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Effects of two differently sequenced classroom scripts on common ground in collaborative inquiry learning

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Abstract

Collaborative learning involves the collaborative regulation of cognitive activities to establish common ground for the coordination of content. Drawing on research on cognitive scripts to embed collaboration in learning, this study examines the effect of the quality of the grounding and testing processes on the quality of the inquiry processes (i.e., generating and evaluating evidence, drawing conclusions) in two differently sequenced classroom scripts. Both script conditions began with the teacher modeling each inquiry skill at the plenary level. After the plenary session, students in the Plenary–Individual–Small Group (PISG) classroom script first worked individually before working in small groups, whereas students in the Plenary–Small Group–Individual (PSGI) condition first worked in small groups before working individually. Overall, 61 students (grades 6–9) participated in a quasi-experimental study: 10 groups of three to four students in each condition. We coded all 20 groups' discourse. Descriptive findings showed no statistical significance in both script conditions. Case studies of the two groups' discourse in each experimental condition showed that occurrences of high-level grounding and high-level testing processes led to more occurrences of high-level inquiry processes in the PISG script condition. Excerpts of students' work at the individual level in both conditions illustrated how the script sequence shaped the discourse moves at the small group level. We discuss these findings against the background of literature on grounding, anticipated interaction, and cognitive scripts in collaborative learning.

Keywords Collaborative inquiry learning · Regulative processes · Common ground · Grounding · Coordination of process and content · Classroom scripts

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Introduction

Collaborative inquiry, as in any collaborative learning, is a negotiated process between individuals and others where individual thinking processes are constantly shaped by communication and social interaction in collaborative activities (Rogoff 1990). Facilitating collaborative learning in science inquiry has remained one of the core research foci in the last two decades (e.g., Bell et al. 2010; De Jong and Van Joolingen 1998; Duschl and Osborne 2002; Gijlers and De Jong 2005; Raes et al. 2012; Saab et al. 2007). Up to now, much of this research on enhancing the collaboration process can be classified into three general strands: the first strand of research examines the use of collaboration scripts with prompts to scaffold learners' contributions in the collaborative discourse (e.g., Kobbe et al. 2007; Kollar et al. 2007; Kolodner 2007), and the second strand of research investigates the sequencing and distribution of learning activities over the various social levels in the classroom to support interaction and communication (e.g., Kollar et al. 2011; Mäkitalo-Siegl et al. 2011; Rummel and Spada 2005). The first two strands of research seek to foster collaborative learning either by providing collaboration scripts to scaffold the knowledge co-construction process or by prescribing activity structure at different social levels to enhance interaction and communication in face-to-face and/or computer-mediated collaboration. In recent years, there has been an increase in the amount of research on the use of mobile technology to support the collaborative inquiry process in outdoor learning (e.g., Laru et al. 2012; Sharples et al. 2009; Tan and So 2011, 2015) and to enable seamless learning across formal and informal learning contexts (e.g., Looi et al. 2010; Milrad et al. 2013). Empirical findings in this third strand of research have shown that technological affordances could enhance interaction with the physical environment in outdoor learning, facilitate the immediacy of feedback from teachers and learning peers, as well as foster interaction and collaboration across contexts. However, empirical studies in these three strands of research have seldom investigated how individuals as a collective unit maintain "a shared meaning and common ground" (Stahl 2005, p. 345) constructed through group discourse (face-to-face and/or technology-mediated).

Clark and Brennan (1991, p. 223) first surfaced the notion of "grounding in conversation" where they foregrounded the significance of achieving common ground in order to coordinate the content in collaborative learning. They argued that individuals in any collaborative task could only begin to coordinate the content after they have assumed a vast amount of shared information or common ground, i.e., "mutual knowledge, mutual beliefs and mutual assumptions" (Clark and Brennan 1991, p. 222). In brief, coordinating the process is instrumental in coordinating the content. In a similar vein, De Jong and van Joolingen (1998) spoke of the significance of regulative processes in shaping inquiry processes in science inquiry learning. Apart from planning, monitoring and evaluating, grounding is one of the core regulative processes to negotiate shared meaning and to co-construct knowledge in collaborative inquiry (De Jong et al. 2005). Grounding is achieved by means of posing verification questions and confirmation statements to check for shared understanding. Bell's (2005, p. 12) work on scientific inquiry also accentuated the significance of *social contexts* for collaboration and learning interactions as these require coordinated group work, communication of ideas and negotiation of shared understanding.

An open empirical question is how we can enhance the grounding process to coordinate both the process and the content in collaborative inquiry learning. Research on classroom orchestration has argued that the distribution of classroom activities across the plenary, the small group and the individual level is a crucial aspect of lesson design in order to enhance the collaborative learning process (Dillenbourg and Jermann 2007). Various theoretical frameworks exist to support the sequencing and distribution of classroom activities. In regular science classrooms, the teacher typically first models scientific activities and/or thinking processes at the plenary level before they are practiced by students in small groups and/or at the individual level (Hakkarainen and Sintonen 2002; Schraw et al. 2006). On the one hand, it may be argued that having teacher modeling (as a plenary activity) followed by small group collaboration before individual practice might represent an instance of gradual fading of the scaffolds (Pea 2004) where the amount of support is incrementally reduced from phase to phase. On the other hand, after teacher modeling, individual work before small group work allows sufficient individual time before collaboration—"think before talking" (Veerman et al. 2000, p. 270) which could in turn facilitate productive communication and collaboration (Rummel and Spada 2005). This empirical study aimed to extend the second strand of research on the sequencing and distribution of classroom activities at different social levels. Specifically, it investigated whether collaboration should precede or succeed individual inquiry activities to enhance the grounding process, and how this in turn, might have an impact on the face-to-face collaborative inquiry process in the field trip and post-field trip.

Theoretical framework

Common ground in collaborative inquiry

Research on cognitive mediators of collaborative learning caution that it is not about working in groups, instead, it is about the possibility that certain kinds of cognitive processes can be activated (Cohen 1994; Dillenbourg 1999). Dillenbourg's (1999, p. 5) review on collaborative learning reiterated that "collaborative learning is neither a mechanism nor a method", but rather a situation where "particular forms of interaction among the individuals in the group are expected to occur". The successful engagement of individuals in a common endeavor requires the negotiation of shared meaning, and shared understanding to collaboratively construct knowledge and/or create new knowledge. In collaborative science inquiry, collective argumentation and scientific reasoning of different viewpoints characterize the scientific discourse (Chinn and Clark 2013; Duschl and Osborne 2002). Veerman et al. (2000) contended that for any effective collaborative argumentation to occur, students would first have to maintain a shared focus on the same issues and negotiate the meaning of one another's varying viewpoints and ideas. Baker et al. (1999, p. 32) defined 'grounding' as "the name given to the interactive processes by which common ground (or mutual understanding) between individuals is constructed and maintained". Studies on collaborative learning showed that students spent most of the time on grounding to ensure that learning partners understood what had transpired (Beers et al. 2005). In other words, they were very busy confirming that their partners understood what had been said to procure common ground. De Jong et al.'s (2005, p. 645) work on regulation of learning found that students engaged more frequently in "grounding" and "common agreement" activities than in any other regulative activity such as planning, monitoring and evaluation during collaborative work. Cognitive regulation such as planning the sequence of activities and division of labour, monitoring the progress of activities, and evaluating the execution of activities as well as the collaboration process enables the student to manage his/her actions based on goals, plans and knowledge of tasks at the collective level (De Jong et al. 2005).

In collaborative inquiry, grounding forms one of the core regulative processes. Common ground is established through group discourse such as asking other students about an idea or suggestion, calling attention to an idea or solution, and posing verification questions to seek affirmation (De Jong et al. 2005). Apart from grounding, testing also forms an important regulative process to achieve common ground and consensus where individuals as a collective unit affirm information and check for shared understanding (De Jong et al. 2005). In the testing process, students provide summary, and check if sufficient information/data has been gathered for the inquiry task. Testing usually occurs during the final evaluation phase of the learning process where learners check for sufficient information, whether something has been correctly understood, whether learning goals have been achieved: they summarize, draw conclusions and comparisons to verify data and/or to identify possible issues or gaps and proposed improvements (De Jong et al. 2005).

