher cannot easily modify intrinsic constraints because they define the key mechanism of a collaborative learning setting, specifically, learning activities that should occur in order to build knowledge. Extrinsic constraints, on the other hand, such as giving grades or defining the group size can be modified by the teacher dependent on his/her learning goals or the school setting.

Drawing conclusions from this example, when a teacher applies his/her knowledge about collaborative principles and macro-scripts to his/her teaching practice in the planning phase, he/she fulfills the following tasks: defining learning goal(s), identifying characteristics of the learning context, selecting and adapting a macro-script, and finally instructing students and composing groups. A teacher has many options to promote beneficial student interaction while planning collaborative learning. This example describes one possible collaborative learning setting. However, as we will elaborate in the following section, intended student behavior and actual student behavior are not necessarily the same (Hämäläinen and Häkkinen 2010).

Inter-active Phase: Monitoring

In this section on monitoring, we first introduce three dimensions on which the quality of the student interaction can be assessed; see also Fig. 3. These relevant dimensions are further illustrated in the teaching vignette that was introduced in the previous section and is continued in this section on the teacher's monitoring of student interaction.

During the inter-active phase, the teacher checks if the planned conditions such as group formation, individual and collaborative phases, as well as the intended learning activities are working. The learning activities, in particular, are considered to be crucial for beneficial student interaction. The quality of the student interaction can be assessed on three dimensions. These dimensions are collaborative, cognitive, and metacognitive activity, which are necessary for effective collaborative learning (see Baker et al. 2007; Meier et al. 2007; Persico et al. 2010). Molenaar et al. (2011) also made the distinction between these three dimensions by developing a rating system for collaborative learning that defines the categories metacognitive activity, cognitive activity, and relational activity, as well as other activities.

Three Dimensions of the Quality of Student Interaction

Monitoring student interaction means that the teacher compares the desired interaction model intended by the macro-script with the actual interaction taking place. By comparing the desired interaction model with the actual interaction, the teacher can diagnose difficulties in student interaction. To diagnose difficulties, the teacher should know the three theory-based

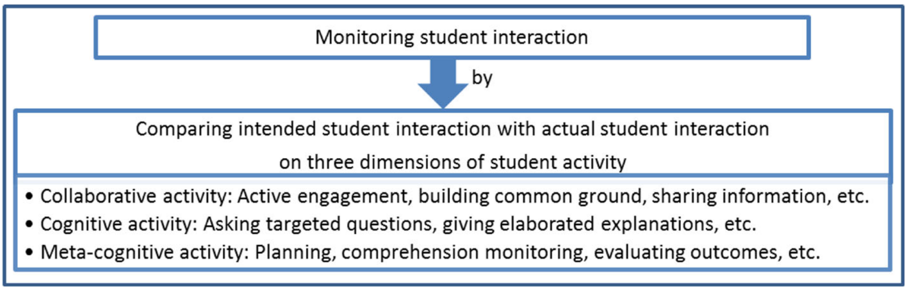

Fig. 3 Key strategies for monitoring student interaction

dimensions, collaborative, cognitive, and metacognitive activity, and pay attention to their behavioral indicators described below.

A successful collaboration requires that all students be actively engaged, build common ground, and share information and ideas (Johnson and Johnson 1998). Especially, when group members have different information due to their assignment of particular roles or resources, the exchange of their information within the group is essential for successful problem-solving (Stasser and Titus 1985). A respectful group atmosphere can be indicated by active listening to other group members' contributions without interrupting them, considering all contributions, and finally praising and encouraging other group members (cf. Wilczenski et al. 2001).

Visible cognitive activities include asking targeted questions and giving elaborated explanations (Webb 1989). Elaborated explanations are characterized by providing examples for different solutions to the problem at hand or considering the question asker's prior knowledge when responding (Webb et al. 1995). Especially in the case of discussions, important indicators of cognitive activity include giving reasons for a line of argumentation and comparing different solution paths that foster knowledge building (cf. Baker et al. 2007).

Metacognitive processes should be monitored, especially since learners often do not show them automatically (Persico et al. 2010). According to Zimmerman's (2002) model of metacognition, three types of metacognitive activities can be determined. The first is preparatory activities such as orientation and planning. The second type is then executive activities such as comprehension monitoring and checking for errors (cf. Persico et al. 2010; Wilczenski et al. 2001), as well as a critical check of ideas and the final solution (Bannert 2003). Finally, the third type is closing activities which include evaluating own understanding, skills, limits, and cognitive processes (Persico et al. 2010).

Most of these behavioral indicators for the three dimensions are directly targeted by macro-scripts. The two collaboration principles, individual accountability and positive interdependence, are signified by collaborative activities such as making individual contributions and sharing information and ideas. To check if students fulfill the activities prescribed by the macro-script, the teacher should pay attention to the behavioral indicators for the three dimensions. In summary, the analysis of student interaction provides insight into individual behavior and group knowledge building (Wilczenski et al. 2001) and thus helps the teacher to support the individual and the group in an appropriate fashion.

Teaching Vignette: a Monitoring Example

After the students have started working, the teacher observes the progress of the group work. She attempts to monitor each group for at least 2 min. She checks whether the students are following the script, especially the different phases. The switching between different phases, working alone, meeting in expert groups, and finally building new groups of three different experts, is easy to observe from afar through the students' body language. For example, the teacher can easily detect that a group of students is not paying attention to the time because they do not change groups when they are supposed to. However, student activities such as exchanging information, explaining and asking questions, and checking for errors have to be monitored by listening to the conversation. This allows the teacher to compare actual activities with the activities as intended by the macro-script. The teacher notes what she observed in the groups, which in turn helps to better support the student interaction, consolidate the group work results, and finally reflect upon the whole process.

