Effects of Differently Sequenced Classroom Scripts on Transformative and Regulative Processes in Inquiry Learning

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God moves in a mysterious way

Judge not the Lord by feeble sense,
But trust Him for His grace;
Behind a frowning providence,
HE hides a smiling face.

Kurzzusammenfassung

Kooperatives Forschendes Lernen hat sich empirisch als ein effektiver Instruktionsansatz für die Förderung des naturwissenschaftlichen Denkens bewährt. Obwohl Forschung zur Orchestrierung von Sozialformen im Unterricht zeigt, dass diese einen wichtigen Einfluss auf die Qualität von Lernprozessen, wie Kommunikations- und Interaktionsprozessen, und damit auf die Lernergebnisse von Gruppe und einzelnen Lernenden hat, wurde im Bereich des Forschenden Lernens die Verteilung und Abfolge von individuellen und kooperativen Lernaktivitäten bislang jedoch kaum untersucht. Basierend auf Erkenntnissen zu Scaffolding, Fading, Productive Failure und dem ICAP-Rahmenmodell wird in der vorliegenden Arbeit der Einfluss zweier Unterrichtsskripts auf die transformativen und regulativen Prozesse des forschenden Lernens bei Individuen und Gruppen untersucht. Das eine Unterrichtsskript sieht die Abfolge „Plenum-Kleingruppe-Individuum“ vor (PKI-Skript), das andere wechselt vom Plenum über die individuelle Ebene zur Kleingruppenebene (PIK-Skript). Transformationsprozesse beziehen sich dabei auf wissensgenerierende Prozesse, während regulative Prozesse meta-kognitive Prozesse darstellen. Deskriptiv zeigten sich unterschieden zwischen den beiden Bedingungen: Lernende mit dem PKI-Skript zeigten mehr und intensivere individuelle transformative Prozesse, z.B. während bei der Datenauswertung und beim wissenschaftlichen Schlussfolgern. Lernende mit dem PIK-Skript zeigten hingegen mehr transformative und regulative Prozessen auf der Gruppenebene. Lernende, die mit diesem Skript arbeiteten, zeigten mehr und intensivere Grounding-Aktivitäten, die das gemeinsame Verständnis und das Entstehen eines Common Ground förderten. Dementsprechend zeigten sich hier auch häufiger intensivere transformative Prozesse auf der Gruppenebene.

Abstract

Collaborative inquiry learning has been empirically proven to be an effective instructional approach to foster students' scientific literacy. However, there is little research on the coordination of individual and collaborative activities during inquiry learning which could shape the quality of communication and interaction, and consequentially, individual and group learning outcomes. Research has indicated that classroom orchestration (i.e., distribution and sequencing of activities) could have profound effect on learning processes and outcomes. Premised on theories of scaffolding, fading, productive failure and the ICAP (interactive, constructive, active and passive) framework on different activity types, this study investigates the effects of two differently sequenced classroom scripts on the individual and group transformative and regulative processes in inquiry learning. Transformative processes refers to processes that yield knowledge and regulative processes are meta-cognitive processes. Descriptive statistics suggest that the Plenary-Small Group-Individual (PSI) script transition facilitated better individual engagement in transformative processes such as generating of evidence and the drawing of conclusions, whereas the Plenary-Individual-Small Group (PIS) script condition fostered better transformative and regulative processes for the group. Establishing shared understanding and forging common grounds through grounding and high-level grounding was more prevalent in this script condition, which also accounted for more occurrences of high-level transformative processes at the group level.

Deutsche Zusammenfassung

Kooperatives Forschendes Lernen hat sich empirisch als ein effektiver Instruktionsansatz für die Förderung des naturwissenschaftlichen Denkens bewährt. Obwohl Forschung zur Orchestrierung von Sozialformen im Unterricht zeigt, dass diese einen wichtigen Einfluss auf die Qualität von Lernprozessen, wie Kommunikations- und Interaktionsprozessen, und damit auf die Lernergebnisse von Gruppe und einzelnen Lernenden hat, wurde im Bereich des Forschenden Lernens die Verteilung und Abfolge von individuellen und kooperativen Lernaktivitäten bislang jedoch kaum untersucht.

Die vorliegende Arbeit beginnt mit einer Diskussion des Forschenden Lernens und Kooperativen Forschenden Lernens als Instruktionsansatz, der den Erwerb von Fähigkeiten zum wissenschaftlichen Denken fördert. Das Forschende Lernen ist eine Form des Entdeckenden Lernens. Hier nimmt der Schüler eine aktive Rolle ein und übernimmt die Rolle eines Wissenschaftlers, indem er Hypothesen aufstellt, Daten auswertet und wissenschaftliche Erklärungen ableitet. Anschließend wird darauf eingegangen, wie durch Forschendes Lernens authentische Erfahrungen mit Naturwissenschaften sowohl innerhalb als auch außerhalb des Klassenszimmers gefördert werden können, um bei Schülern das Verständnis für wissenschaftliche Konzepte zu erhöhen. Daran anschließend wird geklärt, wie durch Integration kooperativer Lernelemente in das Forschende Lernen der Erwerb naturwissenschaftlicher Konzepte und das Verständnis von Wissenschaft durch gemeinsame Wissenskonstruktion und gemeinsames wissenschaftliches Denken gefördert werden kann. Danach werden die transformativen und regulativen Prozesse des Forschenden Lernens diskutiert. Schließlich werden die kognitiven, metakognitiven und sozio-kognitiven Herausforderungen des Forschenden und des Kooperativen Forschenden Lernens dargelegt.

In Kapitel 3 wird die Orchestrierung des Forschenden Lernens durch Unterrichtsskripts diskutiert. Es geht es um die grundlegende Frage, wie Lernaktivitäten auf den verschiedenen sozialen Ebenen (Plenum, Kleingruppe, Individuum) so zusammengestellt werden können, dass Kooperatives Lernen so in das Forschende Lernen integriert werden kann, dass förderliche Lernergebnisse sowohl auf der individuellen als auch auf der Gruppenebene entstehen. Dabei werden verschieden theoretische Ansätze zu Scaffolding, Fading, Produktive Failure und das ICAP-Modell (Interaktiv, Konstruktiv, Aktiv, Passiv) herangezogen. Anschließend werden zwei mögliche Unterrichtsskripts erklärt: Das Skript Plenum-Kleingruppe-Individuum (PKI-Skript) und das Plenum-

Individuum-Kleingruppe-Skript (PIK-Skript). Das PKI-Skript folgt theoretisch dem Prinzip des Fadings von Scaffolds, hier grob gesagt die Verringerung der sozialen Unterstützung. Das PIK-Skript baut demgegenüber auf der Theorie des Produktive Failure auf. Abgeleitet aus den theoretischen Überlegungen wird die Hauptfragestellung der Arbeit vorgestellt: Welche Auswirkungen haben die verschiedenen Unterrichtsskripte (PKI und PIK) auf die Transformations- und Regulationsprozessen auf der Individuums- und Gruppenebene, sowie auf die Qualität dieser Prozesse beim Kooperativen Forschenden Lernen?

Um diese Fragen zu beantworten, werden sowohl quantitative als auch qualitative Methoden herangezogen. Es wurde eine quasiexperimentelle Feldstudie mit zwei Experimentalgruppen durchgeführt (PKI-Skript versuch PIK-Skript). Vier Schulklassen (6. Und 9. Klasse) von zwei internationalen Schulen mit insgesamt 61 Schülern, davon 43 männlich und 18 weiblich, nahmen an der Studie teil. Innerhalb jeder Klasse wurde ein Teil der Schüler jeder der beiden Experimentalgruppen zugeordnet. 29 Schüler in zehn Gruppen wurden der PKI-Bedingung zugeordnet und 32 Schüler in ebenfalls zehn Gruppen wurden der PIK-Bedingung zugeordnet. Jede Gruppe setzte sich aus drei bis vier Schülern zusammen. Die Schüler bearbeiteten Lerneinheit zu den Themen Photosynthese und Zellatmung, die basierende auf dem Web-based Inquiry Science Environment (WISE) entwickelt wurden. Die Studie umfasste sowohl Lernaktivitäten im Klassenzimmer als auch Lernaktivitäten während einer Exkursion in den Botanischen Garten, die sich in drei Phasen teilten (vor der Exkursion, Exkursion, nach der Exkursion). Die Lerneinheit erstreckte sich über neun Unterrichtstunden von je 45 Minuten. Die Lerneinheit „Photosynthese und Zellatmung“ begann mit einer einführenden Stunde, in der die Themen Photosynthese und Zellatmung eingeführt wurden. Daran schloss eine Sitzung an, in der der Lehrer im Plenum den Prozess des Forschenden Lernens an einem Beispiel vormachte, indem er die transformativen Prozesse der Orientierung, des Fragenstellens, des Aufstellens und Testens von Hypothesen, das Sammeln und Auswerten von Daten und das Ziehen von Schlussfolgerungen zeigte. Schüler in der PIK-Skript Bedingung bearbeiteten anschließend individuell eine weitere Aufgabe und im dritten Schritt eine weitere Aufgabe in der Kleingruppe. In der Bedingung mit PKI-Skript bearbeiten die Schüler hingegen nach der Plenumssitzung eine Aufgabe in der Kleingruppe und lösten die letzte Aufgabe individuell.

Die Ergebnisse der Studie weisen darauf hin, dass die zwei Unterrichtsskripts sich sowohl unterschiedlich auf Individuums- und Gruppenebene auswirken als auch unterschiedliche Auswirkungen auf die Transformations- und Regulativprozesse und deren Qualität (High und Low-Level) haben. Die beiden Skripts wirken sich insbesondere auf die transformativen Prozesse, sowie High und Low-Level-Transformationsprozesse während und nach der Exkursion aus, insbesondere bei der Datenanalyse und den wissenschaftlichen Schlussfolgerungen. Darüberhinaus hat das Plenum-Kleingruppe-Individuum-Skript (PKI-Skript) ein besseres individuelles Engagement bei transformativen Prozessen ermöglicht, während das Plenum-Individuum-Kleingruppe-Skript (PIK-Skript). bessere transformative und regulative Prozesse für die Gruppe und regulative Prozesse für das Individuum fördert.

Insgesamt gibt diese Dissertation Hinweise darauf, dass Lernende mit dem PKI-Skript mehr und intensivere individuelle transformative Prozesse zeigten, z.B. während bei der Datenauswertung und beim wissenschaftlichen Schlussfolgern. Lernende mit dem PIK-Skript zeigten hingegen mehr transformative und regulative Prozessen auf der Gruppenebene. Lernende, die mit diesem Skript arbeiteten, zeigten mehr und intensivere Grounding-Aktivitäten, die das gemeinsame Verständnis und das Entstehen eines Common Ground förderten. Dementsprechend zeigten sich hier auch häufiger intensivere transformative Prozesse auf der Gruppenebene.

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1 Problem Statement

Teaching science through inquiry has long been established as an instructional approach to develop scientific literacy in students. Inquiry-based learning can be traced as far back to Socrates and his preoccupations about questioning as a method to acquire knowledge. In a similar vein, advocates of inquiry learning since the 1960s have long contended that science education should be taught as an *enquiry into enquiry* (Schwab & Brandwein, 1962) and students should be *doing science* (Barab & Hay, 2001) through an active and critical engagement in scientific discourse to understand the nature of science (DeBoer, 2000). Scientific literacy should transcend reading and understanding science texts to doing science to acquire and construct scientific knowledge.

Inquiry learning has been conceived of as scientific discovery; exploratory in nature where learners undertake inquiry activities such as hypothesis generation, experimentation and evaluation to form scientific conclusions (De Jong & Njoo, 1992). Further, De Jong and Van Joolingen (1998) identify two core processes in inquiry learning: transformative processes which yield knowledge and regulative processes which manage the transformative processes. Inquiry learning is therefore, a highly self-directed learning process where one engages in core regulative processes such as planing, monitoring and evaluation to manage the transformative processes of hypothesis generation and testing, evaluation and drawing conclusions. Hence, what essentially distinguishes inquiry learning from other forms of learning is that learning is intentional in the inquiry process where students diagnose problems, determine alternative solutions, develop investigation plans, debate with peers and develop scientific explanations (Linn, Clark, & Slotta, 2003). On the same note, discovery learning through collaborative inquiry has witnessed increasing empirical research in the last five decades (e.g., De Jong & Van Joolingen 1998; Gilgers & De Jong 2005; Saab, Van Joolingen, & Van Hout-Wolters 2007; Van Joolingen, 2000). Collaborative inquiry enhances the discovery process where collective articulation makes the scientific processes explicit, thus yielding more diverse generation of ideas and richer co-construction of scientific knowledge. A more pronounced conviction about collaborative inquiry stems from socio-cognitive theories where socio-cognitive conflicts is said to foster cognitive growth (Tudge & Rogoff, 1999) and such forms of conflicts during peer interaction often occur in the inquiry process as well (Lethinen, 2003).

Importantly, argumentative practice forms the foundational activity of scientists and the scientific enterprise (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Lawson, 2010; Osborne, 2010; Osborne, Enduran, & Simon, 2004). Collaborative inquiry, through exploration and explanation of scientific issues enhances students' understanding of science and how scientists derive scientific conclusions.

Notwithstanding the benefits of enforcing collaboration in inquiry, collaborative inquiry imposes high degree of cognitive, metacognitive and socio-cognitive demands. Prior research has evidenced that inquiry learning needs to be scaffolded to ensure learning gains for both the individual and collaborative inquiry learning (e.g., Bell, Urhane, Schanze, & Ploetzner, 2010; De Jong & Van Joolingen, 1998; Hakkarainen & Sintonen, 2002; Sandoval & Reiser, 2004). Without instructional scaffolds or support, the knowledge inferences processes in inquiry learning can be overwhelmingly challenging for the students. Apart from the issues of cognitive scaffolds, research has shown that learners may not know how to support one another in the collaboration process (Bell et al., 2010; Cohen, 1994; Saab et al., 2007). This could imply more implicit problems of coordination, communication and interaction which instructional scaffolds per se to support the transformative and regulative processes may not suffice. Kaptelinin and Cole (1997) spoke of a *pre-and-post intersubjectivity* activity to coordinate individual and collective activites which primarily aims to help the learners coordinate two different views: the individual and the collective view. In like manner, Rummel and Spada's (2005) study suggests that alotting sufficient individual time prior to joint work, has significant bearings on the integration of individuals into the joint work space during collaborative learning. It affords better coordination, communication and interaction.

Collaborative learning is a situation, not an instructional method where the desired patterns of interaction could only occur by designing the learning situation (Dillenbourg, 1999). Classroom orchestration (Dillenbourg, 2013) by means of classroom scripts aims to sequence and structure tasks to improve learning (Dillenbourg & Jermann, 2007). Research on classroom scripts examines how the distribution and sequencing of learning activities over the various social planes of a classroom could enhance collaborative inquiry learning (Kollar, Wecker, Langer, & Fischer, 2011) or help students in individual knowledge acquisition (Wecker & Fischer, 2011). However, there is little research on the coordination of individual and collaborative activities during inquiry learning, i.e., if collaboration should precede or succeed individual inquiry activities to enhance learning effectiveness for both the individual, as well as the collective entity. It is therefore the aim of this study to leverage the affordances of classroom scripts to support and enhance both the individual and collaborative inquiry learning process. Essentially, it investigates how classroom activities at the individual, small group or plenary level could be sequenced and distributed across these three social planes to embed collaboration during the inquiry learning process which could bring about the desired learning outcomes for the individual, as well as the collective unit. Theory of scaffolding in cognitive apprenticeship (Collins, Brown, & Newmann, 1989) foregrounds interaction and collaboration as an important scaffold to enable individuals to acquire target and complex skills through observation of experts, teachers and undertaking similar tasks with peers for support and feedback. Pea (2004) contends that a critical component of scaffolding is the platform for fading to afford individuals greater agency to enact and execute their own task. On the other end of the spectrum, the idea of productive failure (Kapur, 2012) advocates the delay of *direct instruction* (Van Lehn, Siler, Murray, Yamauchi, & Baggett, 2003), *delayed feedback* (Mathan & Koedinger, 2003) and *delayed structure* (Kapur, 2008) to foster better and more successful appropriation of target skills. To this end, Kapur and Bielaczyc (2012) proposed a 'generation and exploration' phase and a 'consolidation' phase as interdependent mechanism to realise productive failure where the latter enables students to compare, contrast and consolidate the diverse ideas generated during the exploration phase, working towards the canonical solution. These two theoretical frameworks resonate with Chi's (2009) works on the effects of interactive, constructive, active and passive (ICAP) activity types on learning processes and outcomes. Theory of scaffolding and fading promotes the transition of interactive activity to active and constructive activity types. Conversely, the productive failure argument sees active and constructive activities preceeding interactive activities as instrumental to foster better learning outcomes.

Against the theoretical background, two possible classroom scripts to support individual and collaborative inquiry learning could ensue: plenary-small group-individual (PSI) and plenary-individual-small group (PIS). Both script transitions commence with the plenary session for two reasons: one to provide *apprenticeship* in a complex process such as inquiry learning (Collins et al., 1989) and two, to provide a *baseline learning context*; one of the design elements for conditions of productive failure (Kapur & Rummel, 2012). Thus, the main research question of this dissertation: What are the effects of differently sequenced classroom scripts on individual and small group transformative and regulative processes in collaborative inquiry learning?

In **chapter 2**, the theoretical perspectives on inquiry learning as an instructional approach to foster the development of scientific literacy will be discussed. Here, the value of creating 'authentic' science experience by promoting in-and-out of the classroom inquiry learning activities to foster students' understanding of scientific concepts will be surfaced. Next, employing collaborative learning in the inquiry process (Okada & Simon, 1997, De Jong, 2006) to enhance the acquisition of scientific concepts and understanding the nature of science through knowledge co-construction and collective scientific reasoning will be discussed. The second part of the chapter will explain the two core processes: transformative and regulative (Njoo & De Jong, 1993) which characterize the inquiry learning process. Finally, the potential and challenges in inquiry learning and collaborative inquiry will be discussed with reference to the transformative and regulative processes at three social levels (i.e., self-, co- and shared).

Chapter 3 introduces classroom orchestration with classroom scripts (Dillenbourg & Jermann, 2007) as instructional scaffolds to distribute and sequence learning activities across the different social planes to enhance learning effectiveness. Here, the potentials and possible challenges of the activities associated with each of the three main social planes (i.e., plenary, small group, individual) will be surfaced. Next, the distribution and sequencing of the classroom activities across the three different social planes will be discussed in the light of three main theoretical frameworks: theory of *fading* (Collins et al., 1989), *productive failure* (Kapur, 2012) and the *ICAP* framework (Chi, 2009) on the hierarchical organisation of activities and their learning effectiveness. Thereafter, two possible differently sequenced classroom scripts to embed collaboration in the inquiry learning process will be presented and discussed. One classroom script moves from the plenary to the small group to the individual level (PSI) and the other moves from the plenary to the individual to the small group level (PIS).

Chapter 4 outlines the theoretical framework on the processes, the outcomes and the facilitation of the two differently sequenced classroom scripts. The research questions regarding transformative and regulative processes, as well as learning outcomes for the individual and the small group level will be formulated.

Chapter 5 presents the method of the study: how it was carried out and how the variables were operationalized. The learning environment, the classroom and field trip activities together with the inquiry tasks of the study will also be featured and explained.

Chapter 6 provides an overview of the results. First, the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the transformative and regulative processes at the individual and the small group level will be presented. Next, the effects on individual and small group learning outcomes will be surfaced. Finally, one case study for each of the two experimental conditions will be presented.

Chapter 7 will discuss, interpret, and compare the findings of the empirical study to prior findings. Here, the case studies will also be reviewed and discussed. The findings of the study will then be put into perspective concerning the possible limitations of this study. Finally, implications for future research and practice on embedding collaboration in inquiry learning to enhance learning effectiveness for both the individual and the group will be outlined.