What essentially counts as grounding? For grounding to have taken place, the grounding criterion would be that both the "giver" and the "recipient" of information must mutually believe that they each have understood what the other meant (Clark and Schaefer 1989, p. 262). Providing accessibility to information and/or presenting information per se is not sufficient. The provision of feedback is pivotal "to ground the material in conversation and that this grounding process is collaborative for it to count as grounding" (Baker et al. 1999, p. 34). Feedback can assume the form of confirmatory statements and/or verification questions. Furthermore, the status of shared-meaning in the grounding process has to be continuously maintained. Stahl (2005, p. 345) posited that "a breakdown of the common ground" is likely to occur where mutual understanding cannot be reached and re-negotiation of conflicting views to achieve shared understanding is necessary. On a similar note, Baker et al. (1999, p. 32) postulated that this common ground will need to be "augmented", i.e., updated from time to time: new information relating to the task and feedback can also assume the form of repairs when common understanding needs to be restored. Hence, partial, disputable and controversial information has to be dealt with until all individuals in the group have arrived at a common understanding and common ground is re-established.

In summary, collaborative inquiry learning requires the coordination of both process and content: it involves the collaborative regulation of cognitive activities to establish common ground and to maintain shared understanding. It also implies a need to look at how we can better assimilate individuals into the collaborative workspace. To this end, the sequencing and distribution of classroom activities at different social levels could play a crucial role to evoke desired forms of interaction in the grounding process.

Classroom scripts for collaborative inquiry

Research on classroom scripts examines how the distribution and sequencing of learning activities over the various social levels could enhance the collaborative inquiry learning process (Kollar et al. 2011). Dillenbourg et al. (2011, p. 512) defined classroom orchestration as the facilitation of "multiple learning activities within a multi-constrained environment" in real time. In classroom orchestration, the teacher assumes the role of a facilitator where he or she exercises the discretion and flexibility to alter and adapt the classroom script for the desired interaction patterns and learning outcomes. Situations in collaborative learning (e.g., the degree of division of labour) could generate interaction patterns such as symmetry and negotiability (Dillenbourg 1999, p. 13). A classroom script can be likened to a macro-script with a primary function and a methodological objective to exert an indirect influence on the learning process by orchestrating classroom activities through sequencing and structuring of tasks (Dillenbourg and Jermann 2007).

Classroom scripts may include individual work (e.g., writing a synthesis, reading a paper), small group (e.g., peer editing, collaborative research activities) and/or plenary activities (e.g., introductory lectures, de-briefing). Different activity types might be necessary to integrate individuals into the collaborative space and to ensure that the collective unit learns. There is cognitive value in every activity type to engender both individual and collaborative learning. By defining the sequence of activities, classroom scripts shape the interaction patterns. There are several possible ways to sequence and distribute classroom activities to foster collaborative learning (Dillenbourg and Jermann 2007). An almost typical starting point of a classroom script is a plenary activity, where the teacher models the targeted skills and/or the thinking processes (Rummel and Spada 2005; Schraw et al. 2006; Schunk 1996; Webb and Palincsar 1996) in the scientific inquiry process. From here, two of the possible sequences for the classroom scripts investigated in this empirical work are: "PISG" (Plenary–Individual–Small Group) classroom script, and a "PSGI" (Plenary–Small Group–Individual) classroom script. The following sections will discuss how the differently sequenced classroom scripts possibly could facilitate the coordination of both process and content in collaborative science inquiry learning.

The Plenary–Individual–Small Group (PISG) classroom script

The PISG classroom script begins with the teacher modeling during the plenary session. Schwartz and Bransford (1998) contend that there is a time for telling where frontal lectures play a critical role. This is because providing higher-level explanation may be time consuming or cognitively challenging without expert help. Following the plenary session, students in the PISG classroom script work individually before working in small groups.

The theoretical constructs framing the PISG script transition are primarily derived from the notions of *coordinated cognitive activity*, *intersubjectivity* and *anticipated interactions* (Levine et al. 1993: emphasis added). Levine et al. (1993, p. 595) argued that whether one is "expecting to present one's position to others and/or expecting to learn about their positions can affect cognitive activity". In "anticipated interactions" (Levine et al. 1993, p. 595), individuals are prepared not only to present information but also to position their arguments. This also mirrors Veerman et al.'s (2000, p. 270) notion of "think before talking" where time-delays in text-based computer mediated communication (CMC) systems provided students with opportunities to reflect and scrutinize information. More time and space for reflection has led to better performance in the collaborative task. Individuals were able to learn better and were cognitively more prepared to interact with others in a more constructive and productive manner, i.e., they were able to criticise their own ideas, as well as provide justifications for their ideas. Next, collaboration is a coordinated activity which requires continued effort to maintain shared perception of the task to construct a joint problem space (Levine et al. 1993; Roschelle and Teasley 1995). The construction of this shared space is contingent on shared understanding, which Levine and colleagues (1993, p. 600) coined as "intersubjectivity". Intersubjectivity is instrumental in facilitating coordinated cognitive activity where group members are able to achieve shared task perception, common goals and strategies. Kaptelinin and Cole's (1997, p. 146) work foregrounded a "pre-and post-intersubjectivity activity" to coordinate individual and collective activities. The pre-and post-intersubjectivity activity aimed to help the learners coordinate two different views—the individual and the collective view. Their research showed that the pre-intersubjectivity activity enabled the individuals assimilate into the collective activity and a post-intersubjectivity activity provided a platform of learning transfer for the individuals as they emerged from the group experience. On a similar note, Rummel and Spada's (2005) study showed that scripted collaboration with an optimal sequence of individual and joint work phases facilitated better collaborative problem-solving process and learning outcomes, than the unscripted condition where participants worked jointly throughout the collaborative undertaking of task, overlooking the need to coordinate the individual working phases.

Allowing individual time before small group work in the PISG script sequence possibly could afford individuals time and space to reflect on their prior knowledge, new ideas and arguments, and to then integrate them more effectively during the collaboration phase. By creating the conditions to facilitate the occurrence of intersubjectivity and coordinated cognitive activity, the PISG script sequence possibly could set up the very conditions necessary to enhance the grounding process: coordinating both process and content when individuals converge to negotiate meaning during the collaboration phase.

The Plenary–Small Group–Individual (PSGI) classroom script

The theoretical framework on the fading of scaffolding forms the underlying premise of the PSGI classroom script. Akin to the idea of fading (Pea 2004), the PSGI script transition (moving from plenary to small group to the individual) gradually reduces the amount of (instructional) support an individual learner receives. Through the fading of the scaffolds, the student gradually receives more affordances to enact the skill, ideally parallel to an incremental increase in cognitive and meta-cognitive skills and knowledge.

The PSGI classroom script also begins with the teacher modeling during the plenary level to foster the development of a conceptual model of the later-to-be-enacted activity for the small groups (Rummel and Spada 2005). Plenary activity is deemed necessary where domain-specific and conceptual knowledge are central to inquiry tasks. Following the plenary, students work in a small group to collectively enact and practice the targeted inquiry skills modeled by the teacher. The collaborative inquiry at the small group level serves as an important platform to foster differentiation and externalisation of the roles and activities in complex problem solving (Collins et al. 1989). Essentially, small group activities also provide an opportunity for explicit discussion of scientific concepts and reflection which promotes metacognition and self-regulation. Teacher modeling during the plenary and working in small groups serve as scaffolds where students can observe, enact and practice the tacit processes with help from the teacher and peers (Pea 2004). The PSGI script transition also leverages on principles encapsulated in the ICAP (Interactive, Constructive, Active, Passive) framework (Chi 2009) where interactivity is better than constructive activity, and constructive activity is better than active activity. Interactivity promotes the externalisation, exploration and elaboration of different ideas leading to the co-construction of new knowledge (Chi 2009). Chi (2009) posited that co-construction in joint dialogues and substantive contribution in interactive activities could lead to emergent knowledge and new perspectives. Small group activities are presumed to evoke and enhance specific cognitive processes, which might be absent at both the plenary and the individual level. For instance, they foster mutually generative processes during interaction through which new knowledge and new perspectives can emerge (Chi 2009). Learning occurs when individuals interact with one another to voice their assumptions, defend and explain their varying viewpoints to arrive at an integrated conception (Levine et al. 1993).