She monitors the following conversations in the collaborative phases: One student explains her presentation for fractions to the other group members by saying "Look, here's a pizza. If I divide it into four parts and color one part, that's one fourth. And look, when I color two parts, then that's half the pizza—one half. And now I know that one fourth is smaller than one half." And another group member elaborates on the pizza example by commenting: "Well, when you cut the pizza in three parts, then each piece is bigger than one fourth but smaller than one half." The teacher is content with these cognitive activities. In another group, however, she observes insufficient reasoning when one group member points at the fractions $\frac{2}{3}$ and $\frac{1}{3}$ and says: "That's easy! $\frac{2}{3}$ is bigger than $\frac{1}{3}$." The teacher also realizes that the students in this group are not defining a rule for the comparison of different fractions. Thus, this group does not fulfill the discovery task as intended in the planning phase of the teacher. When the teacher observes another group, she diagnoses that these students struggle in finding the correct solution because the two fractions seem to be the same to them. Finally, the group decides to stop working on the task and turn their attention to their homework. This shows the teacher that individual accountability is missing in this group. The teacher also monitors a student interaction in which two group members ignore the questions of the third group member, a rather low-ability student who has difficulties in understanding the solution and the defined rule. In this group, the two high-ability students do not involve the low-ability student in the discovery and solution process, which indicates that positive interdependence is also missing here.

Conclusion

In this example, the teacher checks if the planned collaborative learning setting is successful. Therefore, the teacher compares the intended student interaction and the given macro-script with the actual student interactions and groups' progress during group work. This example also demonstrates that because the teacher cannot be everywhere in the classroom at once, she gains only impressions of the different student interactions taking place. The different student interactions presented here should illustrate behavioral indicators for the three dimensions: collaborative, cognitive, and metacognitive activity.

It is known that intended student behavior and actual student behavior in the group do not always align (Hämäläinen and Häkkinen 2010). As our example shows, there is a difference between the interaction processes intended by the given macro-script and the actual interaction processes that occurred in this scripted collaborative learning setting. While macro-scripts can foster beneficial student interactions, they do not guarantee them (Hämäläinen and Häkkinen 2010). To fully realize the intended student interactions, groups need additional, individual support by the teacher.

Inter-active Phase: Supporting

We introduce micro-scripting as ad hoc support given by the teacher. We then describe important aspects for effective support of student interaction (level of support, domain, mode of support, timing, and adaptivity). We adapted this description to face-to-face collaborative learning from a framework for collaboration support in e-learning by Diziol and Rummel (2010). We then tackle the question of whether support should always be given by the teacher or whether it can also be provided by peers. Finally, all key concepts relevant to supporting student interaction (see also Fig. 4) are illustrated in another teaching vignette.

Micro-scripting

Planning the collaborative learning environment is the first step in providing students with support in the form of macro-scripts. The macro-scripts, which prescribe essential activities for

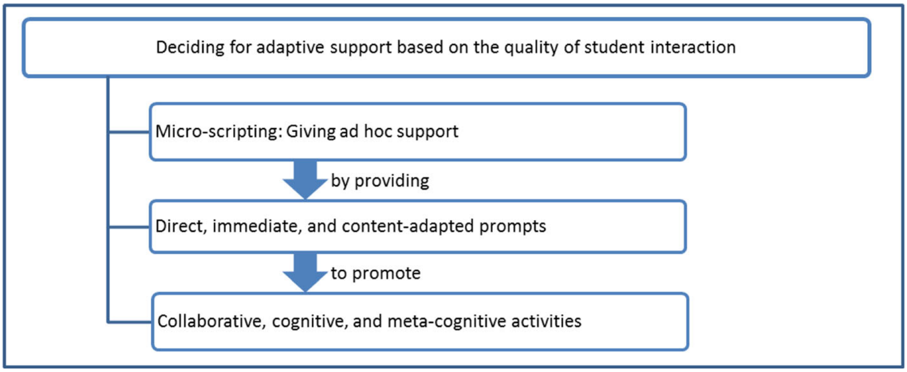

Fig. 4 Key strategies for supporting student interaction

common knowledge building are observed by the teacher through noticing behavioral indicators. When macro-scripts do not offer enough guidance to student interaction (Dillenbourg and Crivelli 2009), micro-scripts are also needed. Unlike macro-scripts, which are considered *pedagogical methods* (Dillenbourg and Crivelli 2009), micro-scripts are seen as *conversational scripts* (Dillenbourg and Crivelli 2009) that should be internalized by the learners as a model of beneficial collaboration. The teacher's micro-scripting is offered during the interaction to enhance, for example, students' argumentation: "Tom, tell them why you think that's a good idea." (cf. Schwarz et al. 2009).

Supporting Dimensions of Student Activity

First, the teacher must determine for which domain and on which dimension of student activity support shall be provided. A teacher can either give prompts to support student interaction or provide instructional and related explanations to support the students' understanding of the learning content (Diziol and Rummel 2010). Regarding support of student interaction, we have proposed collaborative, cognitive, and metacognitive activity to be the three dimensions of student activity. These dimensions can all be monitored and supported. In case of a lack of activity on one or more dimensions, support should target specific dimensions (cf. Diziol and Rummel 2010). This support of the peer interaction enhances domain-general knowledge of good collaboration (Walker et al. 2009).