2 Inquiry Learning in Science Education

Inquiry learning has been increasingly acclaimed as an effective educational approach to help students attain scientific literacy. This growing recognition is largely associated with the contemporary definition of scientific literacy and the purpose of promoting it. In the past five decades, scientific literacy has meant different meanings to different interest groups. Laugksch's (2000) works on the conceptual overview of scientific literacy provides a functional sense of scientific literacy where she defines a scientifically literate individual as someone who is able to use science to perform a function in the society. Other advocates of scientific literacy align their theoretical arguments with the standards of the National Research Council (NRC) (1996) where literacy in science should be expanded to encompass the capacity to engage in scientific discourse; to initiate and evaluate arguments (DeBoer, 2000; Norris & Philips, 2002). Scientific literacy is, thus, more than the ability to read, comprehend, interpret, analyse and critique scientific texts, it means possessing the capacity to make interpretive connections of the pieces of scientific information. This new understanding of what scientific literacy embodies, also saw emerging science education reforms since the 1990s. Transformation in instructional methodologies has since sought to involve students more actively in learning science: from a passive consumer of scientific texts to an active participant in constructing scientific knowledge. Researchers and educators alike have come to recognize inquiry learning in science education as one of the most effective means to help students attain scientific literacy.

This chapter begins with a discussion on scientific literacy: what it connotes and why it is important to make it an educational goal. Next, it foregrounds inquiry learning as an instructional approach to facilitate scientific literacy and to enhance students' understanding of scientific concepts, the nature of science and the interconnectedness between scientific theories. To foster the authenticity of the inquiry process by engaging students in doing science, in-and-out of the classroom inquiry learning activities will be presented. Thereafter, collaboration as a core element to enhance the inquiry learning process will be discussed. Finally, the processes and outcomes of inquiry learning will be discussed, followed by the challenges of inquiry learning and embedding collaboration in inquiry learning.

2.1 Scientific Literacy as Educational Goal

The term *scientific literacy* has been in use since the 1950s, however, agreeing on one and only definition of scientific literacy remains challenging. The changing definitions of scientific literacy also explain the progressive reforms in science education and the different possible paths to attain scientific literacy. Amid the varying conceptions of scientific literacy, the 'functional view' (DeBoer, 2000; Laugksch, 2000) and the 'fundamental sense' (Norris & Philips, 2002) of literacy in science provide a baseline definition of what scientific literacy embodies. The functional view of scientific literacy conceives of scientific literacy as what the general public should know about science for effective daily transactions with respect to the natural world (DeBoer, 2000; Laugksch, 2000). That is, one possesses the capacity to deal with science issues in the regular everyday life and applications. On the other hand, the fundamental sense of scientific literacy foregrounds reading, comprehending, interpreting, analyzing and critiquing scientific texts (Norris & Philips, 2002). Scientific literacy, however, in its fundamental sense is not unique from other forms of literacy, save for its scientific text. The fundamental sense of scientific literacy should entail the capacity to interpret the substantive content and infer the interconnections between specific pieces of scientific information (Norris & Phillips, 2002). Here, scientific literacy is more than the ability to read scientific text: it encompasses the ability to interpret and to reason about scientific information; accentuating a constructivist approach to gain scientific literacy.

Both the functional view and the fundamental sense of scientific literacy are equally important for the general public, as well as the school going population. Laugksch (2000) posits that attaining scientific literacy is important for two perspectives: the macro and micro. The macro view sees a connection between scientific literacy and the general well-being of the economy and the micro view focuses on the scientific-literate individuals who are able to be actively and effectively engaged in the economic front and in the society they live in. On the same note, Laugksch (2000) calls scientific literacy a 'socially defined concept' for its definition is contingent on the context in which it operates. In a nutshell, the different conceptions reflect the agenda of the corresponding different interest groups. The science education community forms the first interest group whose primary concern is about the relationship between formal science education and scientific literacy. In a similar vein, DeBoer (2000) argued for a boarder approach to scientific literacy so that schools, teachers and students are able to set and pursue goals that are relevant to their specific situations. Scientific literacy has since been continuously pursued as an educational goal. What could possibly define the educational practices would be the definition of scientific literacy one adopts.

In the past five decades, there appears to be a paradigm shift towards Norris and Phillip's (2002) notion of a fundamental and derived sense of scientific literacy. This is apparent in science educational reforms which epitomizes the active engagement of students in science learning. In the 1990s, there was increasing need to improve scientific literacy on grounds of a sufficient level of scientific literacy (Duit & Treagust, 1998). The National Research Council (NRC) (1996; 2000) advocates instructional approaches in science education that enable students to develop scientific understanding through a continual process of theory building, criticism, and refinement by pursuing their own scientific questions, developing hypotheses, and undertaking data analysis activities. The conception of scientific literacy has evolved to encompass the capacity to identify questions and to construct evidence-based conclusions, which are deemed instrumental in understanding how the natural world functions, and how human actions and decisions could shape the natural world (Duit & Treagust, 1998). This implies that students need to be active agents in science learning and be engaged in critical scientific discourse. It also exemplifies an inquiry approach to learning the nature of science where students can develop critical and reflection skills. Infact as early as the 1960s, Schwab and Brandwein (1962) advocated that science should be taught as an 'enquiry into enquiry'. To harness critical inquiry skills in science learning, some educational researchers advocated transforming classrooms into learning communities to engage students in scientific research (e.g., Brown & Campione, 1996). Direct participation in scientific work is believed to be able to support students' science learning and help them attain scientific literacy goals (Bell, Bricker, Tzou, Lee, & Van Horne, 2012). Scientific literacy has also given greater priority to leveraging scientific knowledge to construct evidence-based conclusions and the ability to engage in scientific reasoning defines a scientifically literate student (Brown, Furtak, Timms, Nagashima, & Wilson, 2010). In a similar vein, Lawson (2010) contends that one of the critical components of scientific literacy is to enculturate students into scientific reasoning, argumentation and discovery, which will enable them to understand how scientists concur at scientific conclusions.

Science education has witnessed major transformations in its instructional methods to foster scientific literacy: from frontal loading of science information in a traditional classroom to active engagement in authentic scientific inquiry. The conception of scientific literacy has since evolved from a baseline definition of acquiring scientific knowledge by *reading* science to *doing* science. Pursuing scientific literacy remains an important educational goal.

Domain knowledge and inquiry skills

To attain scientific literacy in its fundamental sense, students must develop both cognitive and metacognitive abilities to critique scientific texts, examine its sources, its limitations and evaluate the claims and the evidences (Norris & Philips, 2002). Akin to Perkins' (1993) notion of higher-order domain knowledge (where he differentiates it from the regular content-level knowledge), this entails discipline-specific problem solving strategies, justification, explanation and inquiry. He contends that regular content knowledge only requires students to know facts and procedures, however, higher-order aspects of a domain demand of students to weigh choices, explore consequences, make decisions and determine courses of action in the *executive function*. Absence of the higher-order structure in a domain would reduce the execution funtion to sheer retrieval and reproduction of content knowledge. In like manner, De Jong and Ferguson-Hessler (1996) spoke of conceptual and procedural knowledge: the former represents static knowledge about domain-specific facts, concepts and principles while the latter refers to applicational knowledge to effectively identify, analyse problems and administer solutions. As Perkins (1993) puts forth, "it is the higher-order aspects of a domain that infuse domain-related activities with significance" (p. 101). The path to scientific literacy would imply that students need to acquire higher-order domain knowledge and skills in order to advance beyond merely comprehending scientific text. This means that students would need to assume greater agency in active participation in the learning process.

The emergent focus of scientific literacy on active participation in science learning also suggests higher competencies and skills. Attaining scientific literacy has come to assume a very active and constructive undertaking on the part of the learners to direct one's own learning in conducting investigations and making judgment. Conceiving of scientific literacy as possessing the capacity to identify scientific questions and to construct evidence-based explanations would require specific competencies to manage these scientific processes. Duit and Treagust (1998) call it the *cross-cutting competencies* such as self-regulated learning, ability to solve problems and communication and co-operation.

Students need to be able to reflect on their inquiry experiences, evidences gathered, construct scientific explanation and communicate this information. This process to achieve literacy in science has become inquiry in nature and "the process is driven by an explicit intention to find out" (Kuhn & Pease, 2008, p. 4). It means students would need to get into a scientific way of thinking. Here, Kuhn, Black, Keselman and Kaplan (2000) proposed a hierarchy of cognitive skills and competencies, beginning with fundamental skills of posing questions and representing data, to more advance skills of constructing mental models representing multivariable causality. Further, conducting scientific investigation also encompasses sub-skill sets such as conducting systematic observation, making accurate measurements, and identifying and controlling variables (Dean & Kuhn, 2007).

Apart from acquiring scientific understanding of the world around them through scientific investigations and inquiry, one of the goals in scientific literacy is to raise awareness in students the importance of understanding their own and other's thinking on scientific issues and questions. Students would need a combination of metacognitive and socio-cognitive skills in collaborative negotiation and construction of meaning, as well as being involved in scientific argumentation and reasoning. Zimmerman (2000) conceived of scientific reasoning skills as content domain skills. Pea (1993) contends that conceptual change and acquisition of scientific concepts occurs through meaning negotation and appropriation by participating in a community of science practice. In a similar vein, Sandoval's (2003) works on epistemic discourse around artifacts, underscores the significance of constructing and defending explanations in scientifc practice. This imply that students need to possess the reasoning skills (Johnson & Lawson, 1998) to be meaningfully engaged in scientific discourse not only, to communicate scientific ideas, but also to collaboratively engage in scientific reasoning in a constructive manner.

In sum, achieving scientific literacy in its current definition demands higher cognitive and meta-cognitive knowledge and skills to embark on a highly self-directed journey of investigation and inquiry. It has also extended to encompass socio-cognitive skills where leveraging the expertise of members of the learning community in scientific undertaking is instrumental in attaining scientific literacy. A general concern in teaching science would be to prepare students for scientific practices to attain scientific literacy.

2.2 Facilitating Scientific Literacy through Inquiry Learning

Fostering the conceptual understanding of science concepts, the nature of science and scientific inquiry remain the perennial instructional objectives of science education for more than five decades. It is commonly advocated by science mentors, educators and researchers that inquiry learning can foster the development of scientific literacy by enhancing students' understandings of science content, the scientific inquiry process and the nature of science. Designing science learning environments accentuates the importance of creating a learning situation where students are able to *talk* rather than *hear* science where students are involved in scientific activities that encourage them to discuss, to analyse and to intepret (Pea, 1993). Teaching inquiry and teaching science as inquiry has thus gained increasing emphasis in the science teaching community. Inquiry learning has been long regarded by many as the hallmark of science education and is increasingly lauded as an effective channel to facilitate scientific literacy.

In inquiry learning, learners are featured as active agents in the knowledge acquisition process. Inquiry learning provides students an essential platform to generate hypothesis, to experiment and to draw conclusions; what De Jong (2006) conceives of as '*learn science by doing science'* (emphasis added) as students are engaged in knowledge inferences processes. Essentially, learning science through scientific inquiry help students to learn how to think like scientists, (Edelson, Gordin, & Pea, 1999), do real science (De Jong, 2006) and engage in scientific discourse (Duschl & Grandy, 2008). These intentions mirror the current definition of scientific literacy to develop in students the capacity to learn and think about science in a scientific way. The focus on inquiry learning stems from its conviction that science learning is about applying scientific concepts and methods, developing theories, models and scientific explanations, which form the core products of scientific inquiry (Sandoval, 2003).

Inquiry learning fosters the much needed scientific discourse to achieve scientific literacy. The epistemic products in scientific inquiry provide such a platform for scientific discourse which is pivotal to deepen both the conceptual and epistemological understanding (Sandoval, 2003). Science education should envision developing students' capabilities to engage in scientific arguments (Pea, 1993). Scientific discourse is an important means to widen and deepen students' understanding of science and the nature of science. Inquiry learning harnesses students' engagement in such discourses: the process of articulating, affirming and arguing enhances students' ability to coordinate new knowledge with existing understanding.

2.2.1 Inquiry Learning as Scientific Discovery

The underlying premises of inquiry learning can be traced to constructivist theories of discovery learning where learners are actively engaged in constructing their own knowledge (Driver et al., 2000; Mayer, 2004; Osborne, 1996; Palincsar, 1998). De Jong and Van Joolingen (1998) liken inquiry learning to scientific discovery by reason that it is highly self-directed, and therefore, a very specific form of constructivistic learning. Constructivist conceives of knowledge and learning as dependent of context, person and social situation (Jonassen, 1991). In discovery learning, students are encouraged to become active agents in their own learning process. The main goal of a discovery learning activity is to construct knowledge about a domain by conducting experiments and inferring properties of the domain from the results of those experiments (Van Joolingen, 2000). It requires students to take an active role in the knowledge acquisition process (De Jong & Van Joolingen, 1998) and in discovering concepts and procedures (Tuovinen & Sweller, 1999). Contrary to direct instruction, students are to discover the properties of a domain through experimentation and interpretation (Giljers & De Jong, 2005) and through undertaking inquiry activities in scientific investigations (Dean & Kuhn, 2007; klahr & Nigam, 2004).

Theories on scientific discovery learning usually leverages on theories of scientific discovery (Klahr & Dunbar, 1988) where the discovery of new scientific concepts can be attributed to a sequential and systemic set of scientific practices from planning an experiment, the execution to the evaluation of data and the development of hypothesis (De Jong & Van Joolingen, 1998). Klahr and Dunbar's works (1988) give considerable focus to the discovery processes where they surface the notion of a dual space: *a hypothesis and a experiment space* in scientific discovery. The hypothesis space involves formulating and evaluation of theory and the experiment phase involves experiment design and observation. The latter works of Dunbar (1993) on *concept discovery in a scientific domain* foregrounds the cognitive processes and mechanisms underlying scientific reasoning which includes the generation of hypothesis, strategies for conducting experiments and the evaluation of evidences. Here, learners explore the natural or material world, ask questions, make new discoveries and test those discoveries to develop new knowledge. It is also important to distinguish scientific discovery learning from pure discovery learning, where the latter provides almost no forms of guided instructional support (Dean & Kuhn, 2007; Tuovinen & Sweller, 1999). De Jong (2006) defines inquiry learning as guided discovery learning where students are provided structural support through the phases of inquiry activities from hypothesis generation to evaluating data and making scientific conclusions. Students perform steps of inquiry similar to that of a scientist, and thereby, acquire knowledge of the scientific processes. In so doing, learners adopt a scientific approach and make their own discoveries; they create new knowledge by activating and restructuring knowledge schemata.

Inquiry learning is also likened to discovery learning where learners discover scientific concepts and knowledge that are usually obtained through traditional direct instruction. Inquiry learning fosters the development of cognitive skills (Kuhn et al., 2000) as it requires students to become active agents of their own learning; assuming initiative in the learning process (De Jong, 2006). However, the approach to inquiry learning exemplifies elements of cognitive apprenticeship (Collins et al., 1989) or science apprenticeship (Bell, Blair, Crawford, & Lederman, 2003) where students are involved in reasoning and discursive practices similar to that of a scientist, but may not undertake the exact activities of real scientists in the professional field (Reiser et al., 2001). The apprenticeship approach to learning science encapsulates important scientific inquiry practices such as devising researchable scientific questions, design experiments and develop compelling scientific arguments (Sandoval & Reiser, 2004). Inquiry activities should seek to promote active engagement and greater agency of the students in this scientific discovery process.

Advocates of inquiry learning have contended that activities should also contain an element of authenticity to enhance learning effectiveness in the scientific inquiry process (Chinn & Hmelo-Silver, 2002). Authentic inquiry promotes active reflection on problems, as well as construction of explicit conceptual understanding of the problem. Authentic inquiry promotes metacognition and self-regulation because students are better able to monitor their learning and evaluate errors in their thinking or gaps in their conceptual understanding (Schraw, Crippen, & Hartley, 2006). The value of authenticity in undertaking scientific inquiry is gaining significance amongst science educators and researchers (Barab & Hay, 2001; De Jong 2006; De Jong & Van Joolingen, 1998; Zimmerman & Bell, 2008). Here, it is noteworthy that the idea of authenticity in scientific inquiry seems to operate on a continuum: from everyday science-related activities to doing science alongside more knowledgeable scientists. Zimmerman and Bell (2008) traces the development of scientific practices in children engaging in out-of-the classroom science inquiry activities. For example, one student experimented with the different habitats she had designed for her hamsters and was able to engage in scientific observation and making predictions about the general trend of her hamsters. On the other end of spectrum, Barab and Hay's (2001) idea of authenticity means engaging students in doing science and they define authenticity as having 'the quality of having correspondence to the world of scientists'. Their empirical research on Science Apprenticeship Camp (SAC) showed that 'doing science and learning science' is intricately interwoven: participants benefit from engaging in practices alongside the more knowledgeable scientists within a context of practice (Barab & Hay, 2001). In both studies mentioned above, students develop scientific practices by being actively engaged in the inquiry process in authentic contexts. On the same note, science educators and researchers could begin with scientific activities in day-to-day context where students are able to identify with, so that they can leverage existing knowledge about scientific practices (Zimmerman & Bell, 2008). Students need to be encouraged to see the connections in the science they are doing in in and out of the classroom setting to the larger scientific enterprise. Only then will they be able to develop more sophisticated understandings of the abstract and complex nature of science and inquiry (Bell et al., 2003).

The conceptual framework of promoting inquiry learning activities in in and out of the classroom aligns with theories of *situated learning* (Lave, 1993; Lave & Wenger, 1991), *situated cognition* and *apprenticeship learning* (Brown, Collins, & Duguid, 1989; Collins et al., 1989) to create authentic science experiences. In a study on science apprenticeship, students gained significant knowledge about the nature of science, scientific inquiry and the scientific enterprise by doing science with scientists serving as mentors (Bell et al., 2003). The provision of authentic learning environments is instrumental in fostering authenticity in inquiry learning when students undertake steps similar to that of real-world scientists. Science education should seek to 'create an experience of inquiry and interpretation that is inspirationally authentic' so that students are able to deepen their understanding of the constitutive scientific practices from collecting data to communicating scientific findings (Anastopoulou et al., 2012). The situated learning experiences require learners to develop a sense of situational intent and the capacity to leverage on relevant resources specific to that particular learning context. Learning in the authentic outdoor environments also enables students to leverage on the physical affordances of the real-world platform for meaningful knowledge creation and production where 'the process of learning is informed by sense of place' (Lim & Barton, 2006). Situated learning in inquiry learning prevents the occurrence of inert knowledge (Whitehead, 1929) when learners are unable to transfer acquired facts and knowledge in solving real problem situations. Students are not only to do science but to do reflective thinking about their intentions and actions, to foster their understandings about the nature of science and scientific inquiry. Like real scientists, students should study the natural world, make their own observations and propose explanations based on the evidence of their own work. In sum, science inquiry across formal and informal settings (from the classroom to the outdoor) provides students a more realistic experience of science.

2.2.2 Inquiry Learning as Collaborative Discovery

In the last two decades, there is increasingly more empirical research moving from individual discovery to collaborative processes in inquiry learning (e.g., Dunbar, 1993; Duschl & Osborne, 2002; De Jong & Van Joolingen, 1998; Gilgers & De Jong, 2005; Klar & Dunbar, 1988; Saab et al., 2007; Van Joolingen, 2000). There are a number of arguments why collaborative effort versus individual undertaking is effective for inquiry learning. Discovery through collaboration has reportedly enhanced the discovery processes for two critical reasons: one, collective articulation makes the scientific processes explicit which brings about more generation of ideas and richer co-construction of scientific knowledge; two, collaborative reasoning and argumentation fosters the constitutive cognitive processes in scientific inquiry. Collaborative activities provide an opportunity for explicit discussion of scientific concepts and reflection that promotes metacognition and self-regulation (Schraw et al., 2006). Collaborative learning also fosters students' motivation and interest in science where they learn to perform steps of inquiry similar to scientists and that they gain knowledge on scientific processes (Bell et al., 2010).

Okada and Simon's (1997) study on discovery learning found that pairs in collaborative discovery are more likely to explore alternative hypothesis than those in individual discovery situation. Likewise, other related studies on collaborative processes also found that group scientific discovery was able to generate more diverse hypotheses, evidences and justifications (e.g., Dunbar 1993; Gorman, Gorman, Latta, & Cunningham, 1984; Klahr & Dunbar, 1988). For instance, Gorman et al.'s (1984) studies comparing groups and individuals, found that groups were able to falsify hypothesis more effectively than individuals. Okada and Simon (1997) posit that it is the collaborative discussion that impact scientific discovery. Collaborative discovery evidently led to richer co-construction of scientific concepts and understanding. In a similar measure, collaborative inquiry learning enhances the discovery learning process (De Jong, 2005) by making the discovery learning processes explicit through the collective articulation, negotiation of the scientific processes (Saab et al., 2007) and elaboration of their think-processes (Okada & Simon, 1997). Learners, working in a collaborative environment can make the discovery learning processes explicit, which can lead to a positive contribution to these processes. Further, when learners communicate their reasoning in the collaboration process, it creates awareness of the gaps or shortcomings in their think-process (Van Boxtel, Van der Linden, & Kanselaar, 2000). The collaborative environment has afforded learners a platform for deep processing of their thoughts. When learners internalise their thoughts through the process of elaboration such as posing questions and providing explanations, it affords a reorganization of existing knowledge.