Next, students in the PSGI script transition proceed to work individually. The gradual fading-out of the scaffolds (Pea 2004) at the plenary and small group levels may enable individuals to internalise the components of the complex set of inquiry skills while teachers and peers may create a zone of proximal development (see Fischer et al. 2013). At the individual level, students regulate their own cognition by internalising the regulation and control skills modeled by teachers and peers. Active and constructive activities at the individual level are necessary to activate prior knowledge, assess knowledge gaps and construct new perspectives beyond given learning materials (Chi 2009). The fading of the scaffolds in the PSGI script transition fosters individuals' acquisition of cognitive as well as metacognitive skills and knowledge, which might in turn facilitate the grounding process during the collaborative learning phase.

Research questions

The two differently sequenced classroom scripts (PISG vs. PSGI) could provide some insights into how the sequencing and distribution of different activity types might have an effect on the quality of the regulative processes of grounding and testing; importantly, how the regulative processes might shape the collaborative inquiry learning processes in generating and evaluating evidence, and drawing conclusions.

Against this theoretical background, the research questions were:

RQ1a. What are the effects of the high- and low-level regulative processes (grounding and testing) on the collaborative inquiry processes (generating and evaluating evidence, and drawing conclusions) in the two differently sequenced classroom scripts (PISG vs. PSGI)?

RQ1b. How did the differently sequenced classroom scripts (PISG vs. PSGI) shape the discourse structures in the grounding and testing processes and their effect on the collaborative inquiry process in generating and evaluating evidence, and drawing conclusions?

Method

Sample and design

Four classes with a total of 61 students (grades 6–9) from two schools in Germany participated in this quasi-experimental field study. The average age of the students was 14.0 years old (SD = 0.89). Half of the students in each of the four classes were randomly assigned to one of the two experimental conditions: the Plenary–Individual–Small Group (PISG) classroom script and the Plenary–Small Group–Individual (PSGI) classroom script. There were a total of 23 males and 6 females in the PSGI script condition, and a total of 20 males and 12 females in the PISG condition. The students were also randomly assigned into groups of 3 or 4, and there were a total of 10 groups in each condition (see Table 1; for the PSGI script condition, two groups experienced dropouts in the post-field trip).

Table 1 An experimental design with two conditions

	Differently sequenced classroom scripts	
	Plenary–Small Group–Individual (PSGI)	Plenary-Individual-Small Group (PISG)
Male	23	20
Female	6	12
	N = 29 (10 groups)	N = 32 (10 groups)

Instructional setting and procedure

The curriculum unit began with an introductory lesson on photosynthesis and cell respiration before students proceeded with the inquiry tasks on plant adaptation in different living conditions in three phases: a pre-field trip phase, a field trip to the Botanical Gardens and a post-field trip phase. Table 2 provides an overview of the execution of the two classroom scripts: PSGI and PISG in the instructional setting. The three phases spanned over 2–3 weeks consisting of a total of seven lessons each lasting approximately 45 min.

The pre-field trip began with the teacher presenting an overview of the curriculum unit on plant adaptation in different living environments. Next, using inquiry task 1, "plants in the dark" as an example, the teacher modeled the inquiry processes: orienting, asking questions, generating hypothesis and developing an inquiry plan. After the plenary session, students undertook two inquiry tasks: "plants in tropical rainforest" (inquiry task 2) and "plants in the desert" (inquiry task 3) in their respective script conditions. For students in the PSGI script condition, they first worked on the inquiry task 2 at the small group level before moving to the inquiry task 3 at the individual level. Conversely, students in the PISG condition first worked individually on the inquiry task 2 before moving to work on the inquiry task 3 in small groups.

The field trip study took place at the Botanical Gardens, Schloss Nymphenburg, Munich, Germany. The same botanist led the guided tour of the two halls: rainforest (inquiry task 2) and cactus (inquiry task 3) for all four classes in four separate sessions. The guided tour for each hall took approximately 30 min. After the tour of the rainforest hall, the students were led to a classroom opposite the green house. Again using inquiry task 1 on plants in the dark, the teacher demonstrated the inquiry process of data collection and interpretation during the generating of evidence. Next, students in the PSGI script condition proceeded to work on the inquiry task 2 (plants in the tropical rainforest) at the small group level whilst the PISG classroom script students worked on the same inquiry task but at the individual level. They had about 15 min to work on the task: list, interpret and analyse the evidence. The guided tour of the cactus hall followed after the students completed inquiry task 2. Similarly, after the guided tour, students in the PSGI condition then worked on inquiry task 3 individually and students in the PISG condition undertook the task at the small group level.

In the post-field trip, the teacher began the lesson with a brief recap of the field trip and moved on to model the scientific skills of evaluating evidence and drawing conclusions using the same inquiry task 1 on plants in the dark. Likewise, after the plenary session, students worked on inquiry task 2 and inquiry task 3 (either individually or in small group) as per the experimental conditions. In evaluating evidence, students had to produce evidence to support their claims in the reasoning process. Finally, with the claims, evidence

Table 2 The execution of the two classroom scripts and the lesson activities

Scripts/inquiry task		Inquiry process(es)
PSGI	PISG	Activity description for each inquiry process
Pre-field trip		
Plenary (P) (Teacher modeling)		Orienting: Students read the given lead information on five plants in the tropical rainforests and select a plant of their choice for the inquiry process
Inquiry task 1: Plants in the Dark		
Small Group (SG)	Individual (I)	Asking questions: Students respond to the following questions
Inquiry task 2: plants in the tropical rainforest		1. What I already know 2. What I need to know 3. What I want to find out Generating hypothesis: Students develop a hypothesis e.g. how the plant (e.g., Bamboo) survives in the tropical rainforest
Individual (I)	Small Group (SG)	Testing hypothesis: Students develop a plan for their inquiry based on the given guidelines
Inquiry task 3: plants in the desert		1. Types of data 2. Data collection method
Field trip to the botanical gardens		
Plenary (P)		Guided Tour of the Rainforest Hall & Cactus Hall
Plenary (P) (Teacher modeling)		Generating evidence: Generating evidence: Students first write down their observations and ideas, next put a tick, a cross or a question mark to the ideas/statements/claims they have written down
Inquiry task 1: Plants in the Dark		
Small Group (SG)	Individual (I)	
Inquiry task 2: plants in the tropical rainforest		
Plenary (P)		
Individual (I)	Small Group (SG)	

Table 2 (continued)

Scripts/inquiry task		Inquiry process(es)
PSGI	PISG	Activity description for each inquiry process
Inquiry task 3: plants in the desert		
Post-field trip		
Plenary (P) (Teacher modeling)		Evaluating evidence: Students review and evaluate their evidences: state the claims, provide evidences to the claims, and develop scientific reasoning for the claims
Small Group (SG)	Individual (I)	Drawing conclusions: Students develop scientific conclusions based on the claims, evidences and reasoning they have provided
Inquiry task 2: plants in the tropical rainforest		
Individual (I)	Small Group (SG)	
Inquiry task 3: plants in the desert		

and reasoning, students drew a scientific conclusion (they were only required to produce a minimum of one scientific conclusion).

Operationalization of independent and dependent variables

The goal of the empirical study was to measure the effects of the differently sequenced classroom scripts PSGI and PISG (the independent variables) on the regulative and inquiry processes (the dependent variables) of small groups in collaborative inquiry learning. The implementation of the two differently sequenced classroom scripts, PSGI and PISG began after teacher modeling during the plenary session. Each of the three phases from pre- to post-field trip of the inquiry process began with the plenary session and followed by the different script transitions in the PSGI and PISG classroom scripts. This script sequence was strictly adhered to from pre-to post-field trip. It is important to also note that inquiry task 1 was consistently used for teacher modeling of the scientific skills during the plenary session from pre-to-post field trip.

This study focuses on the inquiry processes in the field trip and post field-trip phase. In this study we specifically examined how the quality of the regulative processes of grounding and testing affect the quality of inquiry processes such as generating evidence, evaluating evidence and drawing conclusions in collaborative science inquiry learning.

Quality of the regulative and inquiry processes

De Jong and Ferguson-Hessler (1996, p. 107) proposed two qualifiers or levels of knowledge: “deep versus surface”. Students who possess deep level knowledge will display the ability to reason and explain, to articulate depth in understanding a domain and acquire different perspectives of a phenomenon or problem (Snow 1989). On the other hand, those who have only surface-level knowledge are only able to reproduce knowledge, similar to that of rote-learning which lacks depth of knowledge to formulate critical judgment (Glaser 1991). The two levels of knowledge (deep vs. surface) shall be applied to qualify students’ regulative and inquiry processes and shall be termed as high- and low-level regulative processes, as well as high- and low-level inquiry processes.