For effective domain-specific support, diagnosing students' misconceptions and errors during the collaborative problem-solving process is necessary. A classic example of domain-specific support is the original version of the Cognitive Tutor Algebra (Koedinger et al. 1997), an intelligent tutoring system for algebra that supports the problem-solving process by detecting learners' errors and flagging them for the learner. This tool also offers explanations and suggestions if needed and puts the students back on the right track of the problem-solving process by giving domain-specific support. With regard to joint problem-solving in a group, collaborative learning might not have positive results if all of the group members strongly lack in domain-specific knowledge or pursue strong misconceptions. Therefore, domain-specific support is critical in these situations.

Providing Direct Support

Regarding mode of support, the next question is whether to support students in a direct or an indirect fashion. In our previous section on planning, we covered indirect support. Macro-scripts, more precisely social scripts, are one way of indirectly supporting interaction by prescribing activities. Epistemic scripts assist students with the learning content. In this section, we focus on direct support such as giving prompts, advice, asking challenging questions, or giving instructional explanations.

A prompt can be a hint, a suggestion, or a reminder to group members of their specific role in the collaborative learning setting (Ge and Land 2004). For example, presenting sentence starters or statements can then be used in the respective role (Morris et al. 2010). With respect to supporting domain-knowledge, prompts can also remind students of specific learning domain concepts (Karakostas and Demetriadis 2011). Prompts can be distinguished between procedural, elaboration, and reflection prompts. Procedural prompts target task completion and cognitive strategies. Elaboration prompts enhance explanation giving and thinking aloud, that is, verbalizing all thoughts that occur during problem-solving. Finally, reflection prompts foster metacognitive processes (Ge and Land 2004). While prompting, the expertise reversal effect should be kept in mind (Ge and Land 2004). Experienced learners should be supported by reflection prompts instead of procedural prompts, which are more helpful for novices that need prompting the most. As learners gain experience, prompting should be faded out (Morris et al. 2010). This is a form of *scaffolding* (Wood et al. 1976).

Scaffolding includes contingency, fading, and transferring responsibility (Van de Pol et al. 2010). A teacher behaves in a contingent way when he/she provides a group of students with adaptive support. To give adaptive support, he/she must first diagnose the group's needs by monitoring student interaction. Continually monitoring and diagnosing the learning process is also needed for fading, that is, reducing the support given to the students according to their ability over time. While fading his/her support, the teacher transfers more responsibility to students. Finally, students' self-regulation increases (Van de Pol et al. 2010).

Content-related support is often given by *instructional explanations* (Renkl et al. 2006). These explanations are clearly structured, comprehensible explanations of the learning content given by the teacher (Schumann and Eberle 2010).

Timing of Support

Another important issue to address is when support should be given without interrupting student interaction and thus disturbing self-regulated learning. We will now elaborate on support during the interaction. Support can be given in a fixed time sequence, such as 10 min after the students have started working together and 10 min before the group work ends. However, the most common way is adaptive timing that is given either immediately or delayed after a critical incident has been diagnosed. In addition to identifying critical incidents, moments of optimal behavior could be detected and positive feedback can be given to strengthen beneficial activities (Deiglmayr and Spada 2010). Delayed support can also be given after a problem-solving sequence (see productive failure approach; Kapur 2008). A crucial decision is whether to give immediate or delayed feedback after a critical moment. Immediate feedback prevents students from becoming unmotivated because they cannot progress anymore. Meanwhile, delayed feedback stimulates students' metacognition, for instance finding mistakes on their own, and thus enhancing their self-regulating skills (Mathan and Koedinger 2005; see also Diziol and Rummel 2010). The question of how long one should delay feedback to get these effects remains open, however.

Adapting Content of Support

The content of the support itself should be adapted to the current situation. Fixed support, however, means that the same structure and guidance are given to all groups in a collaborative learning environment (Karakostas and Demetriadis 2011; see also Diziol et al. 2010). Fixed support can be represented as instruction on good collaboration (cf. Saab et al. 2007), presenting a model of good collaboration beforehand (cf. Rummel and Spada 2005), or a macro-script (cf. Ertl et al. 2005). The drawback of fixed macro-scripts is that under- or overscripting (Dillenbourg 2002) may occur when students' individual expert levels (Karakostas and Demetriadis 2011) or students' individual ability to self-regulate (Romero and Lambropoulos 2011) is not taken into account. It has been shown that providing only a macro-script is not effective when students' domain-specific knowledge is not sufficiently developed (Karakostas and Demetriadis 2011). Consequently, the alternative to fixed support is adaptive content support, which tries to prevent an under- or overscripting effect by responding to the current interaction and needs of a specific group (Walker et al. 2009). Informed decisions for adaptive support of collaborative learning are made possible by constantly monitoring student interaction and thus identifying difficulties or particular needs in different groups. Monitoring and diagnosing also allow a teacher to include students' ideas and solutions in his/her support (Chiu 2004). Karakostas and Demetriadis (2011) showed that adaptive domain-specific support improved learning outcomes in a scripted collaborative learning environment. Kumar et al. (2007) found that adaptive support in a collaborative learning setting brought better learning results compared to fixed support in a collaborative learning setting.