Another important element of collaborative discovery is the presence of collective reasoning and argumentation. Advocates of collaborative inquiry attribute the learning effectiveness to the affordances of collaborative reasoning and argumentation in the scientific discourse (Driver et al., 2000; Duschl & Osborne, 2002; Okada & Simon, 1997; Osborne, Enduran, & Simon, 2004). Collaborative argumentation is seen as central to inquiry and science education to improve conceptual knowledge, epistemic understanding and fosters the development of skills and ability of students to engage in intellectual inquiry (Chinn & Clark, 2013). Two prominent theories underscore the potential of collaborative effort in science education: socio-constructivist and socio-cognitive theories. First, socio-constructivistic learning theories posit that knowledge is an emergent product of collaborative effort in search of problem solutions in communities where knowledge is distributed amongst its members (Duit & Treagust, 1998). The construction of scientific knowledge is a complex enterprise, involving both cognitive and social factors for the choices of hypothese and experiments is a consequent of communication, negotiation and consensus with peers in the scientific community (Reiser et al., 2001). Similarly, the provision of collaborative explanatory activities in science inquiry forms a critical platform for successful intellectual behaviour (Okada & Simon, 1997).

Second, socio-cognitive theories on collaborative inquiry and reflective learning conceive of the learning communities as interacting agents, each possessing specific expertise to achieve higher goals (White, Shimoda, & Frederiksen, 1999). Socio-cognitive conflicts arising from peer interaction is said to have enhanced cognitive growth (Bearison, Magzamen, & Filardo, 1986; Tudge & Rogoff, 1999) and socio-cognitive conflicts often occur in the inquiry process as well (Lethinen, 2003). Interesting to note is Piaget's (1926) and Vvgotsky's (1978) theoretical arguments on the role of social interaction: Piaget sees social interaction as giving rise to cognitive conflicts which is crucial for cognitive development and Vvgotsky contends that collaborative peers provides 'zone of proximal development' to each other. Recent works on scientific reasoning and argumentation contend that the argumentative practice forms a core activity of scientists and the scientific enterprise (Driver et al., 2000; Duschl & Osborne, 2002; Lawson, 2010; Osborne, 2010; Osborne et al., 2004; Saab et al., 2007). Saab et al. (2007) found that there is a strong relation between the communication process of argumentation and the discovery process of drawing conclusion. Students were able to evaluate evidences and converge at sound scientific inferences by engaging in scientific argumentations. Bell (2004) contends that 'argumentation and collaborative debate are central features of intellectual inquiry in the natural sciences' for it is beneficial to science learning where there is collective exploration of issues and evidences. Conversation analysis showed that students posed relevant questions, probing questions to each other and integrated out-of-school experiences into the debate as evidences in the collaborative debate activity using a paper-based debate activity to enhance students' participation in a prototypical form of scientific debate. Students are better able to understand how scientists arrive at scientific conclusions when students undergo similar process of reasoning and argumentation (Lawson, 2010).

Collaborative inquiry fosters scientific argumentation which promote an understanding of how scientific knowledge are co-constructed and how scientific theories ensued. Collaborative learning has thus been increasingly acknowledged as a core element of inquiry learning.

2.3 Processes of Inquiry Learning

The active role of the learner is given focus in both individual inquiry learning and collaborative inquiry. In inquiry learning, learners engage in a domain by carrying out experiments within a guided discovery environment undertaking a sequence of inquiry steps to generate hypothesis, conduct experiments and construct domain knowledge (De Jong & Van Joolingen, 1998). In collaborative inquiry, learning becomes a social process, where collective meaning-making and shared knowledge is achieved through negotiation, reasoning and argumentation (Van Joolingen, 2000). However, whether inquiry learning is realized at the individual level or in a collaborative environment, there are specific cognitive skills and strategies peculiar to the inquiry process such as formulating questions, generating hypothesis, accessing and evaluating evidence to construct scientific knowledge and to recognise theoretical connections (Kuhn et al., 2000; Reiser et al., 2001). The core processes involved in inquiry learning are similar to that of discovery learning. Njoo and De Jong (1993) distinguished between transformative and regulative processes in the inquiry learning process: the former refers to cognitive processes that produce knowledge and the latter are meta-cognitive processes necessary to manage the transformative process, such as planning and monitoring. The succeeding sections will discuss the transformative, regulative and socio-cognitive processes in greater details.

2.3.1 Transformative Processes

Knowledge of the inquiry processes is seen as an important skill (Njoo & De Jong, 1993) where it involves the externalization and differentiation of the different processes driving the inquiry process. Transformative processes are cognitive processes relating to all mediating learning activities that effect the internalization of information (De Jong, 2005), in which domain information is transformed into knowledge (De Jong & Njoo, 1992). This includes all transformative processes that promote the generation of information such as orientation, generating hypothesis, hypothesis testing and conclusion (Njoo & De Jong, 1993). However, it is important to note that different domains and disciplines require different approaches. In biology, knowledge claims and theory-building is achieved through observational arguments rather than controlled experiments (Reiser et al., 2001). Hence, for the focus of this research on biology-based inquiry on plant adaptation, concepts of evidence (Roberts, 2001) and reasoning abilities (Zion et al., 1998) are of particular significance. The transformative process, *conclusion* (Njoo & De Jong, 1993) is thus further defined to encompass processes such as generating evidence, evaluating evidence and drawing conclusions (Fischer et al., 2014; National Research Council, 2012). Likewise, *asking question* will be added to the transformative processes as it fosters the development of reasoning abilities in scientific inquiry. The definition of each of these transformative processes (e.g., orienting, asking question, generating hypothesis, testing hypothesis, generating evidence, evaluating evidence, drawing conclusion) will be discussed in greater details in the following segments.

Orienting: In the orientation phase, students activate individual prior knowledge and the group's prior knowledge (in collaborative inquiry): retrieve domain information available from the learning environment and conduct search for additional information about the domain and the given inquiry task (De Jong & Njoo, 1993; Giljers & De Jong, 2005). Students also identify parameters and variables of the subject of inquiry, and thereafter, make initial interpretations of the given information and data (Saab et al., 2007). Here, students develop initial conjecture about a scientific phenomenon with exisiting knowledge and given learning materials. The orienting phase usually occurs at the start of the inquiry process though not restricted to it.

Asking Question*:* To become 'critical consumers of scientific knowledge' asking questions is pivotal to 'developing scientific habits of mind' (National Research Council, 2012). These initial questions also facilitate subsequent reasoning which affords a systematic search of evidence in the inquiry process (Fischer et al., 2014). In scientific inquiry, students could be guided to formulate questions such as, what exists and what happen, why and how does one know? These scientific questions could be driven by a curiosity to know how the world functions and/or by a need to find solutions to a problem (National Research Council, 2012). Asking question also forms part of the orienting process where students' interest and curiosity are aroused about scientific phenomena (Bell et al., 2010). Asking question occurs during the initial observations of how things happen in the natural world and where learners display the initial attempts at making connections between pieces of science to generate new scientific queries.

Generating Hypothesis: One of the central processes in inquiry learning is the generation of hypotheses where students formulate relations between one or more variables (Giljers & De Jong, 2005). Importantly, students should develop testable hypothesis (De Jong & Njoo, 1993) that can be investigated with the available resources in the classroom, laboratory or field, and where appropriate, hypothesis can be derived based on an existing theoretical framework or a model (National Research Council, 2012). Formulating a researchable question and testable hypothesis remain a challenging task for most students. This is particularly more challenging in the initial stages of an inquiry process where students have yet to be acquainted with the scientific point of view. Hence, the preceding processes of orienting and asking questions are instrumental in hypothesis generation.

Testing Hypothesis: Testing a hypothesis encompasses all processes that have to do with the design and execution of experiments (Giljers & De Jong, 2005). Testing hypothesis usually consists of sub-processes such as designing an investigation plan, making predictions and making preliminary interpretations (De Jong & Njoo, 1993). In the planning phase, students need to decide the data type and quantity necessary to effect reliable measurements, and consider limitations and possible confounding variables (National Research Council, 2012). It also means designing a viable plan that is suitable to pursue the scientific inquiry. In biology, unlike controlled experiments, observations form an important platform to test hypothesis. Testing hypothesis here may involve taking measurements, noting environmental changes and recording observations for compare and contrast. The process of testing hypothesis also demands metacognitive strategies such as monitoring (Bell et al., 2010). In testing hypothesis, students need to monitor and manage the situation: take measures to address unforeseen variables (e.g., changes in environmental factors) and readapt plans where necessary.

Generating Evidence: Generating evidence is the empirical aspect of scientific inquiry and the process itself also enhances the understanding of science concepts and the nature of science. In biology-based inquiry, evidence generation very often assume an inductive approach which includes observation, comparison and description of phenomena to draw conclusions e.g., the structure of a plant and its specific functions (Fischer et al., 2014). Further, generating evidence in the form of artifacts or observations provide an important source for meaningful scientific discourse to promote scientific understanding and knowledge construction (Sandoval, 2003). The process of generating evidence during collaborative inquiry engages students in scientific reasoning and argumentation. The rise of socio-cognitive conflicts (Lethinen, 2003) in the inquiry process is imperative for exploring different viewpoints which entails explanations and elaborations. These activities often lead to new knowledge and perspectives.

Evaluating Evidence: This process requires students to use evidence to assess, to advance and/ or to substantiate a claim or theory. Using the claim, evidence and reasoning framework, students are to provide justifications for their scientific claims (McNeill & Krajcik, 2008). Importantly, students are to be able to make comparisons of different evidences to investigate the quality of evidence (Fischer et al., 2014). Students develop their own explanations of phenomena leveraging on their knowledge of existing theory and /or infer connections to scientific evidence (National Research Council, 2012). In evidence evaluation, students engage in scientific practices of constructing and defending explanations; a process of central importance to develop conceptual and epistemological understanding of science (Driver et al., 2000; Duschl & Osborne, 2002; Sandoval, 2003). Bell (2000) conceives of these *scientific arguments as learning artifacts* to foster students' views of the nature of science (emphasis added).

Drawing Conclusions: In constructing scientific conclusions, students have to distinguish the core features in the structure of scientific arguments such as claim, evidence and reasoning in constructing scientific conclusions (National Research Council, 2012). Here, students are able to show how the data support a claim using evidence and reasoning. The explanation framework also guides students in developing a grand scientific statement or theory (McNeill & Krajcik, 2008). Importantly, students are able to identify weaknesses or flaws in their arguments and suggest improvements or further plans of investigations.

The above list of transformative processes does not in anywise suggest that they are fixed in a chronological order though the inquiry processes is usually driven through the sequential scientific practices of orienting, generating and testing hypothesis, evaluating data and making scientific conclusions. In science inquiry, students may return to the processes where necessary.

2.3.2 Regulative Processes

Inquiry learning engage students in knowledge inference processes, what Njoo and De Jong (1993) coined as transformative processes which develop scientific understanding by *doing science* (Barab & Hay, 2001; De Jong, 2006). Importantly, this knowledge gains in the inquiry process are also largely shaped by metacognitive skills (Manlove, Lazonder, & De Jong, 2007) or regulation processes (Njoo & De Jong, 1993). Metacognition includes skills that enable learners to understand and monitor their cognitive processes (Schraw et al., 2006). Consequentially, the quality of one's regulation has implications on one's transformative processes and the eventual learning outcomes. Regulation refers to the ability of the individual or group to manage his/ their actions based on goals, plans and knowledge of tasks (De Jong, Kollöffel, Van der Meijden, Staarman, & Janssen, 2005). Therefore, developing metacognitive expertise to facilitate inquiry learning (Kuhn et al., 2000; White et al., 1999) has become one of the objectives of inquiry learning. At the collaborative level, metacognitive and socio-cognitive skills become more challenging where collective reflection is instrumental for successful inquiry. White and Shimoda (1999) liken the collaborative inquiry process to a *reflective learning process* where individual members as a collective unit come together to think about their plans and goals, adapt or abandon to form new goals and task stratgies. These skills at the meta-level are imperative in order for students to benefit from inquiry learning whether as individuals or as a collective entity. Cognitive regulation consists of three main phases: planning, monitoring and evaluation (Manlove et al., 2007; White & Shimoda, 1999) which align with the regulative processes students engage in during inquiry learning. De Jong et al. (2005) put forth a coherence list of regulative processes which shall be taken up for a more in-depth description to illustrate how they could possible shape the transformative processes in inquiry learning. The following will present and discuss these regulative processes in greater details.

Orienting: In the orienting process, students think about desired learning outcomes and task goals in preparation of the learning process. Azevedo, Cromley and Seibert (2004) liken the orientation phase to an analysis of the learning situation. Here, students mobilize prior knowledge and existing information for the execution and completion of task at hand. The discussion of task requirements, task goals and one's own desired learning outcomes come to the fore (De Jong et al., 2005). For this reason, orienting to prepare for the learning process is a first critical phase (Saab et al., 2007). It sets the stage and to some measure, plays a determinant role in the unfolding of the inquiry processes, and consequentially, the learning outcomes.

Planning: The structuring and sequencing of the learning activities take place during the planning stage. Simply put, students define what activities they are to carry out and how (Winne, 2001) which very often includes the division of labor (De Jong et al., 2005). Here, students also consider the goals, subgoals and strategies to accomplish the task and to achieve the desired learning outcomes (Azevedo et al., 2004; Boekarts, 1999, Saab et al., 2007; Zimmerman, 2000). In the context of inquiry and scientific reasoning, the transformative processes (orienting, hypothesis generation, investigation, evidence gathering and drawing conclusions) will form the main *process goals* (White & Frederiksen, 1998). However, the strategic plan developed for the hierarchy of main and sub goals is temporal (De Jong et al., 2005) as students are likely to adapt or refine their plans, task goals and expected standards in the course of the execution (Manlove et al., 2007).

Instructing: It is about giving instruction or direction to fellow group members to carry out or lead an activity (De Jong et al., 2005). Instructing requires good communication skills as it has a bearing on the group's working ambience and team spirit in a collaborative situation. Instructing does not imply dominance of one member over the others; instructing can be achieved through a consensus-driven approach.

Grounding: Grounding forms a critical process in collaborative inquiry learning where students bring to bear their knowledge, ideas, suggestion in a collaborative space. Establishing common grounds is an essential feature to achieve shared cognition, shared meaning and shared understanding. The process of collaborative meaning-making is poignantly illustrated by Stahl's (2005) notion of a *shared meaning and common ground* constructed through group discourse in the context of a joint activity, where he contends that the "status of this shared meaning must be continually achieved in the group interaction; frequently the shared status of 'breaks down' and repair is necessary" (p. 345). Grounding can occur at the co- or shared regulation level when pair or group renders support in the negotiation and construction of shared knowledge (Järvelä & Hadwin, 2013). To this end, the posing of verification questions to arrive at shared understanding and consensus (De Jong et al., 2005) are important activities in socio-cognitive conflicts.

*Note: Both instructing and grounding processes occur only at the co- or shared level.

Testing: In the testing process, students provide summary, check if sufficient information/ data has been gathered for the inquiry task. Here, they pose questions, think of possible problems such as information gap, make comparison and draw conclusions (De Jong et al., 2005). In collaborative inquiry, testing also implies occurrences of grounding where members of the collective unit affirm information and check for shared understanding.

Monitoring: One of the most important regulative processes is monitoring where active observation and discussion of task progress occurs (De Jong et al., 2005). It involves making comparison of the present status to a set goal or an expected standard where students ask reflective questions to assess their state of progress (Azevedo et al., 2004). Self-questioning strategies enable students to make metacognitive judgements about their learning process and progress (Manlove et al., 2007). Boekaerts (1999) surfaced the notion of *monitoring standards* which culminate from the set goals to evaluate the ongoing learning activities and to direct students towards the desired outcomes they have laid out. Where the progress does not match the intended goals and outcomes, students will modify, adapt or form new strategies or approach (Winne, 2001). Monitoring is an important regulatory process and is even more pronounced in the inquiry learning where adequate and accurate judgements have implications on the transformative processes.

Evaluation: De Jong et al. (2005) posit that the evaluation process primarily takes place at the end of the execution of a task where students reflect on the learning and collaboration process, as well as the execution of the task. It also forms an important aspect of *reflective learning* in collaborative inquiry (White et al., 1999) where students exhibit metacognitive and socio-cognitive knowledge to take stock of the inquiry process. It entails an analytical and critical reflection to check for emerging understanding of the learning content/ topic and determine whether the employed learning strategies have been effective to arrive at the learning goals (Azevedo et al., 2004). Evaluation leads to a suggestion on improvement or refinement of the inquiry process (Manlove et al., 2007; Saab et al., 2007).

Similarly, the above list of regulative processes does not in anywise suggest that they are fixed in a chronological order though regulative processes such as orienting and planning usually occur at the beginning of a task while more monitoring and evaluating activities take place during and toward end of task execution.

2.3.3 Sociocognitive Processes at Three Social Levels

The preceding discussion surfaces the importance of cognitive knowlege and regulating one's own cognition. Both metacognitive and socialcognitive processes play a deteminant role in inquiry learning in collaborative inquiry and reflection (White & Frederiksen, 1998; White et al., 1999). In collaborative inquiry as in any collaborative learning, Järvelä and Hadwin (2013) posit that three forms of regulation take place: self- , co- and shared regulation where they occur concurrently and *exist along a continuum* (see figure 1; adapted from Järvelä & Hadwin, 2013). Regulated learning is social; involving dynamic social interactions at all three levels of regulation processes in successful collaboration. It would hence be more appropriate to conceive of collaborative learning as a negotiated process between the individual and the others, where the individual thinking processes are shaped by the communication and the social interactions in social activities (Rogoff, 1999). The three forms of regulation shall be further explicated in the succeeding paragraphs.

Figure 1: *Three forms of regulated learning in collaborative learning*

Self-regulation is largely derived from a socio-cognitive perspective (Zimmermann, 2000) which encompasses an individual's cognition, metacognition and motivation towards an intended goal (Hadwin & Oshige, 2011). Pintrich (2000) defines self-regulated learning as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features of the environment" (p. 453). Primarily, it is an intrapersonal process with the focus on the individual regulating one's own behaviour. However, this supposedly individual oriented process is subjected to the influence of one's social context. Akin to the idea of a *socially constructed self-regulation* (Järvelä & Järvenoja, 2011), the individual regulation of motivation is *socially constructed*, i.e., constantly shaped and reshaped in collaborative undertaking of an activity. Self-regulation is developed through reciprocal interactions between the individuals and the social-context (Meyer & Turner, 2002). The conceptual framework on self-regulation suggests some possible development of one's regulation in a collaborative learning situation. First, one is likely to align one's regulatory strategies and skills with the others in an attempt to collaborate. Second, one is also likely to adopt better regulation strategies and adapt or abandon one's own.

Co-regulation is seen as an interpersonal process whereby one member regulates the activities of a fellow member (Saab, 2012) to offer transitional support for each other's self regulation (as illustrated in figure 1). It has its theoretical grounds in Vygotsky's (1978) idea of the *zone of proximal development* where corregulation brings about *emergent interaction* and activity within this ZPD zone (McCaslin & Hickey, 2001). Here, it speaks of an element of interdependency, goal and strategy use are constrained and shaped *by and with the other* through *questioning, prompting and restating* (Järvelä & Hadwin, 2013). Saab (2012) differentiates between the occurrences of self- and co-regulation: the former refers to instances when a student monitors his own knowledge to regulate his own learning outcome while the latter occurs when a student monitors the cognitive activities of another.