We defined a high-level inquiry statement (see Table 3), e.g., high-level generating of evidence, where it demonstrated observations, comparisons and descriptions to make valid inferences. A low-level statement would be one without any scientific reasoning and explanation. And for the regulative processes (see Table 4), e.g., high-level grounding occurs where students pose sound verification questions to arrive at shared understanding and to bring the group’s contributions to a higher platform in the process of affirming or

Table 3 Examples of high- and low-level generating of evidence

	Group discourse	
Student N	The golden barrel cactus is round, and with little surface area at the crown	Generating evidence (high)
Student L	… reduces water loss	
Student M	Minimum surface area at the crown and a succulent stem	
Student T	The golden barrel cactus is round	Generating evidence (low)
Student Z	… store lots of water	

Table 4 Examples of high- and low-level grounding

	Group discourse	
Student J	How do they withstand the heat?	Grounding (high)
Student M	They have a different structure	
Student L	They have a different structure, a different type of metabolism	
Student V	Let's write down the keywords… against dryness… yes?	Grounding (low)
Student T	Ok… done… and… the reason is…	

constructing scientific explanations. Conversely, low-level grounding occurs when students show immediate agreement without further probes or disagreement without sound scientific reasoning.

Data collection and analytical approach

Group discourse and interaction of the 20 groups was video-and audio-recorded. Each student wore a voice recorder. Data for the analysis of the discourse in the field trip and post-field trip was derived from the audio recordings.

Quantitative analyses

We coded every 5 s of the audio recordings for the regulative processes and the inquiry processes. Each idea forms one unit of analysis, which may contain one or more sentences depending on the discussion threads, ideas and turn of talks (Chi 1997). Furthermore, we coded whether students showed those processes on a high or low quality level. Next, we used frequencies of each type of activity (at both quality levels) as dependent variables in our analyses. Two independent raters were trained to code for the inquiry and regulative by processing the audio recordings of two small groups which constituted 10% of the total data. Any disagreements between the coders were resolved by means of collective listening to the audio footages. Cohen's Kappa as an indicator of inter-rater agreement was satisfactory with $\kappa = 0.78$ for high- and low-level inquiry processes and $\kappa = 0.73$ for high and low-level regulative processes respectively. For all the analyses, absolute frequencies were used, and independent-samples *t* tests were conducted to investigate the effects of the PSGI and PISG scripts on the frequencies for high- and low-level regulative and inquiry processes. An alpha level of .05 was used for all statistical tests.

Analysis of discourse structure

An in-depth analysis of the two small groups' discourse from each of the experimental conditions was carried out to exemplify the descriptive findings. The in-depth analysis served to evaluate the discourse structures in the two differently sequenced classroom scripts, and illustrated how the two differently sequenced classroom scripts affect the regulative and inquiry processes at group level. The two small groups in each of the experimental conditions that were selected for analysis were those that best represented the effects of the two different classroom scripts as well as the average length of the discourse representing all 10 groups in each experimental condition. Other criteria for selection of discourse included similar group size and attendance for the three phases of inquiry from pre-to-post field trip. Also, the length of discourse for these two selected groups best mirrored the average length of the twenty groups of students in this study. In the analysis of the small group discourse, the unit of analysis was coarser and semantically defined based on discussion threads and ideas (Chi 1997). That is, one unit of analysis may contain more than one line of utterance.

In order to illustrate the discourse structures and moves, an overview of all discourses in the field trip and post-field trip was presented with the help of a graphical coding analysis (Keefer et al. 2000) to visualize the effects of the two different script sequences on the regulative and inquiry processes. The labels for high- and low-level regulative and inquiry processes are abbreviated. Chi's (2009) ICAP framework is applied to each unit of analysis to indicate if the activity is active, constructive or interactive. Essentially, the ICAP model hypothesizes a hierarchical organization of activity types and their learning effectiveness. The activity types evoke different cognitive processes and engagement behavior with interactivity as better than constructive, and constructive activity is better than active activity. A green triangle indicates that the activity is interactive, an inverted black triangle represents a not interactive activity, an orange rectangle means the activity is constructive and a dark blue circle represents active. Furthermore, for the PSGI classroom script, a red arrow indicates instances where individuals' ideas were integrated into the collaborative inquiry process to negotiate shared understanding and to create new knowledge, and for the PISG classroom script, a blue arrow is used. Excerpts of students' work at the individual level in both script conditions were also highlighted to discuss how the differently sequenced classroom scripts could have shaped the discourse moves at the small group level.

Results

This section addresses the aforementioned research questions. We shall begin with RQ1a presenting the descriptive findings on the quality of the regulative processes (i.e., grounding and testing) and collaborative inquiry processes (i.e., generating and evaluating evidence, and drawing conclusions) in the two different script conditions. To answer RQ 1b, we discuss how the differently sequenced classroom scripts shape the discourse structure in the grounding and testing processes and their effect on the collaborative inquiry processes.

Quality of regulative and inquiry processes in PISG versus PSGI classroom scripts

Descriptive findings showed that there were higher occurrences of high-level grounding and high-level testing for the small groups in the PISG condition as compared to PSGI condition (see Table 5). However, there was no significant difference between the two script conditions on the high-level grounding and high-level testing processes and their effect sizes were small. Likewise, the results were not significant for low-level grounding and low-level testing in both script conditions though students in the PISG condition showed lower occurrences of low-level testing with close to medium-effect size.

For the collaborative inquiry processes, overall descriptive findings showed that PISG script sequence facilitated more occurrences for high-level generation of evidence, high-level evaluation of evidence and high-level drawing of conclusions as compared to the PSGI script condition, again, there was no statistical significance and the effect sizes were small (see Table 6). Similarly, findings showed that the PISG script condition reduces the occurrences of all three low-level inquiry processes but the results were not significant.

Table 5 Effects of PISG and PSGI on the quality of regulative processes in grounding and testing

Regulative processes	PISG script (n = 32) 10 groups M (SD)	PSGI script (n = 29) 10 groups M (SD)	*F(1,18)*	*p*	*Cohen's d*
Grounding high	3.90 (4.51)	3.00 (4.14)	0.22	0.65	0.21
Grounding low	20.80 (21.21)	19.00 (15.48)	0.05	0.83	0.10
Testing high	7.40 (5.87)	5.50 (5.80)	0.53	0.48	0.33
Testing low	19.50 (9.22)	24.50 (10.91)	1.23	0.28	0.49

Table 6 Effects of PISG and PSGI on the quality of collaborative inquiry processes