Peer Support

Finally, support can also be provided by the group members themselves. Asking questions about and explaining the learning content to each other are both forms of peer tutoring (cf. Walker et al. 2011). Mutual support within the group enhances self-regulated collaborative learning. Furthermore, peer feedback can be given exactly when it is needed (Falchikov and Goldfinch 2000), as students may know better what is going on within the group than the teacher. Peer feedback on the collaborative learning process combined with students' reflection makes students aware of their cognitive and social behavior within the group (Phielix et al. 2010). However, peer support has to also be structured. Peer feedback for instance in academic writing (e.g., Wichmann and Rummel 2013) has to be structured through guiding questions (Gielen and de Wever 2013) in order to be effective. Peer feedback also improves when students are trained on how to assess peers and give feedback (Sluijsmans et al. 2002). The teacher should monitor and assist the peer feedback process by reminding students to give feedback and offering them hints. For example, the teacher might indirectly provide prompts to the group by giving instructions to the group member who is serving as the tutor (cf. Walker et al. 2011).

Teaching Vignette: a Supporting Example

When the teacher realizes that a group of students is not paying attention to the time and thus does not change groups when the next phase is supposed to start, she reminds them of the time and of changing the group. In the group where a student had provided insufficient reasoning, the teacher directly asks this student to give reasons for his/her statement and to explain it to the other group members. If they tend to finish the group work without defining a rule, the teacher also reminds the whole group to define a rule for the comparison of fractions. The teacher comes to the group that has difficulties in finding the correct solution and encourages them to search for the error. Yet they still give up and turn their attention to their homework. That is why the teacher tries a second intervention to stimulate their metacognition by prompting them to try to remember the solution attempts they have tried so far and to write down what their problem was so that it could be addressed in the following plenary session. Finally, the teacher intervenes in the group where two students ignore the questions of the third group member. She gives an elaboration prompt to the two students by saying “Listen and explain your solution to each other because it is important that all of you understand the solution path.”

Conclusion

This example illustrates how a teacher can support different student interactions, adapting his/her supporting strategies based on the specific student activities and the point in time. The adaptive support regarding timing and content is based on the teacher’s observations and analysis of difficulties in student interaction. She here intervenes directly when she observes a discrepancy between intended student interaction and actual student interaction. She also decides to give only prompts to students because instructional explanations will follow in the consolidating phase. Another reason for this decision is that students are allowed to struggle while solving the discovery task and thus instructional explanations given by the teacher would interrupt the discovery process.

Inter-active Phase: Consolidating

In this section on consolidating, we will describe fundamental theoretical aspects of the consolidation process from a learning sciences’ point of view. We focus on a typical instructional approach, namely productive failure (e.g., Kapur 2010, 2011; Kapur and Bielaczyc 2012), which is one of few instructional approaches that takes a closer look at consolidating group work results. Finally, we provide practical examples of different consolidation strategies that a teacher can use in the classroom and further illustrate them by our teaching vignette. For the key concepts of consolidating collaborative learning, see also Fig. 5.

Activation of Students’ Cognition and Metacognition

Consolidating the groups’ work, and thus securing all students’ individual learning successes, is a very challenging final part in the inter-active phase for a teacher. Consolidation becomes much easier when the teacher has planned for it and has gained a good impression of the observed group discussions, namely, knowing which learning goals still need to be accomplished. The collaborative learning phases provide a good base for teaching targeted domain concepts in the classroom after the group work is completed (cf. Loibl et al. 2013, submitted for publication). Consequently, group work usually ends with a plenary or whole-class session, which is structured and led by the teacher (cf. Kapur 2011). To consolidate knowledge, and thus ensure individual learning gain, students’ metacognition should be stimulated (Loibl and Rummel 2013). Students should become aware of the difference between diverse groups’ solutions. Students should also become aware of differences between their groups’ solutions and a canonical solution that may be presented by the teacher. Furthermore, students should detect their own knowledge gaps and misconceptions. Besides metacognitive activation, cognitive activities should also be stimulated to deepen students’ thinking about the targeted concepts. Relevant principles, critical features, and functions of the concepts should be examined by students (cf. Durkin and Rittle-Johnson 2012). Students have to detect relationships among different concepts (Brophy 2000), realize the different functions of a concept, and

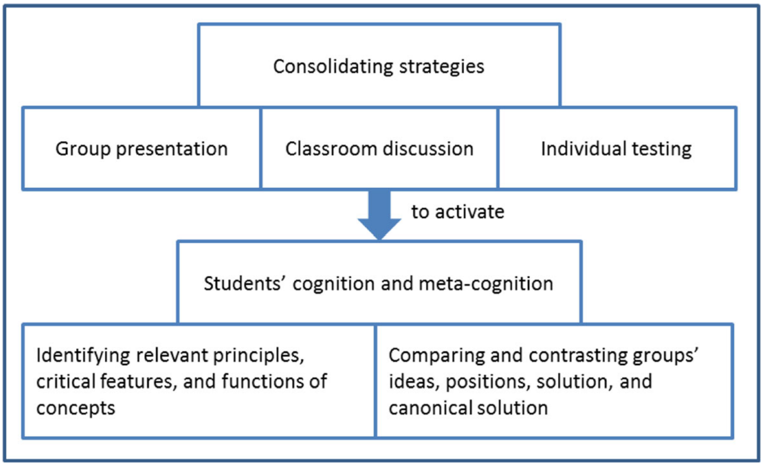

Fig. 5 Key strategies for consolidating collaborative learning

finally learn that a problem can be solved in several ways (Loibl et al. 2013, submitted for publication).