Shared regulation occurs where group members work together to help each other construct *meta-cognitive, meta-motivational, and meta-emotional knowledge* about collaborative work (Jarvela & Hadwin, 2013). It is an interpersonal process where there is collaborative regulation of the cognitive activities of the group. The collaborative negotiation and monitoring of the shared goals, shared task perception and shared work space occurs through interaction and discourse (Hadwin & Oshige, 2011). Arriving at shared understanding is a challenging process for it requires "metacommunication awareness, shared motivation regulation and successful coordination of strategies" (Järvelä & Hadwin, 2013). Thus, the self-regulation skills, metacognitive knowledge and experiences each individual bring to the group level, has significant implications on the quality of coordination, communication and interaction.

In the words of Meyer and Turner (2002, p. 18), “autonomy is a relationship, not an individual attribute and self-regulation is a social process”. Hence, locating self-regulation within the social, shared and interactive processes is pivotal to understand the element of interdependency and mutual support in a social learning environment. Further, Järvelä and Järvenoja (2011) advocate a cognitive angle and a situative perspective with focus on group processes to understand the social construction of individual regulation in collaborative learning where “the individual group members represent interdependent self-regulating agents (cognitive angle) who at the same time constitute a social entity that creates affordances and constraints for group and individual engagement (situative angle)” (p. 9). Here, it is useful to visit Flavell’s (1979) model of cognitive monitoring where he surfaces the idea of ‘metacognitive experience’ and posits that these experiences usually occur in situations that trigger high-level and careful thinking such planning and evaluation. These metacognitive experiences will render significant effects on cognitive goals and strategies, as well as metacognitive knowledge. Relating the concept of metacognitive experiences to the notion of a ‘socially constructed self-regulation’, one can assume that the metacognitive knowledge base of both the individual and the group undergo a process of change by adding to it, abandoning it or advancing it.

2.3.4 Types and Qualities of Transformative and Regulative Processes

The above-mentioned transformative and regulative processes should likewise be the outcomes of inquiry learning where these higher-order domain knowledge and skills in inquiry activities should be eventually internalised (Perkins, 1993). It is in the interest of this study also to investigate the quality of the transformative and regulative processes in inquiry learning. De Jong and Ferguson-Hessler (1996) differentiate between four types of knowledge: situational knowledge, conceptual knowledge, procedural knowledge and strategic knowledge. This section will discuss the four types of knowledge in relation to the transformative and regulative processes, as well as the conceivable qualities of these two core processes framing the inquiry learning process.

Situational knowledge: De Jong and Ferguson-Hessler (1996) defines situational knowledge as having knowledge of situations which are domain specific. Relating this to inquiry learning, students who possess situational knowledge is likely to display understanding of task characteristics, features and recognise probable challenges associated within this domain. A demonstration of situation knowledge is likely visible during the orienting processes in both transformative and regulative processes

Conceptual knowledge: Conceptual knowledge can be likened to declarative knowledge about domain-specific facts, concepts and principles (De Jong & Ferguson-Hessler, 1996). Applying this knowledge type to the inquiry process, students mobilise conceptual knowledge in the orienting and asking question processes to generate hypotheses and to develop plans to test hypotheses. In the regulative processes of orienting, this is manifested in the students' activation of prior knowledge and attempt to establish connections to new knowledge while making inferences.

Procedural knowledge: Procedural knowledge refers to 'actions or manipulations' that are relevant within a particular domain (De Jong & Ferguson-Hessler, 1996). Students with procedural knowledge are able to effectively identify and analyse problems, and importantly administer the relevant solutions. It also implies that students with procedural knowledge are able to apply knowledge acquired. Procedural knowledge is also conceived of as the ability to execute sequential steps and measures to solve problems (Rittle-Johnson, Siegler, & Alibali, 2001). Planning in the regulative processes is likely to exhibit evidences of procedural knowledge in inquiry learning.

Strategic knowledge: Strategic knowledge affords students an understanding of the sequence and steps in problem-solving tasks (De Jong & Ferguson-Hessler, 1996). It enables students to formulate a plan defining the course of actions to arrive at their task goals. In the light of inquiry learning, strategic knowledge is knowledge of the inquiry-driven steps in scientifc practices, i.e., the constitutive transformative processes from orienting to drawing conclusions. This will involve most, if not all of the constitutive processes in cognition regulation.

Applying these knowledge types to the transformative processes in inquiry learning, situational knowledge is likely to activate both conceptual and procedural knowledge when students undertake inquiry task, for example, to investigate ways of plant adaptation in different living environments. Students will invoke prior knowledge and information on given plant species and applied known facts and concepts in the planning of the inquiry to collate evidences for scientific explanations. In addition, procedural knowledge can be subsumed under higher-order knowledge (Perkins, 1993) for it entails discipline-specific problem solving strategies, justification, explantation and inquiry. This knowledge type is peculiar to scientific reasoning and argumentation where students have to provide evidence to substantiate a claim, which evidently occurs in the inquiry processes such as generating evidence, evaluating evidence and drawing scientific conclusions. To the four knowledge types, De Jong and Ferguson-Hessler (1996) proposes two qualifiers or levels of knowledge: deep versus surface. Deep level knowledge displays the ability to reason and explain, to articulate depth in understanding a domain and acquire different perspectives of a phenomenon or problem (Snow, 1989). Surface-level knowledge remains at the level of reproducing knowledge, similar to that of rote-learning which has no depth of knowledge to formulate any critical judgement (Glaser, 1991). To distinguish between these two qualities in regulative processes, research showed that the better students who were actively regulating their cognition outperformed those who did not (Azevedo et al., 2004). Good regulation is usually demonstrated in an orderly and sytematic manner which shows deep orientation and reflection, adequacy and accuracy in judgement (De Jong et al., 2005). Highly self-regulated learners also display flexibility and knowledge in adapting to change or cue for change (Manlove et al., 2007). In other words, a perceptive individual employs critical thinking and reflection in task management.

For the objective of this empirical study on inquiry learning, these two levels of knowledge (deep vs. surface) shall be applied to qualify students' transformative and regulative processes. For the coding scheme, it shall be termed as high- and low-level knowledge.

2.4 Characteristic Problems of Inquiry Learning

As aforesaid, the transformative and regulative processes in inquiry learning impose high degree of cognitive, metacognitive and socio-cognitive demands. Students need to be equipped and empowered with the know how to initiate, to manage and to execute this highly self-directed learning approach. The intrinsic problems of inquiry learning can be traced to the aforementioned two main theoretical constructs of inquiry learning: inquiry learning as discovery learning and inquiry learning as collaborative discovery. The effectiveness of inquiry learning hinges on overcoming these inherent challenges arising from this mode of learning which confronted many students (De Jong & Van Joolingen, 1998; Manlove, Lazonder, & De Jong, 2006; Van Joolingen, 2000). Challenges ensued when one combines discovery and collaborative learning. Much as collaborative inquiry learning promises better engagement and learning effectiveness in science education, research has shown that there are multiple constraints and challenges of collaboration. The succeeding discussion will present these challenges with specific reference to cognitive, metacognitive and socio-cognitive aspects.

Notwithstanding inquiry learning engages the learner in authentic scientific practices which are instrumental in acquiring scientific literacy, the complexity of the inquiry process cannot be undermined. The knowledge inference processes such as formulating hypotheses, gathering data, evaluating data and constructing scientific explanations are considered highly challenging and requires both higher cognitive and metacognitive demands. Prior research has shown that inquiry learning needs to be scaffolded to yield significant learning gains (Bell et al., 2010; De Jong & Van Joolingen, 1998; Hakkarainen & Sintonen, 2002; Sandoval & Reiser, 2004). Learners may not have the know-how to drive through the various scientific practices in the inquiry process without reasonable guidance. De Jong and Van Joolingen (1998) surface the need to structure the discovery learning process, whereby they propose structuring the learning environment: by means of providing learners with sequence of experimentation steps as a means of instructional support, thereby segmenting the inquiry process into distinguished steps. Another example is the provision of a top-level inquiry model as a sequence of goals for the learners to emulate and to appropriate (White et al., 1999). Other studies on inquiry learning explore use of software scaffolds to prompt and support the different phases of inquiry learning (Manlove et al., 2007; Van Joolingen, 2000; Van Joolingen & De Jong, 1991; White et al., 2002). For instance, use of software tools such as hypothesis scratchpads to support hypotheses generation process (Van Joolingen & De Jong, 1991) to assist students to formulate testable hypotheses. Another challenge is students found it challenging to manage unexpected results and were unable to leverage all available experimenting manipulations, e.g., in simulation learning environments (De Jong & Van Joolingen, 1998). Additional instructional measures have to be put in place to help learners overcome the problems with scientific discovery learning.

Another class of problems pertains to the students' ability to regulate their own learning, be it individually or collectively. Metacognitive factors such as the learners' knowledge and regulation of one's own cognition also influence the acquisition of scientific knowledge in the inquiry process (Chin & Brown, 2000; Kuhn et al., 2000). White and Frederiksen (1998) implement *Thinker Tools* curriculum to foster regulative skills via scaffolds for planning, monitoring, and evaluation. Planning, monitoring and evaluation are core regulative processes in the inquiry learning. For successful inquiry learning, learners must be able to apply a systematic and planned discovery learning process. In collaborative inquiry learning, regulation at the collective level becomes more complex in that students need to monitor progress and also check for shared understanding to evaluate their inquiry learning processes (Manlove et al., 2006). Collective decisions and sound judgement in making change, modifying and readapting goals and task strategies play a crucial role to determine the course of learning. White et al. (2002) leverage the technological affordances of a *multi agent simulation environment* - *Inquiry Island* to support students' cognitive, metacognitive and socio-cognitive processes. Essentially, it seeks to enhance both scientific inquiry, as well as reflective learning. Collaborative inquiry learning typically requires high degrees of cognitive regulation.

The complex process can be made even more challenging when collaboration is embedded in the inquiry process. As aforementioned, collaborative learning is increasingly recognized as a core element of inquiry learning for collaborative inquiry fosters the acquisition and the execution of the knowledge schemata when individuals collectively articulate and elaborate their think-processes; making the scientific process explicit (De Jong, 2006; Linn & Eylon, 2011; Okada & Simon, 1997; Saab et al., 2005; Sandoval, 2003). However, the engagement of collective individuals in a common endeavour (Dillenbourg, 1999) requires the negotiation of shared meaning, shared understanding to collaboratively construct knowledge and/or create new knowledge. Research on collaborative inquiry has shown that learners may not know how to support one another in the collaboration process (Bell et al., 2010; Cohen, 1994; Hakkarainen & Sintonen, 2002; Saab et al., 2007; White et al., 1999). For instance, Saab et al.'s (2007) research showed that there was a relation between the communication process of argumentation and the process of drawing conclusions. Another study showed that learners working individually did not check with their partners for common understanding of the shared task (Baker et al., 1999). Other studies found that learners could not collaborate constructively without instructional support (Chan, 2001; Kollar, Fischer, & Slotta, 2007; Linn, Lee, Tinker, Husic, & Chiu, 2006; Mercer, 1996). Reiser et al.'s (2001) use of technological support and instructional scaffolds in *Biology Guided Inquiry Learning* (BGuILE) has helped students construct empirically-supported scientific explanations. Students need to be supported to form constructive arguments and to be engaged in meaningful collaborative debate (Bell, 2004; Reiser et al., 2001). Although most challenges in collaborative inquiry could be supported or improved by means of cognitive scaffolds or software support, there are more implicit problems such as coordination, communication and interaction which may require design and orchestration of the collaborative learning space. Rummel and Spada's (2005) study showed that the design of individual and collaborative learning phase had significant bearings on how individuals integrate into the joint work space during collaborative learning. Hence, apart from cognitive scaffolds to foster the collaboration processes, designing the classroom activities at different social levels is probably an avenue that could be explored to foster learning effectiveness for both individual and collaborative inquiry.

2.5 Summary

Inquiry learning has become a perennial term in science education; playing dual roles. First, it is conceived of as an instructional approach to facilitate scientific literacy and second, inquiry is perceived to be the desired outcome of science learning. Inquiry learning has become a dominant approach to develop scientific literacy through an active and constructive process of constructing domain knowledge from engaging in scientific practices similar to that of a real scientist. As Abd-El-Khalick et al. (2004) put forth, inquiry learning has become both *means (an instructional method) and end (instructional outcome)* (emphasis added).

As afore-discussed, inquiry learning is a process oriented and a highly self-directed undertaking whose inherent challenges also lie in the two core processes underlying this operation: transformative and regulative. Learning through inquiry is viewed as an active and constructive rather than a passive and linear process. Learning here is intentional where learners assume an active role to charter their learning course with goals, strategies and plans. This process is driven by a motivation to pose science questions, pursue scientific queries and to solicit scientific explanations (Lonka, Hakkarainen, & Sintonen, 2000). Therefore, it imposes higher cognitive and metacognitive demands on the learners to reflect on their learning processes and to assume responsibility for their learning outcomes. These challenges are further aggravated when collaboration is embedded into inquiry learning. Task and team regulation became equally significant in successful collaboration (Saab, 2012). Research on regulation foregrounds regulatory strategies and skills as primary determinant of successful collaborative engagement where three levels of regulation occur concurrently during collaboration (Järvelä & Hadwin, 2013). Hence, apart from cognitive and meta-cognitive challenges in inquiry learning, socio-cognitive demands cannot be undermined. In collaborative inquiry and reflective learning, the quality of coordination, communication and interaction plays a determinant role in shaping the group discourse. It can either facilitate or impede the learning process. Whilst there is a plethora of research on scaffolding and supporting the individual and collaborative inquiry process, more attention might be needed to examine how individual can be better integrated into the collaborative inquiry learning setting or vice versa, how collaboration can be embedded into inquiry learning to bring about the desired learning outcomes for the individuals, as well as the collective entity.

3 Orchestrating Inquiry Learning with Classroom Scripts

Inquiry learning has been the hallmark of science education to foster scientific literacy. To enhance the scientific inquiry processes, collaboration forms the core element of inquiry learning (De Jong, 2006; Kaartinen & Kumpulainen, 2002; Linn & Eylon, 2011; Okada & Simon, 1997; Saab et al., 2005; Sandoval, 2003). However, the successful engagement of collective individuals in a common endeavour (Dillenbourg, 1999) requires the negotiation of shared meaning, shared understanding to collaboratively construct knowledge and/or create new knowledge. Collaborative inquiry is a complex process which imposes higher cognitive, meta-cognitive and socio-cognitive demands. Meta-cognitive and socio-cognitive processes are of significant signpost as they have bearings on the individuals', as well as the group's learning processes and outcomes. This, in turn, inevitably shapes the cognitive processes and outcomes at the group level.

The orchestration of inquiry learning in the science classroom is pivotal to ensure learning effectiveness in inquiry learning for both the individual and the group. Dillenbourg (2013) defines *classroom orchestration* as the facilitation of "multi-layered activities in a multi-constraints context" 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 *script* for the desired interaction patterns and learning outcomes. The term 'script' was first used by Schank and Alberson (1977) to refer to cognitive structures or schemata, i.e., individuals possess procedural knowledge to act and respond in everyday situations. Hitherto, there has been a multitude of research on the use of scripts to support individual and collaborative learning. Research on scripts could be classified into two general strands. The first strand of research examines the use of scripts such as collaboration scripts to better the quality of collaboration (e.g., Kobbe et al., 2007; Kollar, Fischer, & Hesse, 2006; Kollar, Fischer, & Slotta, 2007; Kolodner 2007; Rummel & Spada, 2005), as well as to enhance individual learning outcomes (e.g., Wecker & Fischer, 2011; Weinberger, Fischer, & Mandl, 2005). The second strand of research examines the use of classroom scripts which sequence and distribute learning activities over the various social planes of a classroom to enhance learning effectiveness in collaborative inquiry learning (Kollar et al., 2011; Mäkitalo-Siegl, Kohnle, & Fischer, 2011). Whilst effective collaborative interaction accounts for successful collaboration (e.g., Barron, 2003), research on individual and joint work space indicated that there are significant implications on allowing sufficient individual time before collaboration for more productive communication and collaboration (e.g., Rummel & Spada, 2005). Reiterating the words of Dillenbourg (1999), “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” (p. 5). An open empirical question is how we can develop ways to increase the probability that the desired discourses and patterns of interaction occur. Essentially, apart from scaffolding for effective collaborative interaction, there could be underlying mechanisms which are equally significant in fostering the individual and collaborative learning process. Hence, this research study takes an interest in the latter strand of research on the use of classroom scripts to orchestrate individual and collaborative inquiry learning.

In this chapter, orchestrating inquiry learning by means of classroom scripts will first be discussed. Here, the potential and problems of the various activities across the different social planes of the classroom will also be presented. Next, the various theoretical frameworks on the sequencing and distribution of classroom activities to support and enhance individual and collaborative learning effectiveness will be introduced and explained. Finally, the design of two differently sequenced classroom scripts for this empirical study will be explicated in the light of the above-mentioned theoretical perspectives.

3.1 Classroom Script

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 & Jermann, 2007). Classroom scripts sequence and distribute learning activities across the social planes of the classroom (Kollar et al., 2011). 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 class-wide activities (e.g., introductory lectures, de-briefing). By defining the sequence of activities, classroom scripts shape the interaction patterns.

Orchestrating inquiry learning can be achieved by means of a classroom script that contains science-making schemata (Dillenbourg & Jermann, 2007). The science-making schema sequences the phases that drive learners through the scientific inquiry process (Hakkarainen & Sintonen, 2002) whilst the classroom script distributes these activities across the different social planes (e.g., the plenary, the group and the individual level). The succeeding discussion of the activities, the potentials and the problems of these activities at each of the three social levels shall not in anywise imply that there is a clear demarcation of the activity types and their corresponding cognitive processes at the three social levels. As in the words of Dillenbourg and Jermann (2007), "Individual cognition does not freeze during class interactions and culture does not stop shaping our thinking during individual work" (p. 291). Essentially, it does not aim to provide an exact definition of the three social levels, but rather to foreground that classroom script activities define the moves across the different planes and activities do occur concurrently on various social planes, however, their focus varies with time.

3.1.1 Plenary Activities

Plenary activities or class-wide activities or collective activities involve all students of the same course (Dillenbourg & Jermann, 2007). Typical activities at the plenary session or class-wide activities could include introductory lectures, readings, exercises, modeling to activate pre-requisite skills, metaphors, etc. or debriefing. At the plenary level, the teacher typically provides an introduction to the topic of inquiry: introduces the core inquiry activities in phases and gives instructions on how to proceed with individual and small group activities. Plenary activities may appear to be passive and frontal loading of information from the teacher or instructor, but Dillenbourg and Jermann (2007) argue that these pre-structuring activities provide the very conditions that are pivotal for the effective execution of the core script activities. It prepares the students for taking on other activity types and on a different social level. In a similar vein, Schwartz and Bransford (1998) contend that there is a *time for telling* where frontal lectures play a critical role in providing higher level explanation which may be time consuming or cognitively challenging without expert help. In designing for *productive failure*, plenary activities at the *consolidation or instruction phase* forms a critical design component (Kapur & Rummel, 2012) for it affords the platform for the learners to compare and contrast their own generated solutions and the teacher to consolidate and model and rework through canonical solution (Kapur, 2012).

Foreseeable problems with plenary activities are the implied underlying cognitive engagement and cognitive processes which could be remain passive most of the time (Chi, 2009). Students engaging in plenary activities may only come away with minimal understanding as they are merely receiving information through these *attending processes* (Chi, 2009). However, a plenary activity involving a teacher or facilitator or instructor and a student or a class can become active, constructive or even interactive. For instance, when the plenary activity invokes interactive participation through a line of questioning and reasoning, the seemingly passive plenary activity become interactive for the students are engaged in sequential construction to create knowledge, which are similar to the cognitive processes invoked through constructive activity (Chi, 2009).

3.1.2 Small Group Activities

'Proper collaboration' is said to occur at the small group level (Dillenbourg & Jermann, 2007) where *two to about five people* collaborate in learning activities (Dillenbourg, 1999). Interactions at the collaboration level form the key learning mechanism in integrated learning (Dillenbourg, 2006). The core script is the collaborative activity in which the interactions that the script is intended to trigger should appear (Dillenbourg & Jermann, 2007). Activities which characterise the small group level usually contain an interactive feature: asking and answering questions through dialoguing (Chi, 2009), converging differing views through reasoning and argumentation (Amigues, 1988; Osborne, 2010), explanatory through reciprocal questioning (King, 1990; Webb, Troper, & Fall, 1995), learning strategies through observations of others (Azmitia, 1988), and listening to explanations (Coleman, 1998).