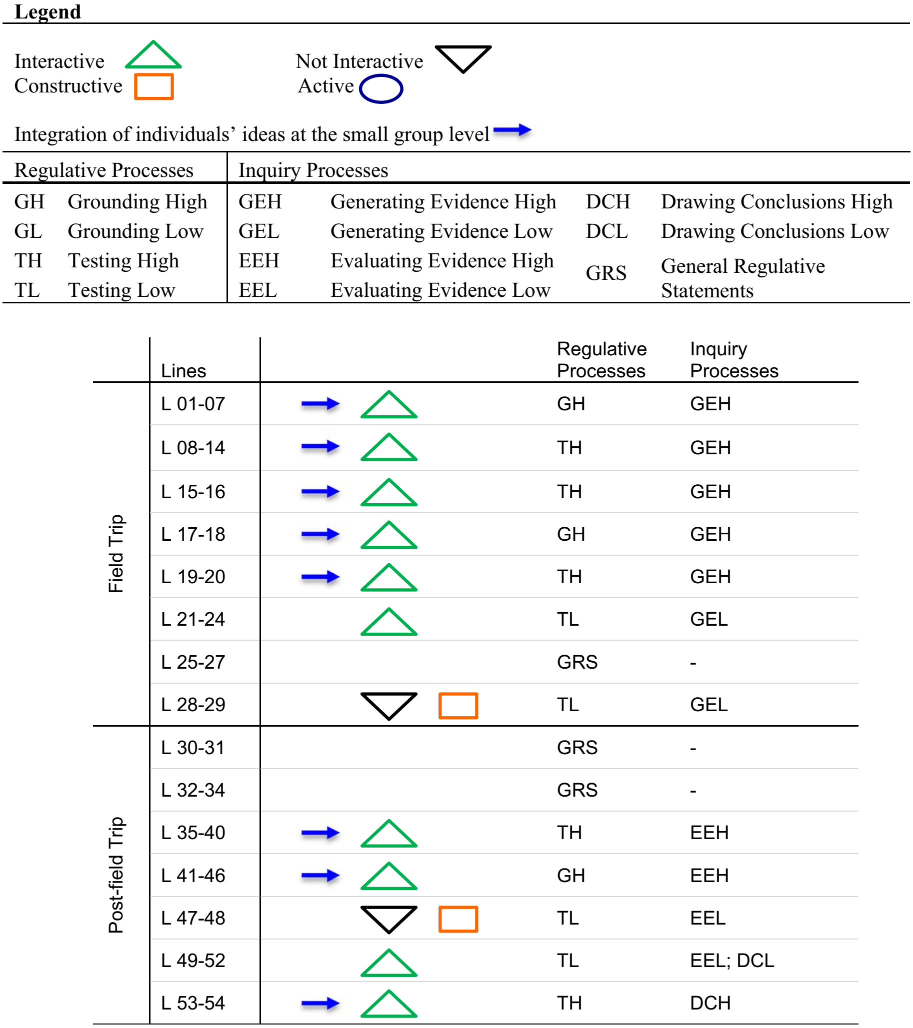
Inquiry processes	PISG Script (n = 32) 10 groups M (SD)	PSGI Script (n = 29) 10 groups M (SD)	*F (1,18)*	*p*	*Cohen's d*
Generating evidence high	5.10 (3.87)	4.00 (4.08)	0.38	0.54	0.28
Generating evidence low	8.20 (6.49)	9.20 (4.37)	0.16	0.69	0.18
Evaluating evidence high	6.80 (5.09)	4.80 (4.61)	0.85	0.37	0.41
Evaluating evidence low	16.40 (13.24)	17.00 (11.19)	0.01	0.91	0.05
Drawing conclusions high	1.70 (1.42)	1.50 (1.51)	0.09	0.76	0.14
Drawing conclusions low	3.20 (2.25)	4.20 (2.70)	0.81	0.38	0.40

Taken together, descriptive findings indicated that there is no script effect in both differently sequenced scripts on regulative and inquiry processes. Although there was a trend that the PISG script had higher occurrences than the PSGI script in high-level grounding and testing processes as well as high-level inquiry processes in generating and evaluating evidence, and drawing conclusions, there was no statistical significance and the effect sizes were small. Likewise, the PISG script showed lower occurrences than the PSGI script in low-level testing, low-level generation and evaluation of evidence, and the drawing of conclusions, but there was no statistical significance and the effect sizes were also small.

Discourse structure in PISG versus PSGI classroom scripts

While the descriptive statistics provide an overview of the effects of the two differently sequenced classroom scripts on the quality of the regulative and collaborative inquiry processes, it could not provide any information on the discourse structure in these two script sequences nor explain the occurrences of those high- and low-level regulative and inquiry processes. However, in-depth analysis of the two small groups' discourse from each of the experimental conditions does provide an insight to the discourse trends and moves. The graphical coding analysis of the small group's discourse in the field trip and post-field will first be presented to provide an overview of the effects of the grounding and testing processes on the collaborative inquiry processes in the two differently sequenced classroom scripts. Then according to the script sequence (individual before small group work or vice versa), observations and excerpts of individual's work and small group's discourse will be discussed to illustrate the findings exemplified in the graphical coding analysis.

Figure 1 presents an overview of the graphical coding analysis of the PISG small group's complete discourse in the field trip (lines 1–29) and post-field trip (lines 30–54) where they discussed how the cactus plant adapts to its living environment. The small group discussion began after the visit to the cactus hall where they collected data via observations to generate and evaluate evidence as well as draw conclusions on how cactus make food and store water. Analysis of the group's discourse in the PISG script condition showed three occurrences of high-level grounding (GH) and five occurrences of high-level testing (TH) which led to five occurrences of high-level generation of evidence (GEH), two occurrences of high-level evaluation of evidence (EEH) and one occurrence of a high-level drawing of a conclusion (DCH). There were four occurrences of low-level testing (TL) and no occurrence of low-level grounding (GL). Furthermore, there were eight instances where collaborative activity at the small group level was interactive and showed integration of



Legend

Interactive △ Not Interactive ▽
Constructive □ Active ◯

Integration of individuals' ideas at the small group level →

Regulative Processes		Inquiry Processes			
GH	Grounding High	GEH	Generating Evidence High	DCH	Drawing Conclusions High
GL	Grounding Low	GEL	Generating Evidence Low	DCL	Drawing Conclusions Low
TH	Testing High	EEH	Evaluating Evidence High	GRS	General Regulative Statements
TL	Testing Low	EEL	Evaluating Evidence Low		

	Lines				Regulative Processes	Inquiry Processes
Field Trip	L 01-07	→	△		GH	GEH
	L 08-14	→	△		TH	GEH
	L 15-16	→	△		TH	GEH
	L 17-18	→	△		GH	GEH
	L 19-20	→	△		TH	GEH
	L 21-24		△		TL	GEL
	L 25-27				GRS	-
	L 28-29		▽	□	TL	GEL
Post-field Trip	L 30-31				GRS	-
	L 32-34				GRS	-
	L 35-40	→	△		TH	EEH
	L 41-46	→	△		GH	EEH
	L 47-48		▽	□	TL	EEL
	L 49-52		△		TL	EEL; DCL
	L 53-54	→	△		TH	DCH

Fig. 1 Graphical coding analysis of the PISG small group discourse. (Color figure online)

one another's idea/contribution to negotiate shared understanding and to advance knowledge (see Fig. 1: the green triangle and blue arrows). Conversely, where the group did not successfully integrate individuals' ideas and/or there was a quick consensus with no sound verification statements/questions to test new perspectives/knowledge, this hindered the process of forging common ground, which led to the occurrence of two low-level generation of evidence (GEL), two low-level evaluations of evidence (EEL) and one low-level drawing of a conclusion (DCL).

Students in the PISG condition first worked individually on inquiry task two (plants in the tropical rainforest) before working in small groups on inquiry task three (plants in the desert). During the individual inquiry task at the field trip, all four students in the PISG group listed three to four observations about rainforest plants. However, out of the three or four statements, only one statement was specific to the plant chosen for the inquiry task. This was the case for all the four students. For instance, all three statements of student I20 were not related to the climbing plant she had chosen, but rather, general observations of rainforest plants' size, structure and functions. Student I19 measured the humidity level, noted general information about two other rainforest plants, and made one statement about the root system of the orchid plant she had chosen. Similarly, student I21 noted four observations she made about tropical rainforest plants but only one was relevant to the bamboo plant she had chosen, e.g., "Wachsen extrem schnell, um möglichst ans Licht zu kommen." (grow very quickly to reach sunlight). She did not make any inferences about the structure of the bamboo plant and its fast growth. This was also true for student I22 who picked the grandleaf seagrape: she noted the huge size of the leaf to absorb water and sunlight but did not make any other observations about this plant. Instead, she included notes about other rainforest plants. At the individual level, it was interesting to note that all four students showed a keen interest in exploring multiple perspectives and diverse ideas about plants' adaptation to rainforest conditions, other than the plant they had chosen for inquiry. They showed potential at generating evidence though some of the data they gathered remained unexplored or was only treated superficially. They were not always able to draw connections between plant structure and its adaptation to the tropical conditions.

The PISG students next worked on inquiry task three at the small group level. The following excerpt of the PISG group discourse illustrates how the individuals applied concepts e.g., plant structure, function and adaptation (generated during the individual inquiry task on rainforest plants) for a scientific explanation of the cactus plant's adaptation to the desert conditions (see Table 7: English translation of the discourse is provided in parentheses). Student I19 focused the group's discussion on the volume of the barrel cactus (line 2) and this triggered an idea from student I20 about the surface area of the barrel cactus (line 3). Student I20 advanced the idea by making reference to the structure of the barrel cactus and the small upper surface area (line 5). Grounding the various contributions, student I21 was able to formulate a coherent scientific explanation on the reduction of water loss and the structure of the barrel cactus (line 6). It was evident that there were visible attempts to forge common ground through posing good verification questions and affirmation statements (lines 2–6). The group also leveraged one another's ideas to advance their new knowledge about the surface area of the barrel cactus and water retention. They integrated one another's ideas to negotiate shared knowledge. This high-level grounding led to the high-level generation of evidence.