Consolidation Strategies

Consolidating the groups' work requires the teacher to pull together and acknowledge each group's solutions to the problem. Simultaneously, the teacher should avoid tiring the entire classroom by presenting similar solutions over and over again. Some macro-scripts (e.g., the jigsaw script; Aronson et al. 1978) make sure that each group works on a different part of the problem, so that the final presentation of each group's result is needed to see the whole picture. The teacher divides the content into several parts for different groups and thus promotes positive interdependence between students. Other macro-scripts, for instance the group rally (Slavin 1995), recommend individual testing at the end to ensure learning gain of each group member. The teacher consolidates the individual test scores into a group score, which also stimulates positive interdependence and individual accountability within each group (Brush 1998; Vuorinen et al. 2000). The group score can either be an absolute score or an improvement score which is more encouraging especially for low-ability students (cf. Rotering-Steinberg 1992). When all groups have worked on the same problem, there can be redundancy in solutions. However, in case of complex problem-solving, groups may have found diverse and even suboptimal or wrong solutions to the problem they have been working on (see productive failure approach; Kapur 2008). To make students aware of differences between solutions, the teacher compares the solutions to each other (cf. Kapur and Kinzer 2009; Kapur 2010). The teacher can further enhance students' metacognition by starting a discussion on these differences (Loibl and Rummel 2013). For an effective classroom discussion, the teacher should structure the comparison of solutions by focusing only one concept feature at a time (Loibl et al. 2013, submitted for publication). To stimulate cognitive activities, the teacher asks students challenging questions to deepen their thinking about the targeted concepts and relationships among these concepts (Brophy 2000). The teacher can ask for difficulties that occurred in the problem-solving process during the interaction. Students may ask questions which came up while solving the problem (Westermann and Rummel 2012). Thus, to explain the solution to students during instruction, the teacher can give students a set of worked-out examples (Salden et al. 2010), prompt students to provide their own explanations for them (Koedinger et al. 2009), and finally stimulate reflection of the canonical solution (White and Frederiksen 1998).

How to contrast group work results is exemplified by Lampert's (1990) instructional approach and the macro-script academic controversy (Johnson and Johnson 1994). Lampert (1990) combines problem-solving in groups with a final discussion, led by the teacher. The teacher ensures that different solutions to the mathematical problem are discussed and explained. This enhances the students' understanding of mathematical principles and mathematical argumentation. The teacher should emphasize certain qualities and drawbacks of each explanation and highlight differences between them. He/she makes students aware of the underlying mathematical principles of each explanation by asking clarifying and elaboration questions (Kapur and Bielaczyc 2012). To actively engage students in the discussion, the teacher asks students to explain their classmates' ideas (Lampert 1990). Finally, the exchange of arguments among the whole classroom builds upon or changes students' initial thinking (Choppin 2007).

The macro-script academic controversy (Johnson and Johnson 1994) aims at provoking cognitive conflicts between students through defending controversial positions. In the end of the group work, students should synthesize the different arguments that occurred, while also defending their controversial positions (Renkl 2007). The groups share their ideas or positions with each other by presenting them to the whole class (Wiener 1986). Wiener (1986) sees the teacher as a synthesizer when consolidating the groups' work. He/she helps the class to make sense of different ideas and positions by comparing and contrasting them. This process should finally lead to a synthesis in which the controversy ideas and positions are integrated (Wiener 1986).

In conclusion, collaborative learning activates students' prior knowledge and eventually makes them aware of existing knowledge gaps. For the consolidation of the groups' work, the teacher should stimulate cognitive and metacognitive activity. Discussing and comparing different groups' solutions with each other and to the canonical solution is one way that the teacher can enhance students' awareness of knowledge gaps, diverse approaches for solving a problem, and multiple functions of the targeted concepts (Loibl et al. 2013, submitted for publication). Finally, misconceptions are corrected and students internalize the correct solutions (Brophy 2000).

Teaching Vignette: a Consolidating Example

After each group has defined a rule for the comparison of fractions, the teacher starts a whole-class discussion. To start this discussion, the teacher asks each group for the defined rule and writes them all on the blackboard.

Before comparing the rules, the students are allowed to indicate problems they had during the group work and pose questions for further clarification. The teacher also notes these questions on the blackboard and invites the whole class to think about them and to try to answer them. She encourages all students to participate and to contribute their answers and ideas. She does this by directly asking students for their opinion. Following the clarification of questions and solving of problems, the teacher asks the students to write down similarities and differences between the rules presented on the blackboard. Finally, the teacher starts a discussion about which misconceptions can be found in any of the rules and how they can be corrected. The teacher finishes the discussion by synthesizing all of the ideas suggested into one correct rule. She writes down the collaboratively defined rule that includes the concepts of numerator, denominator, and common denominator of fractions.

For homework, students have to solve similar tasks with fractions in order to deepen their understanding of the learned concepts. The teacher intends to check the homework in the next lesson to evaluate each student's individual learning gain.

Conclusion

This example shows how the teacher applies the consolidation strategies proposed by the productive failure approach and Lampert's (1990) instructional approach, namely, clarifying questions and problems as well as discussing and comparing different groups' solutions. In doing so, the teacher stimulates students' cognitive and metacognitive activity, which is necessary to reach the second learning goal of learning the new concept of a common denominator.