Research on cognitive mediators of collaborative learning cautions that it is not about working in groups but rather, the possibility that certain kinds of learning processes can be activated (Cohen, 1994; Dillenbourg, 1999). Small group activities are presumed to evoke and enhance specific cognitive processes which might be absent at the individual level. For instance, it fosters *mutually generative processes* during interaction which new knowledge and perspectives could emerge (Chi, 2009). Socio-constructivistic learning theories (Duit & Treagust, 1998) posit that knowledge ensues when members of communities collaboratively search for solutions to problems with distributed information among its members. Piaget (1959) accentuates the importance of social interaction for the emergence of cognitive conflicts. These socio-cognitive conflicts form the basis of considerable cognitive developments and performances and might appear in inquiry learning processes as well (Lethinen, 2003). Vygotsky's (1978) idea of the zone of proximal development demonstrated the positive effects of collaborative experiences; collaborating peers offer zones of proximal development to each other. Lazonder's (2005) research on information problem solving showed that students working in pairs demonstrated higher-level online search processes, for instance, employ more monitoring and evaluation strategies during search than those working individually: these high-level search processes led to higher-quality search results. There are unique affordances of joint thinking which enhances reflective learning where the collective undertaking of tasks fosters reflective work (Shirouzu, Miyake, & Masukawa, 2002). Advocates of small group work for instance, Schoenfeld (1983) posits that small group work is profitable for the differentiation and externalization of the roles and activities involved in solving complex problems, which an individual must internalise to be a successful problem solver.

The promises of small group activities come with inherent challenges. Research has oft times shown that the desired collaborative interaction at small group level often do not occur without scaffolds or instructional interventions. One of the main problems lies with communication and coordination which shaped the group learning processes and outcomes (e.g., Barron, 2003; Rummel & Spada, 2005). Relating to this is the issue of individual and group cognition. The collaborative process itself entails corresponding individual processes (Stahl, 2005). Roschelle (1992) has described the processes of learning during collaboration as a cycle of *convergent conceptual change*: the partners exchange ideas, evaluate them in discourse, make corrections and finally establish convergence. Establishing shared meaning undergoes a process of negotiation through which the individual members of the group had to interpret the meaning from their own personal perspectives, to display their understanding of the meaning and to affirm that meaning is shared (Stahl, 2006). This also implies a relational effect between task and team regulation (Saab, 2012). In collaborative learning, the individual members of the group represent "interdependent self-regulating agents who at the same time constitute a social entity that creates affordances and constraints for group and individual engagement" (Järvelä & Järvenoja, 2011, p. 9). Hence, the quality of the regulation processes at the small group level will inevitably determine the quality of learning processes and outcomes, for both the group, as well as the individuals.

3.1.3 Individual Activities

Where is the place for individual activities or is the individual work phase still necessary if collaboration enhances learning effectiveness in inquiry learning. Individual or solo activities (e.g., reading papers, writing a synthesis) are necessary as they constitute the 'didactic envelop' around the core collaborative activities (Dillenbourg & Jermann, 2007). Akin to Chi's ICAP framework (2009), both active and constructive activities at the individual level facilitate different cognitive processes. *Active activities* such as note-taking and highlighting sentences facilitate the activation of prior knowledge and assimilation of new information, whereas *constructive activities* such as self-explaining and asking questions promotes the integration of new knowledge with prior knowledge which could generate new inferences and/ or repaired existing mental models.

The importance of the individual work phase or activities at the individual level can also be understood from Bandura's (1997) social-cognitive learning theory where *reciprocal determinism* suggests that learning is the result of personal, environmental and behavioral factors. Individuals learn to become self-regulated by advancing through four levels of development: observational, imitative, self-controlled, and self-regulated levels (Schunk & Zimmerman, 1997; Zimmerman, 2000). This mirrors Gutwin and Greenberg's (2004) postulation of *mixed focus collaboration* where people shift frequently between individual and shared activities in a joint work session. Hence, awareness of team cognition is pivotal for effective collaboration. Therefore, individual activities provide the bridging platform to develop self-awareness and self-regulation. This, in turn, eases the integration into collaborative work space. On similar grounds, the empirical study on learning to collaborate, Rummel and Spada (2005) gave emphasis to the importance of individual work phase preceding the joint work efforts as it has implications for the eventual quality of collaborative problem-solving processes and outcomes. Alotting sufficient individual time enables the individual to contribute their domain-knowledge. Successful collaboration is contingent on the pooling of shared (known to all members of a group) and unshared knowledge (known only to individual members of the group) (Hermann, Rummel, & Spada, 2001). Their studies 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 work jointly throughout the collaborative undertaking of task, overlooking the need to coordinate the individual working phases (Hermann et al., 2001). The individual phase enables one to better assimilate into the collaborative space; integrating one's contributions and aligning one's regulation strategies with the others as a collective entity.

3.2 Embedding Collaboration in Inquiry Learning

The preceding discussion foregrounds the potential and problems of the activities at each of the three social planes: plenary, small group and individual. However, what would be an effective classroom script sequence to embed collaboration in inquiry learning with the aim to foster both the individual and collaborative inquiry learning processes and outcomes. The following sections discuss three important theoretical frameworks on individual and group cognitive processes which could provide helpful insights in the design of classroom scripts to enhance learning effectiveness for both individual and collaborative inquiry learning.

3.2.1 The Scaffolding and Fading Approach

The scaffolding approach mirrors a constructivist framework where scaffolded activities are designed to engender learning, with gradual fading of the scaffolds as learners acquired the target skills (Puntambekar & Hubscher, 2005; Schmidt, Loyens, Van Gog, & Paas, 2007). A rich body of research in the last four decades on designing learning environments and instructional support for inquiry learning leverages heavily on the elements of 'scaffolding'. These empirical research usually focus on scaffolding the inquiry process by means of interaction or collaboration (e.g., Barab & Hay 2001; Driver, Asoko, Leach, Scott, & Mortimer, 1994; Okada & Simon, 1997) or designing software systems or online learning environment (e.g., Manlove et al., 2007; Quintana et al., 2004; Reiser et al., 2001; Tabak & Reiser, 1997; Van Joolingen, 2000; White et al., 1999) or combining both the social and technical aspects of scaffolding (e.g., Tabak 2004 on distributed scaffolding). This section gives focus to the social conception of 'between-people scaffolding' (Pea, 2004) as surfaced in the first strand of research.

Wood, Bruner and Ross (1976) first introduced the term *scaffolding* to illustrate how a child was able to construct a wooden pyramidal puzzle through interaction with a tutor. Akin to Vygotsky (1978)'s concept of zone of proximal development (ZPD) where a person is able to achieve a task with help from the more knowledgeable others. Vygotsky advocates interaction with experts and/ or more capable peers as an effective measure to develop skills and strategies. In a similar vein, the scaffolding process conceives of interaction and collaboration as instructional support to accomplish a complex task which could be impossible or overwhelmingly challenging than doing it alone without assistance. Another critical property of ZPD is the *psychological developmental progress* where it posits that an induction first occurs on an interpsychological level and only second on an intrapsychological level, i.e., "a child's experiences of participating in activities are first externally accessible that the structures and content of mental life that can be played out internally" (Pea, 2004, p. 426). Here, modes of individual thoughts have been internalized from communicative interactions with other people (Stahl, 2006). Hence, individual learning occurs where one internalizes or externalizes knowledge that was first constructed with others.

The scaffolding theory also exemplifies aspects of cognitive apprenticeship which situates the acquisition of skills and knowledge in the social and functional context of use (Collins et al., 1989). Cognitive apprenticeship advocates the *between-people scaffolding* (Pea, 2004) where students can observe, enact and practice the tacit processes with help from the teacher, experts and from fellow learning partners. Embedding social context ensures students have continual access to visible participants in the acquisition of the target skills. As Stahl (2006) puts it, "Learning is always accomplished by individuals, but this individual learning can be assisted in settings of collaboration, where individuals can learn from each other" (p. 5). By structuring the social context, the presence of other learners serves as a source of scaffolding to carry out one's own task, thereby encourages independent and self-directed learning. This resonates with Perkins's (1993) argument that the very act of working or collaborating in a group amounts to a kind of cognitive scaffold that would make it difficult for the individual to lose his or her place in the process. Further, the presence of other learners can be seen as an important platform to foster differentiation and externalisation of varied roles and activities in complex problem solving: the discussion and decision-making enables the individuals to internalise the skills and processes (Collins et al., 1989). Similarly, a number of studies on scaffolding the inquiry process have proven that interaction fosters the acquisiton of scientific skills and knowledge. For instance, Okada and Simon's (1997) study on collaborative discovery showed that pairs were more successful in engaging actively in explanatory activities than those who worked individually. Apprenticeship also emphasizes the processes that experts engage in, to use or acquire knowledge in carrying out complex or authentic tasks. Barab and Hay's (2001) works on *doing science* enabled students to engage in authentic scientific inquiry with real scientists, which fosters *reflection-in-practice* and *reflection-on-practice* during the two week long camp. Here, apprenticeship includes mentoring and scaffolding learners to think and act more like the experts, engaging in authentic problems and resources as in the community of practice.

Notwithstanding the potentials of scaffolding, Pea (2004) accentuates that, *fading* forms a critical component of the scaffolding framework. The primary purpose of scaffolding is to build students' confidence in the acquisition of the target skills independently. Importantly, the scaffolds should gradually fade out as students become more skillful and knowledgeable to assume greater agency in executing the task on their own. An example of *fading in scaffolding* is the provision of explicit procedural supports e.g., in the teaching of writing (Scardamalia & Bereiter, 1985) with gradual withdrawal or reduction of support. This instructional approach provides students a grasp of the complex processes, as well as opportunities for reflection of their own work and their peers. Another exemplar is the works of Wecker and Fischer (2011) where the fading of the instructional scaffold with peer monitoring and feedback afforded learners greater agency over their own cognitive activities.

In sum, the *scaffolding* and *fading* approach relies on elements of cognitive apprenticeship: where the observation, the enactment and the practice (fosters the development of a conceptual model), the embedding of social context (observing other learners in incremental stages of the learning process) effectuates a gradual fading of the scaffolds in empowering and equipping learners to assume greater agency over one's own learning.

3.2.2 The Productive Failure Approach

The theory of *productive failure* seems to contradict the advocates of cognitive apprenticeship for it suggests that learners in un-scaffolded, ill-structured groups may initially experience struggle in defining and solving problems, but eventually outperform those in scaffolded and well-structured groups in the learning transfer (Kapur, 2006). In essence, failure plays a central role for effective learning in 'productive failure' where this initial 'failure' could foster better and more successful approximation of the target skills in subsequent similar learning situations. The idea of *productive failure* advocates 'conditions' that maximise learning in the long run, notwithstanding, these same conditions may not promise immediate performance in the short term (Kapur, 2012). It is also this self-same conflict between short-term performance and long-term learning where productive failure distinguishes itself from other theories on learning and instruction (Schmidt & Bjork, 1992).

There are several theoretical arguments for conceiving of *productive failure* as an instructional method or even as a form of *scaffolding* to foster learning and transfer. Kapur (2006) surfaces the works of Kauffman (1995) on the laws of self-organization and complexity to position the arguments for productive failure where the sufficiency of complexity or chaos could harness the flexibility to adapt and to innovate. In the words of Kaufmann (1995), “the compromise between order and surprise - appear best to coordinate complex activities and best able to evolve as well.” (p. 26). In a similar vein, un-scaffolded processes may deem inefficient in the short term, however, the unordered processes in the long run may facilitate more flexible, adaptive and innovative ways of managing complex problems. Kapur (2006) proposes a continuum to locate scaffolded and un-scaffolded processes where the former stand on the ordered end of the continuum and the latter as operating on the chaotic end of the continuum. Further, Kapur (2006) posits scaffolded processes are efficient for short term gains but for long term benefits, “un-scaffolded processes may provide a more optimal compromise between efficiency and innovation” (p. 6). Designing learning experiences should thus seek to provide opportunities for students to innovate and opportunities for students to learn efficient solutions from experts (Schwartz, Bransford, & Sears, 2005). In a similar fashion, Reiser (2002) spoke of the two complementary mechanisms in scaffolding: *structuring and problematizing*. In most typical learning situations, the scaffolding and fading approach seeks to provide instructional support (social or technical scaffolds) to help students proceed through tasks. However, it is equally important to enable students to construct conceptual knowledge and to acquire transferable skills and strategies by problematizing the tasks to force students to reflect and explore uncharted territories.

Several empirical arguments for ‘productive failure’ have evidenced the role of failure in learning for instance, *delayed instruction* (Van Lehn et al., 2003), *delayed feedback* (Mathan & Koedinger, 2003) and *delayed structure* (Kapur, 2008). Van Lehn and his colleagues’s (2003) study on delayed instruction found that impasses were strongly related to learning. An optimal tutoring strategy delayed instruction till learners reached an impasse; prompting them to find the right solution and tutors only provided explanation when students were unable to do so (Van Lehn et al., 2003). In another experiment with *intelligent tutoring systems*, Mathan and Koedinger (2003) found that students who received *intelligent novice feedback* demonstrated better overall learning gains than those who received *expert model based feedback*. The *intelligent novice feedback* model provided learners the platform to first detect their own errors before obtaining feedback. This learning orientation explains the better retention and application in subsequent similar problem-solving situations. Kapur (2008) in his earlier experiments on *productive failure* proved that there was hidden efficacy by *delaying structure* in the ill-structured groups which not only helped the learners to structure ill-structured problem, but also facilitated spontaneous transfer of problem-solving skills. By withholding external support structures or scaffolds, the ill-structured groups apparently generated richer variety of methods for solving ill-structured problems and, discussions were proven more complex and divergent than those in well-structured groups. This could possibly account for the successful learning transfer. Similar to the idea of *delay structure*, Schimdt and Bjork's (1992) study found that *introducing difficulties* during the learning phase to force learners retrieve and organise a different outcome in every task trial, is an effective measure to foster effective skill retention.

Given that there is hidden efficacy in 'failure', a challenging task lies in designing the conditions for productive failure; to conceptualize ways to extract this potentiality in the unscaffolded or what might appear to be unproductive learning situations (Kapur, 2006). On this note, Collins' (2004) review on 'productive failure' reiterates that a teaching method that combines both invention and productive failure would be more effective than direct instruction. Essentially, two phases characterize such an instructional approach: a *generation and exploration* (invention) phase which allow students to 'struggle' to figure out the solution and a *consolidation* (or instruction) phase where the standard solution would be presented (Kapur & Bielaczyc, 2012). Of significant signpost is the provision of supports to assist students during the 'invention' phase for instance, role-play scripts (Westermann & Rummel, 2012); metacognitive scaffolds with prompts and contrasting cases for comparison (Roll, Holmes, Day, & Bonn, 2012) and metacognitive strategies that help students generate different representations and solution methods (Kapur, 2012). In designing for productive failure, Kapur (2012) accentuates the criticality of employing core design principles to embody interdependent mechanisms: (1) creating the contexts; (2) providing the opportunities for explanation and (3) providing contrast cases. Therefore, the case for productive failure should not be misconceived as total absence of scaffolds and leaving learners to fumble with prior knowledge and available learning materials.

In essence, one could also argue that 'productive failure' hinges on elements of cognitive apprenticeship, only that these scaffolds are either delayed or problematized to set up the conditions necessary for 'successful failure' to bring learning to a higher platform.

3.2.3 The ICAP Framework Approach

The Interactive, Constructive, Active and Passive (ICAP) (Chi, 2009) framework elucidates how different learning activities might mediate learning: invoking different cognitive processes and facilitating different learning outcomes. Essentially, the ICAP model hypothesizes a hierarchical organization of activities and their learning effectiveness with interactive activities as better than constructive activities, which in turn might be better than active activities, which are better than passive activities. Chi (2009) defines an activity as passive when learners merely receive instruction e.g., listen to a lecture; an activity becomes active when learners do something with their hands or bodies e.g., listen to a lecture and taking notes; a constructive activity is where learners generate information beyond the given learning materials and an interactive activity refers to two or more learners engage with each other through dialoguing or with a system in self-construction (incorporates the partner's contributions), guided construction (from interacting with an expert), sequential and/ or co-construction with a partner. However, this is not to say that an intended activity mode e.g., interactive shall maintain its status quo throughout the learning process. Importantly, what essentially qualifies an activity as interactive, constructive, active or passive, is contingent on the output. This is to say that the correct classification of an activity rests on the analyses of the content of the outputs. An interactive activity is no longer interactive if partners are not responding to each other's contribution (Chi, 2009). Likewise, interaction with an expert in instructional dialogues (such as explaining, providing corrective feedback and scaffolds) is regarded as guided-construction, and is therefore, considered as an interactive activity when students respond in a meaningful and substantial way. An intentionally designed e.g., constructive activity can become active instead of constructive when either the activity or the learner has compromised the intended activity type. For instance, a learner is merely being active and not constructive when the learner is only reproducing what is presented in the learning materials. Thus, to determine if a learner is generating new ideas in a constructive activity, one must analyze the content of the outputs.

The ICAP framework provides two helpful insights in the design of classroom learning environments. First, it focuses our attention on the roles of overt learning activities and their relationship to the internal processes. Second, by making a distinction between interactive, constructive, active and passive activities, the framework compares and contrasts one learning activity with another learning activity during a learning phase from a learner's perspective (Chi, 2007). Given that interactive activity type is ranked above all the other three activity types by reason of its promised learning effectiveness, the question is where would be the best place for active, constructive or even passive activity. Here, it brings to bear the various theoretical positions on the unit of learning: group cognition (Stahl, 2006), shared cognition (Resnick, 1991) and distributed cognition (Salomon, 1993). This may enable us to see the affordances of each activity type encapsulated in the ICAP framework and its implications on the distribution and sequencing of these four activity types.

In group cognition, learning is seen as a result of both individual and group processes where the processes of meaning-making or knowledge building in the interaction cannot be attributed to any individual group member nor the sum of the individuals' knowledge (Stahl, 2006). Akin to Chi's (2009) postulation of co-construction in joint dialogues, substantive contribution in interactive activities could lead to emergent knowledge and new perspectives. Cognitive product is a consequence of the interaction of individuals with the others in the group. Group knowledge is interactively achieved and negotiated through group discourse. Likewise, shared cognition (Resnick, 1991; Resnick, Levine, & Teasley, 1991) articulates similar theoretical convictions that mean-making and knowledge co-construction occur in social context of interaction and collaboration. Social interactions can stimulate and promote cognitive development and cognitive change in the individuals (Levine, Resnick, & Higgins, 1993). As such, the cognitive product(s) that emerges from these interactions cannot be attributed to any individuals in the group but rather, it is the result of a collective effort. More important, cognitive challenges and cognitive conflicts are instrumental in facilitating intellectual growth for both the individuals and the collective unit (Levine et al., 1993). The theory of distributed cognition (Salomon, 1993) expands cognition beyond the individual and the group to embrace interaction with environmental resources and artifacts. Cognitive processes are not only distributed across members of a group members and time span, but also require coordination with the resources and artifacts of the environment (Hollan, Hutchins, & Kirsh, 2000). Similarly, Perkins (1993) asserts that the distributed thinking and learning of the *person plus* comes most to the fore in situations of authentic and extended inquiry, where the *people plus* must not be undermined in collaborative processes.

The above theoretical perspectives incite some fundamental questions about individual, group learning and the learning context, which may relate to the ICAP activity types. Going back to Stahl's (2006) theoretical position on group cognition, he also cautions that the knowledge and abilities of people in individual setting differs from group setting. Citing Vygotsky's (1978) contrast between a person's individual developmental level and his or her social developmental level in the ZPD, an individual may be able to deliver in a group setting, does not necessarily implies that he or she is able to do the same on his or her own accord (Stahl, 2006; Stahl, Koschmann, & Suthers, 2006). Further, empirical studies on group cognitive processes showed that successful collaboration lies in sustaining collaborative effort and fostering substantive interaction. According to Roschelle and Teasley (1995), collaboration is a 'coordinated activity' which requires continued effort to maintain shared perception of the task to construct a joint problem space (Teasley & Roschelle 1993). The construction of this shared space is contingent on shared understanding, which Levine and colleagues (1993) coin as *intersubjectvity*. Intersubjectivity is pivotal to facilitate coordinated cognitive activity where group members have shared task perception, common goals and strategies. This parallels the view on grounding as critical to coordinate both the content and the process in collaborative undertaking (Clark & Brennan, 1991; Koschmann & LeBaron, 2003). Noteworthy is Kaptelinin and Cole (1997)'s proposition of *pre- and post-intersubjectivity* activity to coordinate individual and collective activites which primarily aims to help the learners coordinate two different views - the individual and the collective. Their research showed how the pre-intersubjectivity activity helps the individuals assimilate into the collective activity and a post-intersubjectivity activity provides a platform of learning transfer for the individuals emerging from the group experience.