At the individual level in the post-field trip, there was some improvement in the individuals' scientific thinking-processes. This was evident in the scientific conclusions they made: substantiating scientific claims with evidence. For instance, student I20 wrote that "Die Kletterpflanze verwendet andere Bäume und Pflanzen um an ihnen

Table 7 PISG discourse excerpt of the grounding process to generate evidence

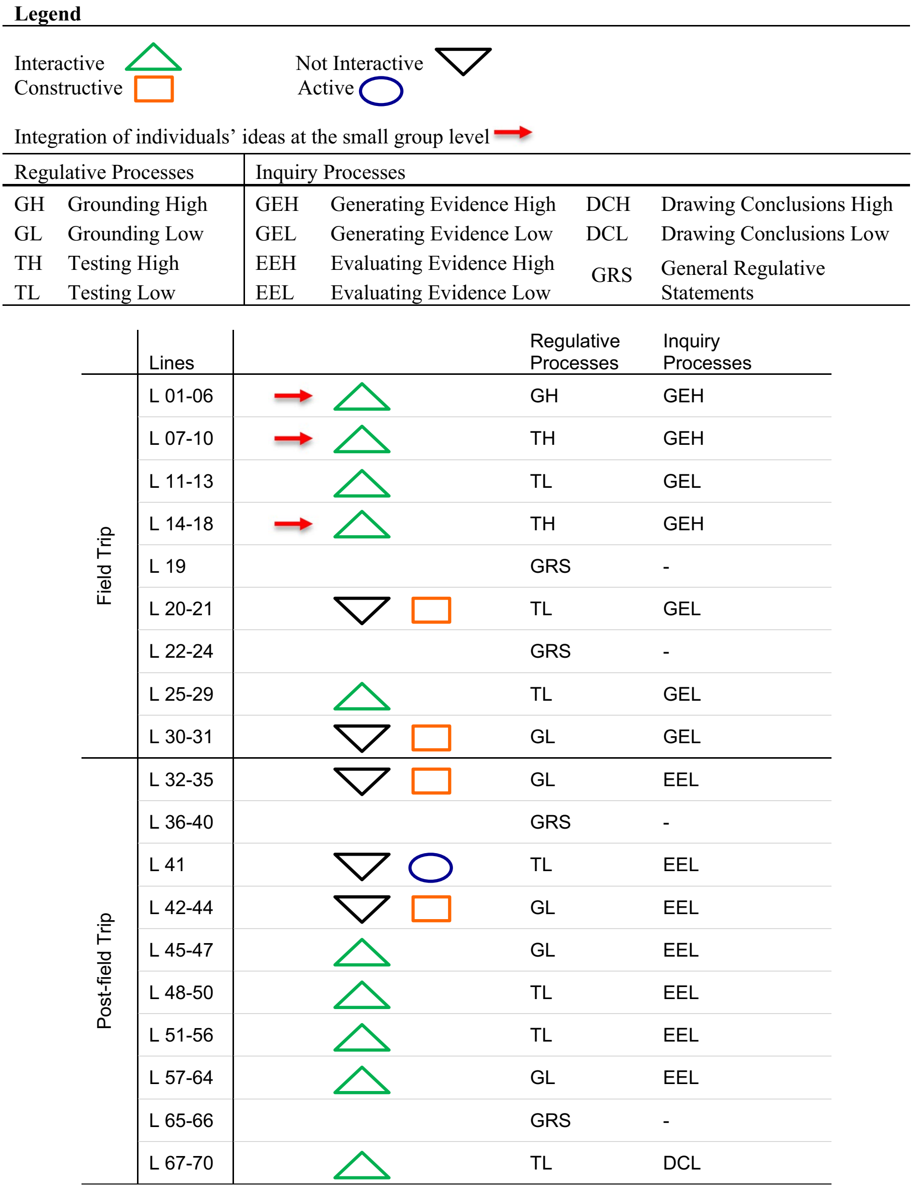
Line	Student	Group discourse	Code
1	I21	Also, was wissen wir… (So, what do we know…)	Grounding (high) Generating evidence (High)
2	I19	Fangen wir mit dem Volumen (Let's start with the volume)	
3	I20	Oberfläche? (Surface area?)	
4	I19	Ja. (Yes)	
5	I20	Oberflächenverkleinerung, damit sie… (A decrease in the surface area so that they…)	
6	I21	Damit sie maximales Volumen mit der geringsten Oberfläche haben (So that they have the maximum volume with minimum surface area)	
7	I20	Yup. (Yes)	

nach oben zu klettern. So kommen sie zum Licht". (The climbing plants make use of other trees and plants to climb to the top for sunlight), student I19 also made a coherent scientific conclusion about the root system of the orchid plants in the tropical rainforest, "Orchideen wachsen auf Bäumen, benötigen also keine Erde, und besitzen Luftwurzeln…können Wasser und Nahrstöffe der Luft entnehmen" (the orchid plants grew on other plants and used their air roots to obtain water and other forms of nutrients). It was also observed that in the post-field trip, the students were better able to focus on their specific plant of inquiry rather than writing about rainforest plants in general.

At the small group level in the post-field trip, students in the PISG condition continued to show good regulatory support to clarify misconceived notions and consolidate pieces of evidence to converge on shared knowledge. They maintained common ground when there was a breakdown in shared understanding. For instance, the grounding statements to correct the misconception that photosynthesis took place at night were coded high as the group took time to re-evaluate the data and posed verification questions (see Fig. 1, lines 41–46). Student I19 student and student I21 initially misunderstood that photosynthesis took place in the night to reduce water loss, "… ja, um ihren Wasserverlust zu minimieren" (…yes, to minimise water loss). The misconception was corrected when student I20 posed verification statements about the transpiration process, "nee, die öffnen … die nehmen Kohlensäure in der Nacht auf, aber Fotosynthese machen sie wegen dem Licht" (No, they open … they take in carbon dioxide in the night but they need the sunlight for photosynthesis to occur). This brought the group to a new level of shared knowledge that for the cactus, transpiration began at night but the process of photosynthesis took place with the help of sunlight. The group showed good collaborative reflection to check for shared understanding before converging on shared knowledge. This was evident in the occurrences of high-level testing (TH) where they not only summarized their findings, but also critiqued their reasoning process and made comparisons to check for emerging comprehension (see Fig. 1, lines 53–54).

The PSGI small group discourse

Overall, the graphical coding analysis of the PSGI discourse structure for the field trip (lines 1–31) and post-field trip (lines 32–70) (see Fig. 2) showed that there were five occurrences of low-level grounding (GL) and seven occurrences of low-level testing (TL) which led to the four occurrences of low-level generation of evidence (GEL), seven occurrences



Legend

Interactive △ Not Interactive ▽
Constructive □ Active ◯

Integration of individuals' ideas at the small group level →

Regulative Processes		Inquiry Processes			
GH	Grounding High	GEH	Generating Evidence High	DCH	Drawing Conclusions High
GL	Grounding Low	GEL	Generating Evidence Low	DCL	Drawing Conclusions Low
TH	Testing High	EEH	Evaluating Evidence High	GRS	General Regulative Statements
TL	Testing Low	EEL	Evaluating Evidence Low		

	Lines		Regulative Processes	Inquiry Processes
Field Trip	L 01-06	→ △	GH	GEH
	L 07-10	→ △	TH	GEH
	L 11-13	△	TL	GEL
	L 14-18	→ △	TH	GEH
	L 19		GRS	-
	L 20-21	▽ □	TL	GEL
	L 22-24		GRS	-
	L 25-29	△	TL	GEL
	L 30-31	▽ □	GL	GEL
Post-field Trip	L 32-35	▽ □	GL	EEL
	L 36-40		GRS	-
	L 41	▽ ◯	TL	EEL
	L 42-44	▽ □	GL	EEL
	L 45-47	△	GL	EEL
	L 48-50	△	TL	EEL
	L 51-56	△	TL	EEL
	L 57-64	△	GL	EEL
	L 65-66		GRS	-
	L 67-70	△	TL	DCL