Consolidating group work results also requires a broad knowledge base about the learning content and typical misconceptions students may have. To ensure an effective consolidating phase, the teacher's observations of student interactions while monitoring are helpful. They give him/her insights into students' misconceptions and the problems which occur while solving the discovery task, and thus he/she can better adapt his/her instructional explanations in the closing session to these misconceptions. While the teacher leads the discussion, he/she should prevent simply asking students for explanations and providing them with the right explanation without considering their ideas.

Post-active Phase: Reflecting

In this section regarding reflecting, we first describe what reflection is and its underlying processes; see also Fig. 6. Finally, we describe the teacher's reflection state during the

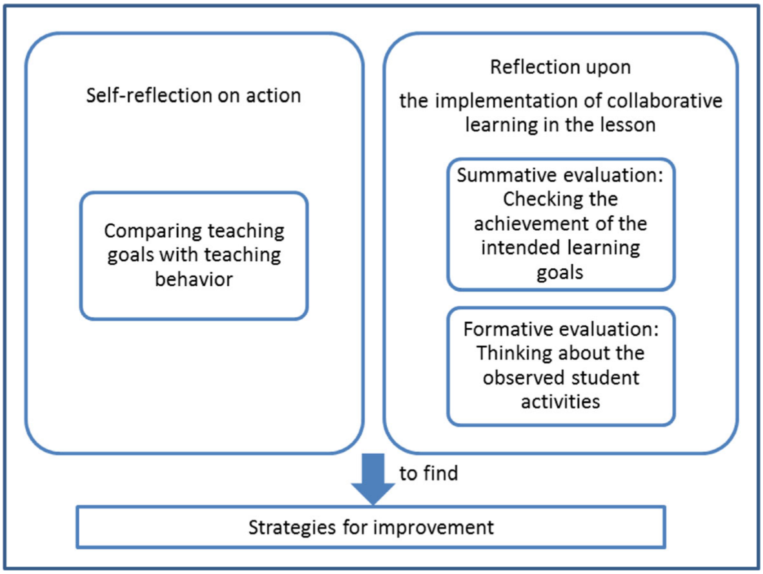

Fig. 6 Key strategies for reflecting upon collaborative learning

implementation of collaborative learning in more detail and further illustrate it by our teaching vignette.

Self-Reflection

Reflecting upon one's own and alternative actions in teaching situations (Xiaodong et al. 2005) is a vital step in improving one's teaching. Reflecting also plays a relevant role in our ICLC framework. It is generally needed in expertise development in different fields of teaching, and few aspects of reflecting are specific to collaborative learning.

Self-reflection is a complex but conscious process in which a person considers and describes his/her own opinion, feeling, knowledge, or behavior (Greif 2008). It can be differentiated between reflection-in-action and reflection-on-action (Schön 1983). Reflection-in-action takes place in the current situation, whereas reflection-on-action happens before or after a particular situation. In a reflection-on-action process, the teacher can fully concentrate on his/her experience without paying attention to occurring events (García et al. 2006). Retrospective reflection about a particular action or situation offers the opportunity to think about problematic aspects more thoroughly and analyze possible reasons for them. It also helps a person to become aware of his/her own behavioral routines and reasoning behind this behavior (Altrichter and Posch 1998).

Reflection includes cognitive and metacognitive processes (Parnell 2012). While reflecting, the teacher compares the initial teaching goals with his/her actual teaching behavior (Korthagen 1992). It also means detecting problems or critical incidents that occurred during the previous teaching situation (García et al. 2006), as well as finding and testing solutions to them (Colton and Sparks-Langer 1993). By identifying important parts of a past situation, recommendations for the future can be drawn (Daudelin 1996). For example, new ideas, goals, and strategies to adapt one's behavior to the given situation (Wiedow and Konradt 2011) can be developed.

Reflection upon the Implementation of Collaborative Learning

With regard to the effectiveness of the collaborative learning setting, the teacher evaluates the different phases of the implementation. This specific evaluation includes both a formative and a summative aspect. In the formative evaluation, activities that occurred and were monitored during the collaboration are considered, whereas the summative evaluation refers to the comparison of the initially intended learning goals with the actual achievement. A successful reflecting phase helps to better plan the next collaborative learning setting and may optimize the likelihood of beneficial student interaction taking place in the classroom.

The *Lesson Analysis Framework* by Santagata et al. (2007) describes four practical steps of analyzing one's own teaching. Following this framework, we describe what a teacher should do while reflecting on the implementation of collaborative learning in the classroom.

The first step included in the framework is the teacher's (re-)identification of lesson learning goals and intended learning activities. Usually learning goals and learning activities have already been identified during the planning phase and now only need to be recalled. The next step is the teacher's analysis of the students' thinking and learning. The teacher recalls what he/she noticed while monitoring the students' interaction. Constructing hypotheses about the effects of teaching on students' learning is the third step of the framework of Santagata et al. (2007). Possible reasons for unfavorable behavior during student interaction should be analyzed, such as the formation of too-large groups, which prevented individual accountability, or overscripting through an inappropriate macro-script because the teacher did not consider students' internal scripts and prior knowledge while planning. Another reason for detrimental student behavior during collaborative learning could be inappropriate supporting strategies by the teacher.