In the light of the above discussion, the ICAP framework and the various theoretical arguments on individual and group cognition seem to suggest that there is cogntive value in every activity type to engender both the individual and the group learning. More important, different activity types might be necessary to integrate individual learning into the collaborative space and to ensure the collective unit learns.

3.3 Differently Sequenced Classroom Scripts

A common theoretical construct across the three theoretical frameworks is the recognition of collaborative interactive activities as instrumental in fostering both the individual and group learning gains. Notwithstanding, there is rich potential of collaborative learning but "cognitive opportunities are not in themselves cognitive scaffolds" (Perkins, 1993). Collaborative inquiry and reflective inquiry are complex performances. White and Shimoda (1999) call it the "product of a social system of interacting agents", each with specific expertise to attain particular high-level goals. In similar convictions, Dillenbourg (1999) contends that collaborative learning is neither a method nor a mechanism, rather a situation where the desired patterns of interaction is contingent on the design of the learning environment.

Applying the above discussed theoretical frameworks to classroom orchestration using classroom scripts, there are several possible ways of sequencing and distributing classroom activities to foster both individual and group learning in the inquiry process. To foster a target skill, 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 & Spada, 2005; Schraw et al., 2006; Schunk, 1996; Webb & Palincsar, 1996). Here, the teacher models and takes the student through the science-making schemata (Hakkarainen & Sintonen, 2002): the different transformative processes from orienting to drawing of conclusions in the scientific inquiry process. From here, there are two possible sequences for the classroom scripts: the Plenary-Small Group-Individual (PSI) and the Plenary-Individual-Small Group (PIS). The following sections will discuss the theoretical constructs and arguments for the plenary activity, and subsequently, the two differently sequenced classroom scripts: PSI vs. PIS.

3.3.1 Modeling at the Plenary Level

Both classroom scripts begin with teacher modeling at the plenary level. The PSI classroom script exemplifies elements of *scaffolding* and *fading* which borrow largely from the theory of cognitive apprenticeship. Modeling and observation is one avenue to provide apprenticeship (Collins et al., 1989). In the case of the PIS classroom script, designing the conditions for *productive failure* involves creating a learning context (Kapur, 2012). Modeling of the complex inquiry process at the plenary level forms the baseline prerequisite in the body of interdependent mechanisms. The provision of some form of support is reckoned necessary during the *invention* phase (Westermann & Rummel, 2012) to prepare students for *successful failure*.

Modeling as an instructional scaffold can be traced to Bandura's (1997) social cognitive theory of learning where individuals learn to be self-regulated learners through four developmental stages of observation, imitation, self-control and self-regulation (Zimmerman, 2000). Hence, modeling aims not only to impart cognitive knowledge, but also to develop meta-cognitive skills and strategies. Modeling also emulates the theory of *reciprocal teaching* (Brown & Palinscar, 1989) where the teacher models expert strategies in problem-solving context. Modeling affords immediacy of guidance and feedback prior to enactment. Modeling first focuses students on their observations and thereafter to exercise reflection learning during the enactment of similar task (Collins et al., 1989). Apart from teacher modeling, other forms of modeling include expert modeling, peer modeling and modeling through small group collaboration (Schraw et al., 2006). Here, learners learn from their peers how to manage and monitor a task. However, both the PSI and the PIS classroom script commence with teacher modeling at the plenary session.

Modeling the inquiry process typically involves modeling the investigation strategies and scientific practices (Rummel & Spada, 2005; Schraw et al., 2006) or question-asking (Chinn & Brown, 2002) or providing an investigation model for student to emulate; making domain-specific skills and strategies salient (Hmelo Silver, Duncan, & Chinn, 2007). Likewise, Kirschner, Sweller and Clark (2006) argue that with respect to domain learning, 'minimal guidance' in inquiry learning poses unnecessary challenges for learners. Modeling of both methods and strategies seeks to enhance learning effectiveness and makes the think-process explicit (Schraw et al., 2006). The decomposition of complex task enables the students to emulate the strategies and skills in going about a task (Palinscar & Brown, 1986). Students require models of processes to acquire or improve specific target and complex skills where these complex skills can be sequenced in incremental stages of complexity to accommodate the changing demands. In inquiry learning, scientific reasoning and arguments form one of the core processes to help students construct scientific knowledge and scientific explanations of phenomenon. Chinn and Hung's (2007) study showed that providing expert models promote seventh graders' scientific reasoning. In a similar fashion, Bandura (1997) contends that modeling is effective for two reasons: first, it provides knowledge about a target skill, second, it increases motivation that the target skill is attainable.

The provision of *explicit examples* and *explicit feedback* in teacher-student modeling facilitates learning, as well as self-regulation (Schraw et al., 2006). Butler and Winne (1995) suggest that detail feedback is able to raise students' metacognitve awareness, improve their self-regulatory skills and increases their self-efficacy. On this note, modeling regulation of a task is of peculiar significance in inquiry learning where regulative processes manage the transformative processes. Self-regulation forms an important aspect of meta-cognition. Modeling presents a *conceptual model* to develop in learners an "internal model of expert performance" to emulate self -monitoring, reflection and correction skills (Collins et al., 1989). Modeling of co-regulative strategies (e.g., teacher-student) such as requesting information, restating or rewording statements provides an effective model for students to appropriate their own self-regulative processes (Hadwin & Oshige, 2011). This facilitates the approximation of regulation strategies and skills in undertaking similar ventures on their own.

3.3.2 The Plenary-Small Group-Individual (PSI) Classroom Script

In the Plenary-Small Group-Individual classroom script, students move from the plenary session to work in small groups before working individually. This transition will be abbreviated as the PSI classroom script. The theoretical framework on the *fading of scaffolding* forms the underlying premises of the PSI classroom script.

Scientific inquiry is an intellectually challenging undertaking for most students regardless of academic capacity (Krajcik, Blumenfeld, Marx, & Soloway, 1998). The transition from plenary to small group to individual inquiry task provides a prototype of *Science apprenticeship* (Bell et al., 2003) where apprentices learn the inquiry procedures and skills such as developing hypothesis, evaluating evidence and constructing scientific explanation. Science apprenticeship aims to foster the development of both cognitive and metacognitive skills in scientific inquiry. The core of apprenticeship lies in the provision of *scaffolding* and *fading*. In the PSI script transition, the fading of the scaffolds for both the small groups and the individuals is materialized in successive steps.

First, the observation of the modeling at the plenary level fosters the development of a conceptual model for the small groups before they proceed to collectively enact and practice the target inquiry skills modeled by the teacher. The teacher models the good strategies for learning and thinking (Hmelo-Silver, 2004). Following the plenary, students worked in small group; the collaborative inquiry serves as an important platform to foster differentiation and externalisation of the roles and activities in complex problem solving (Collins et al., 1989). Collaboration in inquiry leads to improved inquiry processes and better results (e.g., Okada & Simon, 1997) and relates positively to self-regulation. Research has shown that students who work together show both higher instances and increased awareness of self-regulation over students who work individually (Lazonder, 2005; Manion & Alexander, 1997; Manlove et al., 2006). Essentially, small group activities also provide an opportunity for explicit discussion of scientific concepts and reflection that promotes metacognition and self-regulation (Davis, 2003). Successful inquiry is contingent on both cognitive and meta-cognitive processes. Small group work itself is a cognitive scaffold (Perkins, 1993): the discussion and decision-making enables the individuals to internalise the transformative, as well as the regulative processes and skills. Next, students in the PSI script transition proceed to work individually. The gradual fading-out of the scaffolds (Pea, 2004) at the plenary and small group enables the individuals to internalize the components of the complex set of inquiry skills while teachers and peers have created 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. The fading of the scaffolds enables students at the small group and individual level to gain competency (Azevedo et al., 2004; Wecker & Fischer, 2011).

The PSI script transition also leverages on theoretical principles encapsulated in the ICAP framework on the activity types. The classroom script begins with the plenary level where the class engages in passive and active activity; observing the modeling and receiving guidance in the inquiry process with note-taking. There could be occasional posing of questions: otherwise, it is predominantly passive. Though seemingly passive, the plenary is deemed necessary as domain-specific factual and conceptual knowledge are central to the inquiry task. Active listeners are given that platform to test their understanding and pursue the issues they have, where apprenticeship may not afford (Collins et al., 1989). Moving onto the small group level, the interactive activity promotes the externalisation, elaboration and exploration of ideas which could lead to new knowledge construction (Chi, 2009; Saab et al., 2007). The emergent of diverse ideas is empirically attributed to the affordances of collaborative inquiry. At the individual level, students would then be in the capacity to assume greater agency in pursuing their own inquiry task. Active and constructive activities are necessary for the individuals to activate prior knowledge, assess knowledge gaps and construct new perspectives beyond the given learning materials.

In a nutshell, the gradual fading of scaffolding in the PSI classroom script condition is achieved through the different activity types at each of the social levels. Similar to the combination approach of classroom script and small-group script, where the modeling phase at the plenary level form a baseline component of a classroom script to assist students in the initial acquisiton of targeted skills, the small group script reinforces the automation of these targeted skills in the actual undertaking of the inquiry task (Kollar et al., 2011).

3.3.3 The Plenary-Individual-Small Group (PIS) Classroom Script

Students in the Plenary-Individual-Small Group classroom script move from the plenary session to work individually before working in small groups. This transition will be abbreviated as the PIS classroom script. The theoretical constructs framing the PIS transition is primarily derived from the idea of productive failure, which shall be discussed alongside theories on group cognition and the ICAP framework.

The PIS script transition seeks to simulate a ‘productive failure’ learning condition to foster better acquisition and approximation of the target inquiry skills in subsequent similar inquiry tasks. Importantly, ‘failure’ here refers to the process of generating and exploring multiple ideas before receiving the canonical solutions provided in direct instruction (Kapur, 2012). Productive failure epitomizes the delay of instruction, feedback and/ or structure as providing the necessary conditions to facilitate more divergent ideas, deeper discussions and spontaneous learning transfer (Kapur, 2012). Instead of delaying direct instruction, the idea of ‘delayed apprenticeship’ will be experimented in the PIS script condition, i.e., the delay of peer support and feedback. Students in this condition first work individually before working in small groups, i.e., active and constructive activities prior to interactive activities. The initial challenges and difficulties at the individual level could set up the very conditions for a more constructive collaboration at the small group level.

The hidden efficacy of 'failure' is subjected to the design of learning conditions. Designing for productive failure encompasses two phases: a *generation and exploration* phase, followed by a *consolidation* phase (Kapur & Rummel, 2012). These two phases embody interdependent mechanisms of creating a learning context (challenging but not overwhelming), providing platforms for explanation and exploration, and finally, providing opportunities for comparing, contrasting and consolidating. Applied to the PIS script transition, the modeling activity at the plenary level creates the baseline inquiry learning context and highlights critical conceptual features in the scientific inquiry process. Following the plenary session, students proceed to work individually. The active and constructive activities at the individual level provide students the platform to activate and differentiate prior knowledge related to the targeted concepts and inquiry skills. The *generation and exploration* phase at the individual level also means that students could possibly attempt to integrate new knowledge with prior knowledge, making connections and inferences. The self-explaining and asking of questions promote reflections and the construction of possible explanations in the inquiry process could amount to generating diverse ideas and exploring perspectives to attempt new inferences. When students move to work at the small group level, the collaboration and interactive activities afford them a *consolidation* phase. Students working in small groups are likely to surface the divergent ideas and perspectives they have at the individual level and attempt to apply them in inquiry task three. The grounding of different opinions, ideas and perspective forms a critical channel at the small group level in establishing common grounds to construct and to converge at shared meanings and knowledge. In the PIS script, the delay of peer support and feedback serves as the platform for productive failure to facilitate better retention of target inquiry skills and the emergent of new knowledge and innovative ideas.

The design of the individual phase prior to small group collaboration in the PIS script sequence also exemplifies other theoretical explanations. Macro-level coordination, micro-level communication and domain-specific demands characterize good collaboration (Rummel & Spada, 2005). Their study showed that by allotting sufficient individual time, learning partners are better able to incorporate their own individual domain knowledge, and thereafter, integrate individual contributions at the collaboration phase. A similar earlier study showed that a well-proportion of individual and joint work phases culminated in fruitful discussion of pooling together unshared information and individual opinions (Hermann et al., 2001). In both studies, the provision of individual time prior to interactive activities apparently has significant implications on coordination and communication during collaborative learning. The successful integration of individual ideas is contingent on mutual understanding, feedback and turn-taking. The same elements are essential composites of successful collaborative efforts in meaning-making and knowledge convergence. Similar to the instructional approach in problem-based learning, where the facilitator and the small group at the plenary first discussed and worked on a problem case, thereafter, the students individually undertook further research before converging with the small group to integrate and apply their knowledge (Hmelo-silver, 2004).

In sum, by designing the individual phase before small group work, the PIS script sequence aims to create the conditions for 'productive failure' to maximise learning, as well as create the relational context necessary to bolster better coordination and interaction in the small group work.

3.3.4 Summary

Collaboration in inquiry learning is lauded as the underlying mechanism to enhance and foster the acquisition of scientific knowledge and science inquiry skills. Hitherto, research has indicated that collaborative learning regardless of inquiry-based or problem-based setting or any other form of pedagogical intention requires instructional scaffold to see its desired outcomes of interaction and learning effectiveness. Supporting collaborative learning by means of instructional scaffolds, collaboration prompts, classroom scripts, small group scripts has received increasing attention in the research, as well as practice field.

Orchestrating inquiry learning in the science classroom aims to enhance the collaborative learning process by taking into account how individuals learn and how they learn as a collective unit. Hence, apart from the provision of collaboration prompts or cognitive scaffolds, classroom orchestration here focuses on the distribution and sequencing of activities across the three social planes of the classroom (Kollar et al., 2011). Essentially, it endeavours to investigate how the sequencing of classroom script could have an effect on the quality of coordination, collaboration and interaction in collaborative inquiry, which in turn shapes the individual and collaborative learning processes and outcomes.

Premised on three main theoretical frameworks of the underlying mechanisms that engender learning for the individual and the collective unit, two possible classroom scripts emerge: the Plenary-Small Group-Individual (PSI) and Plenary-Individual-Small Group (PIS). The PSI script embodies theory of scaffolding and fading (Collins et al., 1989; Pea, 2004), whereas, the PIS script exemplifies idea of productive failure (Kapur, 2006). The two differently sequenced classroom scripts also embrace the ICAP conceptual framework on different activity types and the different cognitive processes they invoke. Both script transitions start with the plenary activity to provide apprenticeship and a baseline learning context for the PSI and PIS respectively: teacher modeling of the inquiry processes. The variation of the script sequence follows after the occurrence of the plenary activity. The different transition in the PSI and PIS classroom scripts is captured in figure 2 which illustrates the sequencing of the different activity types at two social levels after the plenary level: the small group and the individual. For the PSI, interactive activity at the small group level precedes active and constructive activities at the individual level. The reverse is true for PIS. The design of the two differently sequenced scripts envisage possible varying effects on both the individual and small group inquiry learning processes and outcomes. The different activity types in the two variations might provide some insights into the coordination, as well as integration of individual ideas, views and contributions into the collaborative work space. This might, in turn, shape the quality of communication and interaction, which is pivotal for successful collaboration.

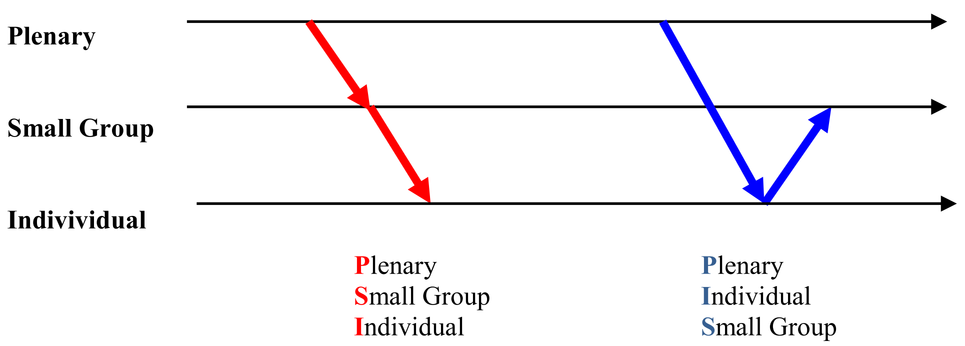


Figure 2: *The two differently sequenced classroom scripts: PSI vs. PIS*

4 Conceptual Framework of the Study and Research Questions

Collaborative inquiry learning has been empirically proven to be an effective instructional approach to foster students' scientific thinking and to develop students' scientific literacy. Collaborative intellectual activity affords opportunities to share insights and unearth diverse perspectives to create scientific knowledge. Theoretical frameworks on *scaffolding and fading*, *productive failure* and the *ICAP framework* underscore the potential of collaborative and interactive activities but from different approaches and perspectives. Orchestrating inquiry with classroom scripts (i.e., distribution and sequencing of activities across the social planes) is a promising approach to embed collaborative inquiry activities. This empirical study aims to analyze and compare the effects of two differently sequenced classroom scripts on both the individual and group processes and outcomes of inquiry learning. This chapter summarizes the conceptual framework of the study with regard to the transformative and regulative processes, outcomes, and the facilitation of the two differently sequenced classroom scripts in collaborative inquiry learning. Finally, the research questions of this study and the respective hypotheses will be presented.

4.1 The Conceptual Framework of the Study

In this study, the curriculum unit on plant adaptation in different living environment provides the platform for the inquiry tasks at the plenary, group and individual level. The two differently sequenced classroom scripts: Plenary-Small Group-Individual (PSI) and Plenary-Individual-Small Group (PIS) are the two independent variables. As for the dependent variables, transformative and regulative processes were measured as individual and small group inquiry learning processes, domain-specific knowledge as individual learning outcomes, and inquiry skills were measured as individual and group learning outcomes. The succeeding section will present the conceptualization of the framework which includes control variables, dependent and independent variables.

Based on the theoretical background presented in chapter 2, a framework for the analysis of the inquiry learning processes is conceptualized. Inquiry learning is characterized by two core processes: transformative and regulative processes (Njoo & De

Jong, 1993) and transformative processes are cognitive processes that yields knowledge and regulative processes are meta-cognitive processes necessary to manage the transformative process. For this study, regulative processes for the individual will be accessed from the individual think-aloud reflection and for the small groups, it will be the group discourse during the inquiry learning. Transformative processes will be accessed and analysed from the individual and the small group written work respectively.

However, transformative and regulative processes in inquiry learning may be influenced by a number of context factors (learning environment, inquiry tasks, individual learning prerequisites, motivational factors, classroom scripts). Regarding learning environment and inquiry task, the students will participate in the same learning environment and undertake the same type of inquiry tasks. In this way, the individual and collaborative learning conditions may be comparable to standard conditions of students within the natural variance. Contextual factors which include individual learning prerequisites are assessed and tested to ensure that all context factors except the two differently sequenced classroom scripts are held constant between the two experimental conditions (see table 1).

Table 1: *Control variables - individual prerequisites for collaborative inquiry learning*

Cognitive individual learning prerequisites
Domain-specific knowledge
Inquiry skills
Interest in domain knowledge, learning with media and learning with others
Epistemological beliefs.
Metacognitive awareness.

Transformative and regulative are two core processes which characterize the collaborative inquiry learning process. However, in collaborative inquiry learning, regulation of learning occurs at three social levels: self-, co- and shared levels. In the context of this study, a conceptual framework can be applied for the transformative and regulative processes at these three social levels as illustrated in table 2 (De Jong et al., 2005; Giljers & De Jong, 2005; Järvelä & Hadwin, 2013; Saab et al., 2007).