Fig. 2 Graphical coding analysis of the PSGI discourse. (Color figure online)

of low-level evaluation of evidence (EEL) and one occurrence of a low-level drawing of a scientific conclusion (DCL). In those occurrences of low-level grounding (GL) or low-level testing (TL) processes, there were five instances where there was little or no interaction in the collaborative inquiry process, but rather active or constructive activities were taking place at the individual level (e.g., see Fig. 2, lines 42–44). Instead of engaging in interactive discourse, active and/or constructive activity was taking place as members were externalising his/her ideas: a case of what Chi (2009) described as self-explaining and affirming one's own ideas. The "interaction" in the process of forging common ground was reduced to a case of accepting, verbalising and confirming one's ideas where each of them were merely articulating their own ideas about plant size, amount of water and sunlight. Also, there was no attempt to integrate ideas with verification statements/questions, consequentially, evaluation of evidence here lacked depth and the scientific reasoning for the claim was weak as a quick consensus was achieved. The same applies to the testing process in the PSGI script condition. Low-level testing (TL) occurred where there was no substantial interaction to integrate individuals' ideas into collaborative work and/or the summary of information/findings were given token treatment with no probing questions or scientific arguments to negotiate shared meaning. This was evident in the group's formulation of the final scientific conclusion (see Fig. 2, lines 67–70) where the group failed to leverage on the data they had earlier collected to make a sound evaluation of their claims. The group made no reference to the observations they had earlier noted about the measurement of the growth of the bamboo plant and its stem structure to explain its resistance to the weather condition in the tropical rainforest and its fast growth. This significantly weakened their scientific reasoning process and the conclusion they made. Conversely, it is noticeable that where there was high-level grounding (GH), the group was able to negotiate shared understanding and to converge on shared knowledge. However, there was only one occurrence of high-level grounding (GH) and two occurrences of high-level testing (TH). Overall, there were only three instances of good interaction and coordination where individual ideas were duly considered and successfully integrated to negotiate shared meaning and to construct new knowledge (see Fig. 2: red arrows).

Students in the PSGI condition first worked in small groups on inquiry task two (plants in the tropical rainforest) before working individually on inquiry task three (plants in the desert). According to the script sequence, the discourse moves and patterns in the small group collaboration will first be discussed before taking a closer look at how the four students performed at individual level in the field trip, followed by the post field trip.

In the field trip, the PSGI group began with good interaction to integrate individuals' contributions and to establish common ground (see Fig. 2, lines 1–6; lines 7–10; lines 14–18). For instance in the testing process to consolidate the evidence, the group built on one another's scientific explanation of the humidity level and moisture in the air to infer connections about the temperature and adaptation of the bamboo plant (their chosen plant for inquiry). This led to high-level evidence generation (GEH) (see Fig. 2, lines 14–18). However, as the group progressed to consolidate other pieces of evidence, their attempts to establish common ground were visibly weakened by the lack of negotiation for shared meaning and a tokenistic treatment of contributions (see lines 20–21; lines 25–29; lines 30–31). This was evident when student S05 voiced an opinion that the fast growth of the bamboo plant was not sufficient in line 25 and again in line 27. Student S07 and S04 did not probe further but simply concluded that the bamboo plant grew fast to reach the sunlight (lines 28–29) without any reference to the structure of the bamboo plant.

At the individual level in the field trip, except for one student who had only two statements, the other three students noted five to eight statements about the cactus plant they had chosen for their inquiry. It is interesting to note that all the statements they made, focused on the respective plants they had chosen without digression to other types of cactus or desert plants. For instance, student S04 wrote that the structure of the barrel cactus enabled it to store more water. Student S05 noted that the stomata open during the night to reduce water loss and student S07 wrote about the spines of the cactus act as a defence mechanism to protect itself. They were able to make inferences about the plant structure and its capacity for adaptation to desert conditions.

In the post-field trip, the group converged again to continue with the small group inquiry on the bamboo plant. Below is the discourse excerpt of the small group in the post-field trip to evaluate evidence and draw scientific conclusions (see Table 8: English translation of the discourse is provided in parentheses). It illustrates that where the interactive activity lacked coordination, communication and collaboration, i.e., the individual's ideas/contributions were dismissed without any collaborative reflection by means of probing verification questions, the superficial interaction was unable to bring about negotiation of shared meaning, let alone to co-construct new knowledge. Here, the series of grounding statements was coded low as the verification questions were not sufficiently dealt with. For instance, S04 said that his reasoning was different (see Table 8: line 59) but it was dismissed by S07 who interrupted that the bamboo plant could absorb lots of light owing to the huge size of the leaves (see Table 8: lines 60 and 61). S04 disagreed that the size of the leaves to absorb light (see Table 8: line 62) was a relevant argument for the case of the bamboo plant, but her argument was not taken up. The group discourse ended with another round of low-level grounding as the grounding statements lacked deeper reflection and no common ground was achieved. The interaction was weak: the group was unable to converge on shared understanding, which led to a low evaluation of the evidence.

During the individual work at the post-field trip, it was observed that the PSGI students attempted to draw better scientific conclusions than at the group level: each of them at the individual level further explored the plant parts and their functions for adaptation in harsh desert conditions. For instance, student S04 further elaborated on the function of the

Table 8 PSGI Discourse excerpt of the grounding process to evaluate evidence

Line	Student	Group discourse	Code
57	S05	Und als Begründung, Pflanzen wachsen so, dass sie möglichst viel Licht bekommen…z.B. haben riesige Blätter (And the reason is that plants grow so that they can get as much sunlight as possible…e.g., by having huge leaves)	Grounding (low) Evaluating Evidence (low)
58	S06	Hatten wir das? (Did we have that?)	
59	S04	Ich habe nicht die Begründung (I do not have this reasoning)	
60	S07	Ich habe meine eigene Begründung…dass sie möglicht viel Licht… (I have mine own reasoning…that they absorb lots of sunlight…)	
61	S05 & S07	Abzufangen, z.B. mit riesigen Blättern (Absorb, e.g., with huge leaves)	
62	S04	Aber das ist zu Stoff für die… (But that is the material/part for the…)	
63	S05	Du kannst zum Beispiel schreiben, wachsen extrem schnell (You can for example, write that they grow extremely fast)	
64	S04	Ok…	

spines of the cactus, “Dellen vom Kaktus werfen Schatten. Durch die Schatten wird das Wasser nicht so schnell erdunstet…” (Spines provide shadow and also reduce water loss). Student S05 wrote, “Kakteen sind so gebaut, das sie wenigst viel Oberfläche haben. Bei einer grossen Oberfläche trift das Sonnenlicht mehr und das Wasser wird stärker erhizt, was zu Wasserverlust führt” (The structure of the cactus: the small top surface area protects it from heat and reduces water loss). Student S07 provided a scientific conclusion about the survival of the cactus in desert conditions with a focus on the transpiration process which took place at night. At the individual level, they adapted some of the scientific concepts not duly explored at the group level and provided a more coherent scientific explanation during their individual work.

In summary, analysis of the small group discourse and excerpts of the individual work showed how the two different script sequences have a bearing on the individual as well as the small group. In the PISG condition, at the individual level, students displayed more inclination to explore diverse ideas and concepts about plant adaptation. However, they did not individually work through these ideas in greater depth. This was evident in the field trip where all four students noted observations of different rainforest plants instead of focusing on their chosen plant of inquiry. At the small group level, they were less inhibited to surface raw ideas or unpolished information that they had explored at the individual level. Furthermore, they worked through those issues by building on one another’s contributions to procure common ground and to converge on shared knowledge. There was also better integration of individual ideas at the small group level and substantial interactive activities in the PISG script condition. On the other hand, the PSGI script condition began with small group collaboration before individual work. Most of the time, the grounding process during the collaborative inquiry was hindered by a lack of substantial negotiation of contributions and reflective thinking. However, students showed ability to adapt group contributions at the individual level. They worked through those scientific concepts such as humidity level, growth, function of plant parts that were superficially discussed at the small group level.

Discussion

This research study investigates the effects of two differently sequenced classroom scripts on regulative processes and collaborative inquiry processes. The first research question was, “What are the effects of high- and low-level regulative processes (grounding and testing) on collaborative inquiry processes (generating and evaluating evidence, and drawing conclusions) in two differently sequenced classroom scripts (PISG vs. PSGI)?” Overall descriptive findings showed that there was no script effect on both the regulative and inquiry processes in the two different script sequences. The PISG classroom script yielded more occurrences of high-level regulative and inquiry processes and reduces the occurrences of low-level regulative and inquiry processes as compared to the PSGI classroom script but there was no statistical significance and the effect sizes were small. However, descriptive findings could not illustrate how the two different script sequences shaped the grounding and collaborative inquiry processes which have a bearing on the coordination of process and content. This brings us to research question 1b, “How did the differently sequenced classroom scripts (PISG vs. PSGI) shape the discourse structures in the grounding and testing processes and their effect on the collaborative inquiry process in generating and evaluating evidence, and drawing conclusions?” Analysis of the small group discourse and excerpts of individual's work discloses to what extent the specific process phenomena aligned with the theoretical assumptions in the two differently sequenced classroom scripts.