Besides this formative evaluation, a summative evaluation provides additional insight into the success of collaborative learning. The teacher can investigate the success of collaborative learning, that is, the achievement of the initial learning goal(s) on three levels: the individual, the group, and the class (cf. Dillenbourg et al. 2011). Individual and group learning gain can be assessed informally during the monitoring and supporting of student interaction. The learning progress of the entire class can be assessed during the consolidation of the group work results. The teacher checks whether there is a sufficient base of understanding of the given lesson and thus whether it is possible to proceed in the curriculum. Individual learning gain and common knowledge of the entire group can also be assessed after the group work through individual test scores, which the teacher then condenses into a group result. The formative evaluation based on the teacher's monitoring of the learning activities helps to better understand the summative evaluation results. In summary, the information that the teacher gained through monitoring, supporting, and consolidating contributes to a final evaluation of the success of the collaborative learning scenario, that is, the achievement of the intended learning goals.

Following the last step of the Lesson Analysis Framework (Santagata et al. 2007), the analysis and the final evaluation of the success of the collaborative learning setting should be used to propose improvements in teaching. Consequently, the teacher considers alternative strategies to better adapt the next implementation of collaborative learning in order to ensure beneficial student interaction. Thus, finding alternative strategies connects reflection upon practice to action upon practice (cf. Van Es and Sherin 2002).

Teaching Vignette: a Reflecting Example

To evaluate the student interactions in a formative way, the teacher looks at her notes, which she took during the inter-active phase while monitoring the different student interactions. The teacher then asks herself questions, such as, "How many groups followed the macro-script and more specifically the prescribed tasks and activities? Where did difficulties occur and why?". Finding explanations for the quality of the student interactions helps the teacher realize improvements and alternative strategies for planning and designing the learning setting. For instance, the teacher decides to compose the groups differently in the next collaborative learning setting because she noticed that a few students did not collaborate well with each other and ignored contributions or turned their attention to other things. Therefore, the teacher intends to separate these students in the next collaborative learning setting. In other groups, the teacher also detected difficulties in reasoning and explanation giving. Therefore, she decides to start the next lesson with a modeling of reasoning and explanation giving. Finally, based on her observations, she concludes that the different phases worked very well and therefore she intends to use this macro-script again.

The teacher also reflects upon her own behavior by asking herself: "Did I support the different groups in an adaptive fashion? How did the students react to my interventions?". She realizes that she spent a different amount of time with each group, and thus adapted her support to each group's needs. Finally, the teacher comes to the conclusion that in most cases the students accepted her prompts and the interaction improved.

After this formative evaluation, the teacher evaluates the success of the group work on the group and class level. While consolidating the group results, the teacher noticed that most of the groups defined highly elaborate rules, but also that two groups struggled with solving the task in the collaborative phase. These group work results are in line with her assessment of the quality of student interactions. Concerning the success on the class level, the teacher is content because in the wrap-up discussion most students made a contribution and it seemed that they could clarify all questions that were brought up. The teacher could also achieve the overarching learning goal of this lesson, namely, the introduction of the concept of the common denominator of fractions. These conclusions of the process are also further supported by the homework students had turned in for the subsequent lesson. The teacher pays special attention to the homework of students that did not participate much in the plenary session, where she finds that those students also have a good understanding of the common denominator.

Conclusion

This example shows that thorough planning becomes important again when the teacher evaluates the success of the collaborative learning setting. The intended learning goals are crucial for the summative evaluation, and the intended learning activities are relevant for the formative evaluation. Coming up with learning goals and learning activities ensures a focused observation of behavioral indicators for the three dimensions of student activity (collaborative, cognitive, and metacognitive activity). Process data gained during monitoring student interaction helps to support the summative evaluation results. The focused observation while monitoring helps to reflect on critical aspects the teacher aims to improve in the future.

Discussion

In this article, we described how a teacher can foster student interaction in collaborative learning settings. We presented our ICLC framework that distinguishes between five teacher competencies (the ability to plan student interaction, monitor, support, and consolidate this interaction, and finally reflect upon it) in three different phases (pre-, inter-, and post-active phase). Relevant concepts and key empirical results were summarized for each of these five competencies. In the following section, we would like to discuss one challenge of monitoring and supporting that we have not previously mentioned. Monitoring and supporting in face-to-face settings is especially challenging for the teacher because he/she cannot be present everywhere at once or pay attention to all of the groups at the same time. However, solutions from computer-supported settings may be transferable to face-to-face situations.

In the CSCL literature, teacher's monitoring of student interaction in a computer-supported learning environment is often facilitated by a teacher *cockpit* (e.g., Voyiatzaki and Avouris 2009) that presents, for instance, snapshots of students' computer screens to the teacher. Monitoring can also be supported by a CSCL platform (cf. Roschelle et al. 2009) that displays students' contributions to the task they are working on. These can be *mirroring tools* (cf. Soller et al. 2005) that visualize data targeting the current interaction processes taking place, such as snapshots of the solutions and contributions made by group members, or *metacognitive tools* (cf. Soller et al. 2005), which even show how the desired interaction would look (Jermann and Dillenbourg 2008). These tools make the teacher and the students aware of the current collaborative learning process and thus indicate problematic interactions or difficulties in problem-solving. The group awareness tool, the *Lantern* (Dillenbourg and Jermann 2010), also works for face-to-face collaborative learning. It is a simple implementation of a teacher cockpit. It gives the teacher an overview of the collaborative working phases the different groups in the classroom are currently involved in and whether they need help. Each group receives a lantern and students can change its color depending on the current phase and progress of their group work.

The main advantage of the technical tools mentioned above is that they can provide a detailed overview of what is going on in all groups at the same time. In a classroom without those tools, a human teacher may struggle with monitoring and diagnosing difficulties. The teacher needs to select which student interactions to pay attention to and while he/she cannot be omnipresent. Nevertheless, the teacher can go from group to group in order to monitor their interactions and give them timely and content adaptive support. This adaptive assistance "on the fly" (p. 280) by the teacher regulates collaborative learning (Jermann and Dillenbourg 2008).