Transformative processes are cognitive processes relating to all mediating learning activities that effect the internalization of information (De Jong, 2005), in which domain information is transformed into knowledge (De Jong & Njoo, 1992). This includes the generation of information such as orientating, generating hypothesis, testing hypothesis and drawing of scientific conclusion (Njoo & De Jong, 1993). Asking question in the initial phase of analysing the inquiry learning task forms one of the initial phases in the transformative processes. Hence, transformative processes are likened to knowledge inference process (Njoo & De Jong, 1993) which poses higher demands on regulation of one's cognition. In biology inquiry, generating evidence, evaluating evidence and drawing conclusions are achieved chiefly through observational arguments.

Regulative processes affect students' engagement in transformative processes. Regulation refers to the ability of the individual or group to manage his/ their actions based on goals, plans and knowledge of task (De Jong et al., 2005) which embody regulative processes from orienting to evaluation, of which planning, monitoring and evaluation form the three core regulation processes (Manlove et al., 2007; White et al., 1999).

In collaborative inquiry, regulation involves three social levels: self, co- and shared. Successful regulation at these three social levels inevitably affects the quality of interaction and collaboration. In collaborative inquiry where reflective learning is pivotal to monitor the inquiry process, both metacognitive and socialcognitive processes play a deteminant role in inquiry learning in collaborative inquiry and reflection (White & Frederiksen, 1998; White et al., 1999). Self-regulation is an intrapersonal process with the focus on the individual regulating one's own behaviour. Co-regulation is seen an interpersonal process whereby one member regulates the activities of a fellow member (Saab, 2012) to offer transitional support for each other's self regulation. And shared-regulation occurs where group members work together to help each other construct 'meta-cognitive, meta-motivational, and meta-emotional knowledge' about collaborative work (Jarvela & Hadwin, 2013).

Table 2: *Dependent process variables*

Regulative processes	Transformative processes
Orienting	Orienting
Planning	Asking Questions
Instructing (applicable for small group level only)	Generating Hypothesis
Grounding (applicable for small group level only)	Testing Hypothesis
Testing	Generating Evidence
Monitoring	Evaluating Evidence
Evaluating	Drawing Conclusions
Social Levels (applicable for small group level only)	
Self-regulation	
Co-regulation	
Shared-regulation	

The above-mentioned transformative and regulative processes should likewise form the *outcomes of inquiry learning* (see Table 3) where these higher-order domain knowledge and skills in inquiry activities should eventually be internalised (Perkins, 1993).

Table 3*: Dependent outcome variables - domain specific knowledge and inquiry skills*

Outcomes of collaborative inquiry learning
Individually acquired domain-specific knowledge
Individually acquired inquiry skills
Collaborative inquiry skills (small group level)

To embed collaboration in the inquiry learning process, two differently sequenced classroom scripts were designed to support individual and collaborative inquiry learning could ensue: plenary-small group-individual (PSI) and plenary-individual-small group (PIS) (see table 4). The PSI script embodies theory of scaffolding and fading (Collins et al., 1989; Pea, 2004), whereas, the PIS script exemplifies idea of productive failure (Kapur, 2006). Both script transitions start with the plenary activity to provide apprenticeship and a baseline learning context for the PSI and PIS respectively. The variation of the script sequence follows the plenary activity.

Table 4: *Independent variables - classroom scripts*

Two differently sequenced classroom scripts
Plenary-Small Group-Individual (PSI)
Plenary-Individual-Small Group (PIS)

4.2 Research Questions

Based on the theoretical constructs and the findings on scaffolding individual and collaborative learning, the two differently sequenced classroom scripts will be investigated on their effects on transformative and regulative processes and outcomes in inquiry learning at the individual and at the small group level. To this end, several research questions can be formulated. First, the effects of the PSI vs. PIS script on the individual engagement in transformative and regulative processes as well as the quality of these processes (high- and low-level) will be examined. Second, the effects of the PSI vs. PIS script on the small group engagement in transformative and regulative processes, as well as the quality of these processes (high- and low-level) will be investigated. Third, effects of the PSI vs. PIS script on the individuals' domain-specific knowledge, as well as individuals' and small groups' inquiry learning outcomes will be studied. Finally, qualitative case studies will be applied to identify and evaluate discourse structures for instances that showed how the sequencing of the activities in the two script conditions have fostered specific high or low-level transformative and/ or regulative processes.

4.2.1 Research Questions on Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Individuals' Transformative and Regulative Processes in Inquiry Learning

(RQ 1a) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individuals' transformative processes, as well as high- and low-level transformative processes in inquiry learning?

The PSI classroom script embodies elements of *cognitive apprenticeship* (Collins et al., 1989) and *fading-out of the scaffolding* (Pea, 2004). Students in the PSI script condition, having received modeling and coaching from the teacher at the plenary, and thereafter, re-enact and practice these target skills with group members at the small group level (Interactive), would consequently, afford them greater capacity to appropriate these scientific skills at the individual level (Active & Constructive). Several empirical studies on collaborative inquiry showed that collaboration and interaction fostered the acquisition and execution of the knowledge schemata when individuals collectively articulate and elaborate their think-processes; making the scientific process explicit (De Jong, 2006; Linn & Eylon, 2011; Okada & Simon, 1997; Saab et al., 2005; Sandoval, 2003). Therefore, the PSI script condition is likely to facilitate more occurrences of transformative processes, more occurrences of high-level transformative processes and reduced the occurrences of low-level transformative activities at the individual level. The pooling together of ideas and perspectives could have increased the individuals' capacity to leverage divergent views and possibilities. On the contrary, students in the PIS script condition may experience 'productive failure' at the individual level, owing to *delayed feedback* (Mathan & Koedinger, 2003) and *delayed structure* (Kapur, 2008). Students in the PIS script condition may not be able to engage as actively in transformative processes nor in high-level transformative processes. Working individually before embarking on interactive activities at the small group level, could have deprived them of the platform to articulate and explore their individual ideas with the others. Reiterating Chi's ICAP framework, active and constructive activities promote the activation of prior knowledge and the construction of knowledge beyond given materials respectively. Hence, the 'delay' of interactive activities with peers at the individual phase could have forfeited them of the platform to co-construct knowledge and develop those new perspectives they have generated at the individual level.

Hypotheses:

The PSI script facilitates more occurrences of transformative processes than the PIS script.

The PSI script facilitates more occurrences of high-level transformative processes than the PIS script.

The PSI script facilitates fewer occurrences of low-level transformative processes than the PIS script.

(RQ 1b) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individuals' regulative processes, as well as high- and low-level regulative processes in inquiry learning?

According to Manlove et al. (2007), their study showed that knowledge gains in the inquiry processes are largely shaped by meta-cognitive processes. This aligns with Njoo and De Jong's (1993) postulation that regulative processes manage the transformative processes in inquiry learning. Based on this theoretical argument and prior empirical findings, students in the PSI script condition would then also be likely to show better engagement in regulative processes including high-level ones after obtaining assistance and transitional support at the small group level. As for students in the PIS script condition, they may encounter more challenges in self-regulation owing to the absence of transitional support (co- & shared level).

Hypotheses:

The PSI script facilitates more occurrences of all regulative processes than the PIS script.

The PSI script facilitates more occurrences of high-regulative processes than the PIS script.

The PSI script facilitates fewer occurrences of low-regulative processes than the PIS script.

4.2.2 Research Questions on Effects of Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Small Groups' Transformative and Regulative Processes in Collaborative Inquiry Learning

(RQ 2a) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small groups' transformative processes, as well as high- and low-level transformative processes in collaborative inquiry learning?

The PIS script is likely to facilitate more occurrences of the small group engagement in transformative processes owing to the *generation and exploration* phase in the individual activities prior to the collaborative inquiry. The active and constructive activities could enable the individuals to explore more diverse ideas and develop multiple perspectives. Further, the small groups in the PIS are likely to show more occurrences of high-level transformative processes. According to empirical studies on *productive failure*, initial poor performance owing to 'delayed' instruction, feedback or structure fostered better learning and transfer in subsequent similar tasks (Kapur, 2008; Mathan & Koedinger, 2003; Van Lehn et al., 2003). Hence, the PIS script which sees conditions of *desirable difficulties*, *delayed feedback* and *delayed structure* could possibly enable the individuals to bring their 'failures', their diverse ideas and methods to the group level; restructure and rework through them as a collective unit. This could imply that the PIS script condition might facilitate more high-level transformative processes than the PSI script. Another theoretical argument is that students in the PIS condition (as compared to PSI) first experienced active and constructive activities at the individual phase before participating in interactive activities at the small group level. This could have instead brought about better transformative processes at the group level as the individual phase might serve as a bridging platform to prepare the individuals for collaborative work. It aligns with Rummel and Spada's (2005) findings on allotting sufficient individual time leading to better coordinated collaborative activities and construction of a joint problem space (Roschelle & Teasley, 1995). Conversely, the small groups in the PSI script condition could possibly generate diverse ideas owing to the interaction and collaborative effort. However, there is possibility of coordination and communication problems during the integration of individual contributions into the joint work space owing to the lack of a pre-intersubjectivity activity to coordinate the individual and collective views (Kaptelinin & Cole, 1997).

Hypotheses:
The PIS script facilitates more occurences of transformative processes than the PSI script.
The PIS script facilitates more occurrences of high-level transformative processes than the PSI script.
The PIS script facilitates fewer occurrences low-level transformative processes than the PSI script.

(RQ 2b) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small groups' regulative processes, as well as high- and low-level regulative processes in collaborative inquiry learning?

A similar trend is likely to occur for the group engagement in high-level regulative processes. Schraw et al.'s (2006) research on the awareness of conditional knowledge posit that individuals with a higher degree of conditional knowledge are better able to assess the demands of a specific learning situation and transfer that knowledge in a next similar situation. The initial difficulties at the individual level affords them greater capacity and awareness, not only to review their regulation strategies, but also to do collaborative reflection at the group level. On the same note, it is likely that there will be more occurrences of high-level regulative activities, in particular, high-level grounding and high-level testing in the PIS script condition as the individuals at the small group level, will need to establish and negotiate common grounds (Clark & Brenan, 1991; Stahl, 2006) to converge at shared understanding. The active and constructive activities at the individual level are likely to afford them the individual space to do reflective thinking about challenges they encounter during the individual inquiry and surface them at the small group level for collective review and resolution. At the small group level, they are also likely to resurface verification and clarification questions they have earlier during the individual phase. In the same line of theoretical argument on coordinated collaborative activities (Rummel & Spada, 2005), small groups in the PSI script condition may see more occurrences of regulative processes as they emerged from the plenary and moved directly to interactive activities. Hence, there could be more occurences of overall regulative processes such as orienting, planning, instructing and monitoring to get into task and to set the group in direction. However, the PSI script condition may not facilitate occurrences of high-level regulative processes when coordination problems ensue. This is due to the absence of a pre-intersubjectivity phase prior to collaborative work to coordinate and integrate individual ideas into the collective unit.

Hypotheses:
The PSI script facilitates more occurrences of regulative processes than the PIS script.
The PIS script facilitates more occurrences of high-level regulative processes, in particular, more occurrences of high-level grounding and high-level testing than the PSI script.
The PIS script facilitates fewer occurrences of low-level regulative processes than the PSI script.

(RQ 2c) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the three social levels of regulation, i.e., self-, co- and shared-regulation in collaborative inquiry learning?

Self-regulated learning, co-regulated learning, and shared regulation of learning co-evolve along a continuum in any collaborative undertaking of a task (Järvelä & Hadwin, 2013). Aligning the *situative angle* on the social construction of regulation (Järvelä & Järvenoja, 2011) with the theory of *scaffolding and fading* (Collins et al., 1989) in cognitive apprenticeship, the PSI script (as compared to the PIS script) optimises all three levels of regulated learning: shared regulation at the plenary phase, the transitional support at small group level, and consequentially, the individual engagement and participation at the individual phase. This likely trend is consistent with the ICAP framework for the PSI condition where interactive activities at the small group level occur before the active and constructive activities at the individual level. When students in the PSI condition first experienced the interactive activities, it is likely to trigger more co- and shared regulatory activities to coordinate and manage the transformative processes.

Hypothesis:
The PSI script will see more activities (both transformative and regulative) occurred at the self-, co- and shared-level, as compared to the PIS script.

4.2.3 Research Questions on Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Individual Domain-Specific Knowledge, as well as Individual and Small Group Inquiry Skills

The aforementioned theoretical arguments and the corresponding hypotheses for the individual engagement in the transformative and regulative processes, should also apply to the individual and small groups' inquiry learning outcomes.

(RQ 3a) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individual acquisition of domain-specific knowledge?

Hypothesis:
Both PSI and PIS scripts facilitate individual acquisition of domain-specific knowledge.

(RQ 3b) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individual acquisition of inquiry skills?

Hypothesis:
The PSI script facilitates better individual acquisition of inquiry skills than the PIS script.

(RQ 3c) What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small group acquisition of inquiry skills?

Hypothesis:
The PIS script facilitates better acquisition of inquiry skills than the PSI script.

4.2.4 Research Questions on the Case Studies

The quantitative analyses illustrate the absolute frequencies of the transformative and regulative processes, as well as the quality of these processes in the two script conditions. Case studies of how the two differently sequenced classroom scripts shape the discourse structures of both the individuals and the group in the inquiry process will afford us an insight into the quantitative results. It facilitates an understanding of the evolvement of transformative and regulative processes, as well as, the quality of these statements both at the individual and the group level in the two differently sequenced script conditions. Therefore, the case studies aims to answer the following research questions.

(RQ 4a) How did the differently sequenced classroom scripts (PSI vs. PIS) shape the discourse structures in the individual engagement in high- and low-level transformative and regulative processes in collaborative inquiry learning?

(RQ 4b) How did the differently sequenced classroom scripts (PSI vs. PIS) shape the discourse structures in the group engagement in high- and low-level transformative and regulative processes in collaborative inquiry learning?

5 Methods of the Empirical Study

The research questions and hypotheses were analyzed in a quasi-experimental field study. The effects of the differently sequenced classroom scripts on the transformative and regulative learning processes and outcomes, as well as their quality levels (high and low) was investigated using a simple experimental design with two conditions. This chapter reports the sample and design, the experimental learning environment, and the variables. Apart from the statistical procedures, the qualitative approach of the case studies will be presented.

5.1 Sample and Design

Four classes of a total of 61 students (grade 6 to 9) from two international schools participated in the quasi-experimental field study. There were 43 males and 18 females. The average age of the students is 14.0 years old (SD = 0.89). 42 of the participants indicated German as their first language and for the rest of the 19 participants, they have spoken German for an average of 7.89 years (SD = 5.12).

Half of the students in each of the four classes were randomly assigned to one of the two experimental conditions: the Plenary-Small Group-Individual (PSI) classroom script and the Plenary-Individual-Small Group (PIS) classroom script. There were a total of 23 males and 6 females in the PSI script condition, and a total of 20 males and 12 females in the PIS condition. The description of sample is illustrated in table 5.

Table 5: *Demographic data of the participants in the two experimental conditions*

	Differently Sequenced Classroom Scripts	
	Plenary-Small-Group-Individual (PSI)	Plenary-Individual-Small Group (PIS)
Gender		
Male	23	20
Female	6	12
Age	M = 14.0 (*SD*= 0.95)	M = 14.0 (*SD*= 0.85)
First Language		
German	21	21
Others	8	11

To investigate the effects of the differently sequenced classroom scripts on the transformative and regulative learning processes and outcomes at both the individual and the group level, the students in the PSI and PIS script conditions were also randomly assigned into groups of 3 or 4 (note that for the PSI script condition, groups which initially began with 3 or 4 experienced dropouts in the later phases). There were a total of 10 groups per condition (see table 6).

Table 6: *An experimental design with two conditions*

Differently Sequenced Classroom Scripts	
Plenary-Small-Group-Individual (PSI)	Plenary-Individual-Small Group (PIS)
N= 29 (10 groups)	N= 32 (10 groups)

5.2 Learning Environment

Students worked on a curriculum unit on plant adaptation in different living environments which was partially realized in Web-based Inquiry Science Environment (WISE) (Linn et al., 2014). The curriculum unit consisted of in and out of classroom activities in three phases: pre-field trip, field trip (Botanical Gardens) and post-field trip. The medium of instruction was German. The curriculum unit began with an introductory lesson on photosynthesis and cell respiration before students proceeded with the inquiry tasks on plant adaptation. The succeeding sections will give focus to the learning material and learning environment for the individual and the group in these three phases that constitute the entire inquiry process.

5.2.1 Web-based Inquiry Science Environment (WISE)

The curriculum unit consists of an introductory lesson on photosynthesis and cell respiration, followed by the core unit of inquiry on plant adaptation in different living environments where students undertake two inquiry tasks: one task individually and one task collaboratively. The introductory lesson was adapted from the WISE online project library, and the unit of inquiry on plant adaptation was designed and developed according to the WISE theoretical framework, known as Scaffolded Knowledge Integration (Linn, 1995). This framework accords with the core national science standards to foster inquiry, student autonomy and critical thinking in the science classroom. The knowledge integration approach primarily aims to help students connect the ideas they bring to the science classroom to new ideas from science instruction. This is achieved by developing students' capacity to make inferences from the evidences, to employ criteria-based evidence evaluation and to draw scientific conclusions from multiple perspectives (Slotta & Linn, 2009). One of the theoretical tenets of WISE is to promote autonomous learning and collaboration by integrating inquiry and technology (Linn et al., 2014). The online WISE can be assessed using Web browser application such as Firefox or Internet Explorer and contains a library of online inquiry projects suitable for middle- and high-school students.

5.2.2 Pre-field Trip in the Classroom

The pre-field trip took place in the classroom. Students worked on laptops in twos or threes. They were given a login ID and password to access the online curriculum unit, entitled "The Energy Mystery". On the welcome page, students obtained an overview of the curriculum unit (see figure 3), the three phases of the inquiry process from pre- to post-field trip (see figure 4) and the scientific inquiry framework (see figure 5). Students are able to navigate the learning activities using the inquiry map on the left-hand frame of the WISE windows.

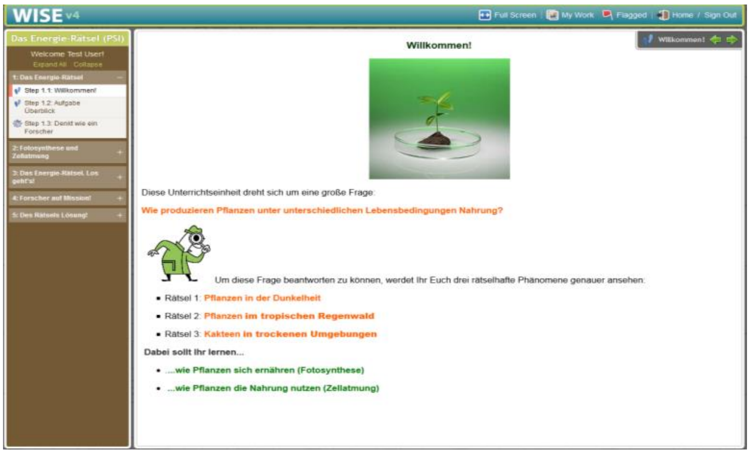


Figure 3: *Screenshot of the welcome page*

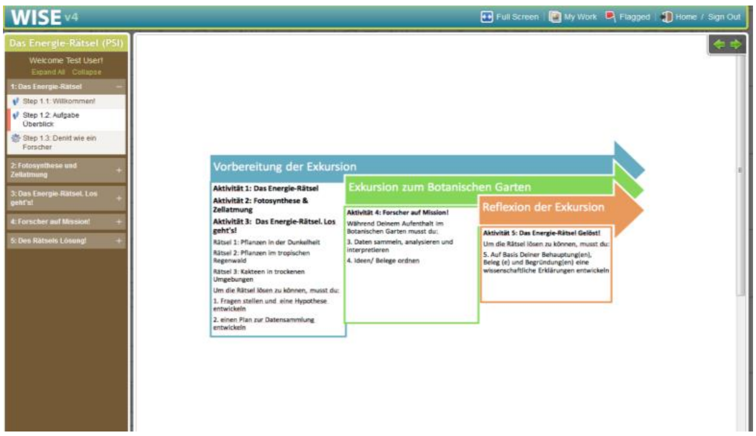


Figure 4: *Screenshot of the curriculum overview*

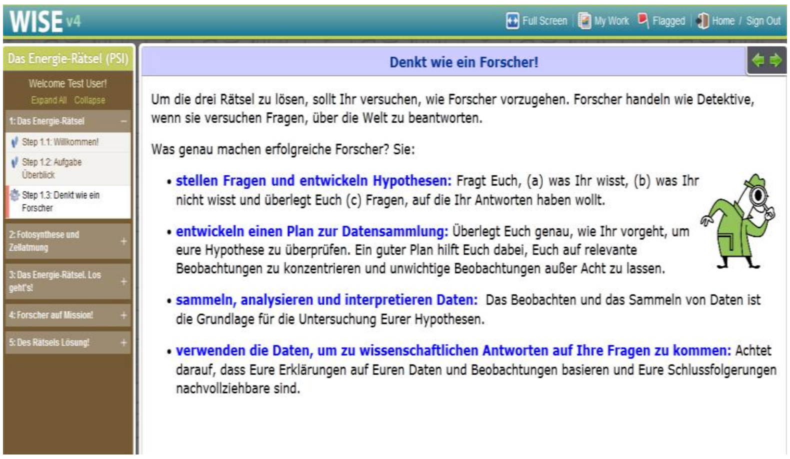


Figure 5: *Screenshot of the scientific inquiry framework*

Following the curriculum briefing by the teacher, students clicked on the introductory lesson on photosynthesis and cellular respiration which comprised nine sequential steps (see figure 6). Each step focuses on a sub-topic with simulations. The sub-topics are: 2.1 “Energy of the Sun”; 2.2 “How do plants make food?”; 2.3 “What do plants need for photosynthesis?”; 2.4 “What do plants make during photosynthesis?”; 2.5 “Where does photosynthesis happen?”; 2.6 “Chlorophyll and Chloroplast”; 2.7 “How do plants use glucose?”; 2.8 “Cellular Respiration in Mitochondria”; 2.9 “Photosynthesis and Cellular Respiration”. For each of the nine steps, students explored the simulations and responded to the questions to gain domain-specific knowledge. For instance, in step 2.1 on the “Energy of the Sun”, students clicked on the magnifying glass, explored the simulation to develop conceptual understanding of solar radiation.