The PISG script sequence primarily embodies theories of coordinated cognitive activity, intersubjectivity and anticipated interactions (Levine et al. 1993). Self-explanation and asking questions during the individual level prior to small group interaction could be instrumental in facilitating anticipated interactions in the PISG script condition. Individual readiness to engage in interactive activities has an impact on the collaborative learning process: whether one receives, shares or exchanges information and how one expects others to engage in the interaction process. In a similar vein, the individual work phase in PISG script sequence also resonates with Kaptelinin and Cole's (1997) study where they showed how the pre-intersubjectivity activity afforded individuals a better transition into the collaborative workspace. This was evident in the eight instances where individuals' ideas were integrated during the grounding and testing processes in the PISG script sequence. These findings are consistent with studies on time-delay to foster thinking before talking (Veerman et al. 2000) and individual time before collaborative task improves interaction, coordination and communication (Hermann et al. 2001; Rummel and Spada 2005).

For the students in the PISG script condition, the active and constructive activities at the individual level before small group interactive activities also invoke cognitive processes such as "gap-filling" and "generative" processes (Chi 2009, p. 85). Generative processes enable learners to reflect on conditions of a procedure and provide explanations. Making provision for individual reflection prior to collaborative work may foster higher level of analysis, evaluation and synthesis (Jonassen and Kwon 2001). Discourse analysis showed that high-level grounding and high-level testing afforded more depth in the collaborative discourse, which led to high-level evidence generation, evidence evaluation and drawing conclusions in the PISG script condition. Students were able to validate knowledge claims with evidence and scientific explanation in the grounding and testing processes. Individuals were able to surface unexplored ideas about plant structure and environmental conditions: discuss and advance these raw ideas as a collective unit at the small group level. Chi and Wylie's (2014) study showed that students perform increasingly better as they progressed from passive to active to constructive and to interactive activities. The PISG script transition mirrored such a movement of cognitive engagement. It was also evident that the interactive activity at the small group level showed instances of in-depth discussion where the students posed questions and preempted possible problems to check the sufficiency and accuracy of evidence in making scientific claims.

The PSGI classroom script sequence exemplifies the theory of the fading of the scaffolds (Pea 2004) and the principles of the ICAP Framework (Chi 2009). The gradual fading of the scaffolds from plenary to small group to individual level could have provided instructional support, i.e., content wise for the individual phase but might not have rendered the necessary transition for the coordination of the process, i.e., the process of grounding to forge common ground at the small group level. At the individual level, the PSGI students adapted group ideas/contributions and further developed these unexplored concepts on plant adaptation. At the small group level, there were some instances of good contributions but there were too few attempts to allow individuals to defend and/or explain their ideas. Hence, where common ground could not be "augmented and maintained" during interaction (Baker et al. 1999, p. 33), shared meaning is absent, and consequentially, emergent knowledge is subdued and new knowledge is forfeited.

Notwithstanding, there were more statements made in the PSGI small group discourse (70 lines in total) as compared to the PISG small group discourse (54 lines in total). However, analysis of the PSGI small group discourse showed a number of non-interactive moments where individual ideas were either dismissed or only given superficial treatment. An interactive activity is no longer interactive if partners are not responding to one another's contribution and there is no co-construction of knowledge (Chi 2009). Chi (2009) also cautioned that an intentionally designed e.g., interactive activity can become active or constructive instead of interactive when either the activity or the learner has compromised the intended activity type. Barron's (2003, p. 332) work on "when smart groups fail" showed that when one or more members displayed "intersubjectivity attitude" and a lack of willingness to coregulate interaction, it "interfered with processes of distributed reasoning resulting in failures to solve a common problem". The PSGI discourse mirrored such a postulation where individual contributions were not sufficiently dealt with nor integrated into the joint workspace during the collaborative inquiry process. There were only three instances where individuals' ideas were explored, negotiated and converged to create new knowledge leading to high-level generation of evidence. Substantive contributions alone do not necessarily imply successful collaboration: presentation of information per se without the process of negotiating common ground does not account for grounding. The occurrences of active and constructive activities instead of interactive engagement could possibly imply that individuals in the PSGI script sequence might have needed some time for self-explanation and reflection before moving into small group work.

Conclusion and implications

This research study showed that the sequencing and distribution of different activity types in two script variations could have different effects on the coordination of process and content in collaborative inquiry learning. There is cognitive value in every activity type. The sequencing of individual and small group phases could play a crucial role in evoking the desired modes of engagement in the grounding and testing processes during collaborative inquiry learning.

There are certainly inherent limitations in the attribution of effects owing to the small sample size. Descriptive findings showed no statistical significance and small effect sizes. However, in-depth analysis of the two groups' discourse seems to suggest that the sequencing of individual and small group phase could carry some implications on the quality of the grounding and testing processes, and consequentially, the quality of the inquiry processes. In both script sequences, there was provision of scaffolds, i.e., teacher modeling at the plenary and collaborative learning at the small group level. The PSGI students experienced the gradual effect of fading of the scaffolds, whereas the PISG students experienced delay of peer learning to facilitate coordinated cognitive activity, intersubjectivity and anticipated interactions. The results of the two case studies seem to suggest that there is hidden efficacy in the PISG script for collaborative inquiry learning. Learners need individual space to reflect, interpret and construct meaning to explore their own ideas and to think before talking so that they are better able to establish common ground and to coordinate both process and content during collaborative inquiry learning.

However, more research with bigger sample sizes: exploring different domains, different learning contexts (with and without technological affordances), and both individuals' and small groups' learning processes and outcomes are needed to thoroughly investigate the effects of differently sequenced classroom scripts on grounding processes in collaborative learning. First, leveraging on technological affordances to support collaborative learning might have implications on the impact of activity sequence on both the individuals' and small groups' learning processes and outcomes. There have been extensive empirical studies on the benefits of mobile devices in collaborative scientific inquiry (e.g., Laru et al. 2012; Rogers and Price 2008; Smith et al. 2005) and computer-assisted collaborative inquiry (e.g., Bell et al. 2010; Kollar et al. 2007), still not much is known specifically about the process of establishing and maintaining common ground in synchronous and asynchronous communication. It would be useful to investigate how technological affordances can mediate and/or foster the "intersubjectivity meaning-making" process (Suthers 2006, p. 321). Where there is intersubjectivity, there is a shared understanding: an agreement between people on what is being discussed and worked on. Extended research is needed on scripting collaboration in technology-enhanced learning environments to enhance the grounding process in two areas: (1) how technology could support the inquiry process by enabling students to annotate new information and share new insights; and (2) how technology could mediate the grounding process by enabling students to co-construct knowledge in synchronous and asynchronous collaboration. Secondly, future research may need to examine how individuals and groups of individuals interact with the physical environment in outdoor inquiry learning and how does the sequencing of individual, pair work, and small group collaboration shapes individual thinking-processes and grounding process with learning peers during interaction. On the same note, learning across contexts, i.e., from the classroom to the field and back to the classroom may also imply that the change of learning contexts might shape the individual and the collaborative learning space differently. The integration of the individual into the collaborative learning space in an outdoor learning setting may require more research attention. Thirdly, the wide-ranging domains and learning settings might witness very diverse and/or contrasting effects of differently sequenced classroom scripts on the collaborative learning process. As an extended research on our current findings, we also aim to investigate the effect of embedding an individual phase prior to collaboration in interdisciplinary collaborative concept mapping.

In this study, we gave focus to the grounding processes of small group face-to-face collaboration in two differently sequenced classroom scripts. We provided some initial insights into how the orchestration of classroom activities at different social levels might invoke cognitive processes that could help facilitate the integration of individual work into the collaborative space to enhance the grounding process in collaborative inquiry. Procuring and maintaining common ground could determine the quality of collaborative learning processes and the emerging cognitive products.

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