To regulate student interaction, the teacher needs to assess the situation based on the comparison of the current interaction to the desired interaction. This comparison is also a unique feature of computer-based guiding tools such as the Cognitive Tutor Algebra (Koedinger et al. 1997) that was enhanced by a reciprocal peer-tutoring environment (Walker et al. 2011). This environment compares students' actual solution and help-giving behavior to a mastery model and thus provides adaptive prompts to the peer-tutor. However, this collaboration support was much less sophisticated than the content support given. This is an example of guiding tools that use models to actively support students. By comparing the current model and the mastery model, guiding tools identify automatically where support is needed and are thus able to give adaptive support to students (Jermann and Dillenbourg 2008), such as, flagging errors to the learners or offering explanations and suggestions. Metacognitive tools and mirroring tools such as the Lantern (Dillenbourg and Jermann 2010) only display the current interaction and/or mastery models, without comparing the models to identify where support is needed.

The tools we briefly presented here may inspire how the teacher's behavior in a classroom can be facilitated. While most of those tools may only work in CSCL settings, their underlying indicators for student activities, such as information exchange and providing explanations, are also relevant in face-to-face collaborative learning settings. Those behavioral indicators for student activities can be summarized in a checklist that teachers can go through while observing student interaction (cf. Strijbos 2011). The checklist corresponds to a teacher cockpit as it helps a teacher to observe relevant student behavior and not be distracted by aspects of the collaboration that are less critical for learning success. It also supports the teacher in constructing a current model and a desired model of interaction comparable to mirroring and metacognitive tools. The beneficial behaviors presented on the checklist also constitute the desired interaction model. By comparing it to the actual interaction taking place, teachers can determine where interaction is suboptimal and needs support. Furthermore, the behavioral indicators presented on such a checklist also serve as objective rating criteria for assessing the quality of student interaction. They can also be considered to be typical interaction patterns that an experienced teacher can detect immediately (Bromme 1992). In the field of teacher education, many studies addressed teacher's professional vision (Sherin et al. 2008). We regard the monitoring competency as a kind of professional vision. Besides facilitating teacher's monitoring and supporting of student interaction in situ, these two competencies should also be taught in teacher education.

Training and assessing competencies make situated approaches necessary (cf. Klieme and Leutner 2006). One possible and often applied situated approach is the vignette technique. Written or video-based typical scenarios are presented and work as stimuli for the competencies. In research on teacher competencies, videos are often used in order to enhance competencies or to assess them (e.g., Oser et al. 2010; Seidel and Prenzel 2008; Sherin and van Es 2005). We also consider this to be a promising approach to train teacher competencies in monitoring and supporting student interaction.

In our own research, we designed and tested a teacher training and assessment tool to enhance and measure teacher's monitoring and supporting competencies. In the following, we briefly describe how we trained and assessed these two competencies.

The training begins with an instruction on how to use the checklist for monitoring student interaction. On the checklist, a typical example is presented for each behavioral indicator. Thus, the checklist can be compared to a simple version of a coding scheme used to analyze classroom discussions (Scherrer and Stein 2013). During the training, participants (pre-service teachers) mainly work in small groups to analyze short video clips of student interactions. The typical, problematic, and beneficial student behavior shown in the video clips is staged and typical of real student interactions. While using the checklist, participants train themselves to notice the behavioral indicators in the video clips. Results are discussed in a following plenary session. In the second part of the training, participants learn how to give adaptive support to enhance beneficial activities. They are provided with different kinds of prompts targeting collaborative, cognitive, and metacognitive activity. The video clips help the viewers practice when and which prompt is most appropriate in relation to the given student interaction.

But how can these competencies be assessed? The assessment tool uses video clips that are similar to those used in the training. As a measure of the monitoring competency, participants are asked to rate the quality of the collaborative, cognitive, and metacognitive student activity shown in a video clip. In addition to these global ratings of quality regarding student interaction, the indicators from the checklist are presented. Participants rate whether behavioral indicators are present in the video clips or not. For assessing the supporting competency, different prompts are presented following each video clip. Participants are asked to rate the appropriateness of each prompt given the specific student interaction shown in the video clip. Participant ratings are compared to an expert rating.

This training is especially useful for pre-service teachers who lack professional vision of student interaction. Even experienced teachers can profit from our checklist, which provides an empirically based structure of three important activities (collaborative, cognitive, and metacognitive activity). Additionally, experienced teachers may use such a checklist as a starting point but then complete their list with additional behavioral indicators based on their own teaching experience.

Future Directions

As the teacher plays a decisive role in fostering beneficial student interaction, his/her role should be more focused in research on collaborative learning, especially in face-to-face collaborative learning settings. We see a need to facilitate teacher's behavior in face-to-face classroom interactions, especially regarding monitoring and supporting student interaction. Research studies should investigate how teacher's monitoring and supporting of student interaction can be facilitated, for example, by providing a checklist of behavioral indicators for student activities. Teacher training, during both pre- and in-service phases, should not only focus on planning collaborative learning, but should also target the monitoring and supporting of student interaction, for instance with a video-based training. Future studies should examine the effects of this teacher behavior on the student level, that is, show how the teacher training affects students' learning.

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Ethical Standards The manuscript does not contain clinical studies or patient data.

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