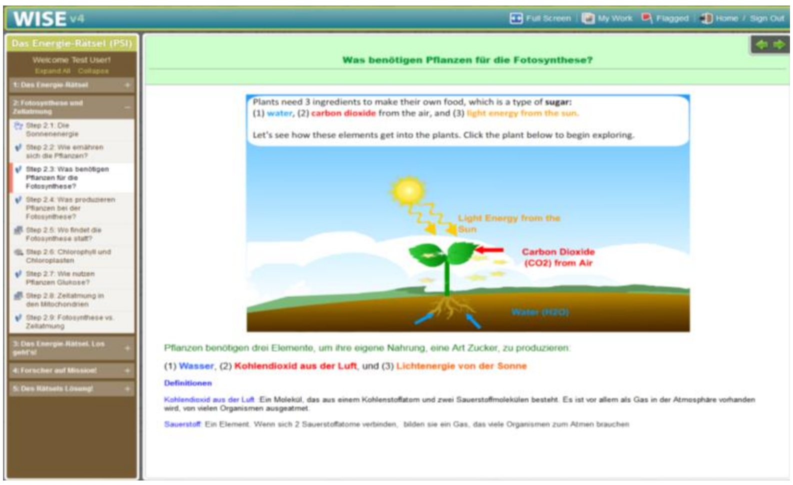
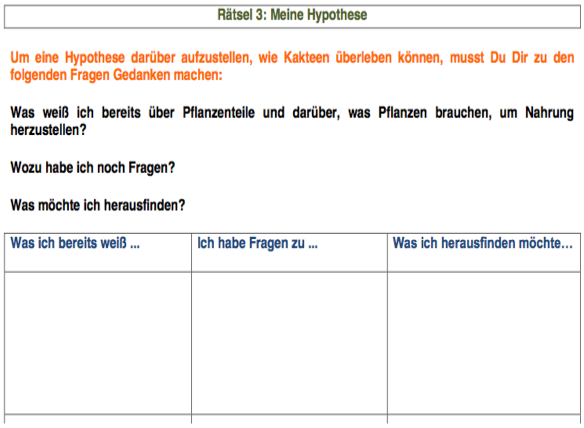


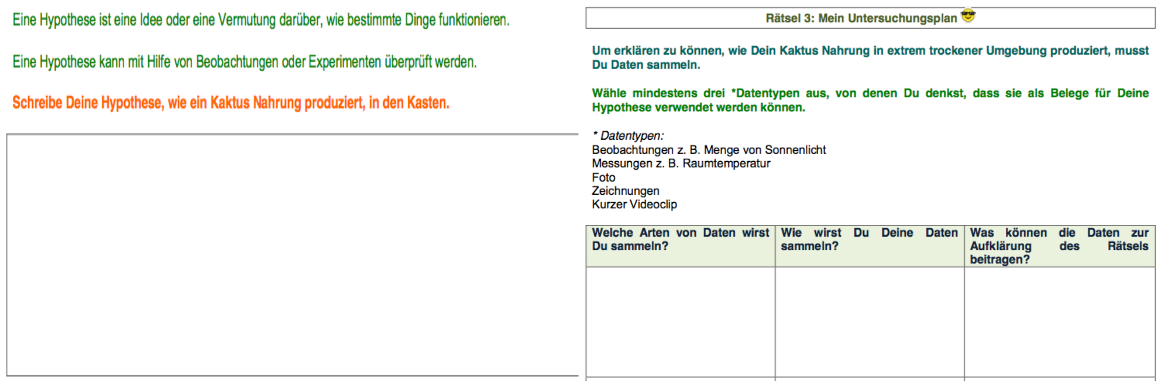
Figure 6: *Screenshot of the sub-topic on “What do plants need for photosynthesis?”*

After the introductory lesson, students proceeded to the inquiry tasks on plant adaptation in different living environments. Owing to the absence of technical facilities and wifi in the field study at the Botanical Gardens, all activities on the WISE platform after the introductory lesson were adapted into worksheets. Copies of the worksheets for the inquiry tasks from pre- to post-field trip can be accessed in appendix A. Here, the teacher first recapped the scientific inquiry practices (embodied in the inquiry framework) that students should be mindful of during the execution of the two inquiry tasks on plants in the tropical rainforest (inquiry task two) and plants in the desert (inquiry task three). Next, the teacher modeled the transformative processes using inquiry task one on plants in the dark before students undertook inquiry task two and three either individually or in small group according to the experimental conditions. For the subsequent inquiry tasks two and three, students went through the similar transformative processes beginning from orienting, asking questions, generating hypothesis and developing an inquiry plan to test their hypotheses. Taking inquiry task three as an illustration (see figure 7), students would first go through the transformative process of orienting, where they were given lead information about the cactus living environment and three species of cactus. They were supposed to select one of the cactus plants as their object of inquiry. Next, they proceeded to ask questions about their cactus plant: what they already knew, what further questions they had and what they wanted to find out. Following which, they had to develop a hypothesis about how the cactus plant made food and survived in the desert place. Finally, they were to develop an inquiry plan to collect evidences to support their hypothesis. These four transformative processes in the pre-field trip were repeated for both inquiry tasks two and three either at the individual or at the small group level.

Orienting



Asking questions



Eine Hypothese ist eine Idee oder eine Vermutung darüber, wie bestimmte Dinge funktionieren.

Eine Hypothese kann mit Hilfe von Beobachtungen oder Experimenten überprüft werden.

Schreibe Deine Hypothese, wie ein Kaktus Nahrung produziert, in den Kasten.

Rätsel 3: Mein Untersuchungsplan

Um erklären zu können, wie Dein Kaktus Nahrung in extrem trockener Umgebung produziert, musst Du Daten sammeln.

Wähle mindestens drei *Datentypen aus, von denen Du denkst, dass sie als Belege für Deine Hypothese verwendet werden können.

Datentypen:
Beobachtungen z. B. Menge von Sonnenlicht
Messungen z. B. Raumtemperatur
Foto
Zeichnungen
Kurzer Videoclip

Welche Arten von Daten wirst Du sammeln?	Wie wirst Du Deine Daten sammeln?	Was können die Daten zur Aufklärung des Rätsels beitragen?

Generating hypothesis Developing plan to test hypothesis

Figure 7: *Screenshot of inquiry task 3 and the transformative processes*

5.2.3 Field Trip at the Botanical Gardens

The field trip study took place at the Botanical Gardens, Schloss Nymphenburg, Munich, Germany. Dr. Kurbasik, the botanist, led the guided tour of the two halls: rainforest (inquiry task two) and cactus (inquiry task three) for all the four classes in four separate sessions. This is to say that at any one time, only one class is present. Prior to the guided tour of each of the two halls, the teacher provided some briefing on lesson procedure and students were then asked to look at the hypothesis and the data collection plan they have developed during the pre-field trip. The guided tour for each hall took approximately 30 minutes. After the guided tours, the students worked on inquiry task two and task three (either individually or in small group) according to the experimental conditions. Here, they first generated evidence(s), before putting a tick, a cross or a question mark next to these evidences. The generating of evidence could come in the form of information from the Botanist, the exhibits, observations of the plant structures and/ or measurements the students took of the temperature, humidity level etc. Figure 8 shows one of the guided tours at the cactus hall and the transformative process of generating evidence students would be engaged in during the field-trip.

Rätsel 3: Meine Ideen und Belege

Entwickle jetzt mindestens fünf Ideen zum Rätsel „Kakteen in trockenen Umgebungen" und schreibe sie in die Tabelle.

Hier sind einige Fragen, die Dir dabei helfen sollen:

- Welche Beobachtungen hast Du bei dem von Dir ausgesuchten Kaktus gemacht?
- Hat der Kaktus irgendwelche Besonderheiten, was seine Bestandteile (z.B. Stamm, Blätter, Wurzeln) angeht und was sind deren Funktionen?
- Was meinst Du, wie der Kaktus genug Sonnenlicht und die richtige Menge an Wasser bekommt, um Nahrung zu produzieren?
- Welche Ideen oder Erklärungen zu der Frage, wie Kakteen in extrem trockenen Umgebungen überleben können, hast Du während Deinen Forschungen entwickelt, und welche Ideen oder Erklärungen hast Du von Freunden, Familienmitgliedern, Lehrern oder Experten gehört?

Nummer	Meine Ideen und Belege	Quelle	√, 'X', '?'

Rätsel 3: Ideen und Belege ordnen

Schaue Dir die Ideen und Belege noch mal an, die Du in die Tabelle geschrieben hast:

- Welche davon sind hilfreich für die Entwicklung einer Erklärung, wie der von Dir untersuchte Kaktus genug Sonnenlicht und die richtige Menge an Wasser bekommt, um Nahrung zu produzieren?
- Welche Ideen und Belege sind nicht hilfreich?
- Bei welchen Ideen und Belegen bist Du Dir unsicher, ob sie Deine Hypothese unterstützen?

Ordne Deine Ideen und Belege in der Tabelle: Verwende ein **Häkchen '√' für relevante** Ideen, ein **Kreuz 'X' für irrelevante** Ideen und **ein Fragezeichen '?'** für Ideen und Belege, bei denen Du Dir unsicher bist!

Guided tour of the cactus hall — Generating evidence

Figure 8: *Guided tour of cactus hall and evidence generation for inquiry task 3*

5.2.4 Post-field Trip in the Classroom

In the post-field trip, the teacher began the lesson with a brief recap of the field trip and moved on to model the transformative process of evaluating evidence and drawing conclusions using the same inquiry task on plants in the dark. Similarly following which students worked on inquiry task two and task three (either individually or in small group) as per experimental conditions. In evaluating evidence, students had to produce evidences to support their claims in the reasoning process (see figure 9). Finally, with the claims, evidences and reasoning, students drew a scientific conclusion (they were only required to produce one conclusion minimum).

Rätsel 3: Kakteen in trockenen Umgebungen: Was ist Deine Lösung?

Rätsel 3: Was ist Deine wissenschaftliche Erklärung für das Rätsel „Kakteen in trockenen Umgebungen"?

Es ist Zeit, das Rätsel zu lösen, wie der Kaktus, den Du ausgewählt hast, in trockenen Umgebungen die richtige Menge an Sonnenlicht und genügend Wasser bekommt, um Nahrung zu produzieren. Nutze die Tabelle, um Deine Behauptung(en), Beleg(e) und Begründung(en) zu notieren.

Behauptung(en)	Beleg(e)	Begründung(en)
z. B. Ein Tiefdruckgebiet bringt meistens schlechtes Wetter.	z. B. Letzte Woche lag ein Tiefdruckgebiet über Deutschland, und es hat bei uns viel geregnet."	z. B. In Tiefdruckgebieten steigt die warme Luft nach oben und kühlt dabei ab – irgendwann erreicht sie eine Höhe, in der die Luft kondensiert, sich Wolken bilden und dann abregnen."

Verwende Deine Behauptung(en), Beleg(e) und Begründung(en) aus der Tabelle, um eine wissenschaftliche Erklärung zu konstruieren, warum Dein Kaktus in trockener Umgebung überleben kann. Füge diese in den Kasten unten ein.

Super! Du hast das Energie-Rätsel erfolgreich abgeschlossen!

Evaluating evidence — Drawing conclusion

Figure 9: *Evaluating evidence and drawing conclusion for inquiry task 3*

5.3 Experimental Phases

The experiment extended over five phases (see table 7). (1) Introductory and pre-tests: the students first received an introductory briefing on the experiment and curriculum unit. Next, they completed four different sets of questionnaires. Following which, they undertook a pre-test on domain-specific knowledge and a pre-test on inquiry skills individually, then in small groups. (2) Pre-field trip: students were briefed on the curriculum unit on plant adaptation. This was followed by an introductory lesson on photosynthesis and cell respiration. Thereafter, the teacher modeled the transformative processes using inquiry task one before students proceeded to work on inquiry task two either individual or in small groups according to the experimental conditions they had been assigned. Upon completion, students moved to inquiry task three. Again, they worked either individually or at small group level depending on the classroom script. (3) Field trip: Students participated in guided tour on plants in the tropical rainforest. This is followed by teacher modeling of the transformative process before students worked on inquiry task two either individually or in small groups according to their respective script conditions. Next, students participated in the guided tour of the cactus hall before working on inquiry task three individually for the PSI script condition and at small group level for students in the PIS condition. (4) Post-field trip: Again, the teachers modeled the transformative processes before students moved on to inquiry task two and inquiry task three. Likewise, the respective classroom script is observed for each inquiry task. (5) Post-test and debrief: students first undertook a post-test on inquiry skills individually, then in small groups. Next, students did a post-test on domain-specific knowledge individually. Finally, they completed four different sets of questionnaires before debriefing. In the following paragraphs, the experimental phases will be described in greater detail.

Table 7: *Overview of the experimental phases*

Social Levels	Phases	Time
	1. Introduction and pre-tests	
Plenary	Introductory briefing	05 min
Individual	Pre-test questionnaire on learning interests, metacognitive awareness computer literacy and epistemological beliefs,	15 min
Individual	Pre-test of domain-specific knowledge	10 min
Individual	Pre-test of domain-specific inquiry skills	10 min
Group	Pre-test of domain-specific inquiry skills	10 min
	2. Pre-field Trip (Classroom)	

Social Levels	Phases	Time
Plenary	Overview of curriculum unit on plant adaptation and inquiry tasks	10 min
Plenary	Introductory lesson on photosynthesis and cell respiration	30 min
Plenary (Teacher Modeling)	Inquiry Task 1: orienting, asking questions, generating & testing hypothesis	15 min
Small Group (PSI) Individual (PIS)	Inquiry Task 2: orienting, asking questions, generating & testing hypothesis	15 min
Individual (PSI) Small Group (PIS)	Inquiry Task 3: orienting, asking questions, generating & testing hypothesis	15 min
	3. Field Trip (Botanical Gardens)	
Plenary	Guided tour of tropical rainforest hall	30 min
Plenary (Teacher Modeling)	Inquiry Task 1: generating evidence	15 min
Small Group (PSI) Individual (PIS)	Inquiry Task 2: generating evidence	15 min
Plenary	Guided Tour of the Cactus Hall	30 min
Individual (PSI) Small Group (PIS)	Inquiry Task 3: generating evidence	15 min
	4. Post-field Trip (Classroom)	
Plenary (Teacher Modeling)	Inquiry Task 1: evaluating evidence & drawing conclusion	15 min
Small Group (PSI) Individual (PIS)	Inquiry Task 2: evaluating evidence & drawing conclusion	15 min
Individual (PSI) Small Group (PIS)	Inquiry Task 3: evaluating evidence & drawing conclusion	15 min
	5. Post-tests & Debrief (Classroom)	
Individual	Post-test of domain-specific inquiry skills	10 min
Group	Post-test of domain-specific inquiry skills	10 min
Individual	Post-test of domain-specific knowledge	10 min
	Debrief	05 min
Total		5.5 hrs.

5.3.1 Introduction and Pre-tests

The introduction and pre-tests formed the first phase and was conducted in a 50 minute lesson. The teacher began the session presenting an overview of the series of lessons, the objectives, as well as the overall schedule in the coming weeks. Students were able to pose questions and/ or clarify any doubts they had regarding the procedure. Next, the teacher put the entire class randomly into two groups: one he called the PSI group and the other the PIS group. Within each of these groups, he formed small groups of three or four. Thereafter, students proceeded to do four pre-test online questionnaires which aim to measure individuals' learning interests, metacognitive awareness and epistemological beliefs (see section 5.6). They were given 10 minutes. These questionnaires were developed using the online platform, soscisurvey.de. After which, students sat for the pre-test on individual domain-specific knowledge and individual inquiry skills (see section 5.5.3). Each of the tests took 10 minutes. Finally in the last 10 minutes, students moved into their assigned small groups to do the same pre-test on inquiry skills, but this time, at the small group level where they consolidated their ideas and presented a group response.

5.3.2 Pre-field Trip

The pre-field trip in the classroom began with the teacher presenting an overview of the curriculum unit on plant adaptation in different living environment which spanned over three phases: pre-field trip, field-trip and post-field trip. Next, the teacher introduced the topic on photosynthesis and cell respiration using the online WISE platform. Here, students worked in groups of two or three to explore a series of simulations to understand how photosynthesis and cell respiration take place as illustrated in figure 6. There were a total of nine different simulations in sequential steps.

Following the fifteen minutes of introductory lesson, the teacher briefed the students on the two inquiry tasks on plant adaptation: plants in the tropical rainforest (inquiry task two) and plants in the desert (inquiry task three). Next, using inquiry task one, “plants in the dark” as an example, the teacher modeled the transformative processes: orienting, asking questions, generating hypothesis and developing inquiry plan to collect evidences to test the hypothesis. After the plenary session, students undertook two inquiry tasks: plants in tropical rainforest and plants in the desert in their respective script conditions. For students in the PSI script condition, they first worked on inquiry task 2 at small group level before moving to inquiry task 3 at the individual level. Conversely, students in the PIS condition first worked individually on inquiry task 2 before moving to work on inquiry task 3 at small group level. The time alotted for each inquiry task is 15 min. As aforementioned, owing to the absence of wifi in the botanical gardens, worksheets for the respective script conditions (PSI and PIS) were given to the students to write down their responses for the transformative processes. This procedure is applied from pre- to post-field trip. The worksheets are similar for both script conditions, only the German independent possessive pronouns on the worksheets vary according to the classroom script sequence.

5.3.3 Field Trip

The field trip began with a brief recap of what the students did during the pre-field trip. The teacher also gave the students some time to look through the questions they had, the hypothesis they had generated and the inquiry plan they had developed to collect data for evidences. This is followed with a 30 minute guided tour of the tropical rainforest plants in the green house at the Botanical Gardens. Dr. Kurbasik, the botanist, conducted the tour, provided information and responded to queries students posed. After the tour of the rainforest hall, the students were led to a classroom opposite the green house. Again using inquiry task one for modeling at the plenary session, the teacher demonstrated the transformative processes of data collection and interpretation during the generating of evidence for plants in the dark (owing to some similar features and concepts for plants in the dark and plants in the tropical rainforest, the inquiry tasks were sequenced in this manner, as well as the tour of the two halls: rainforest followed by cactus). Next, students in the PSI script condition proceeded to work on inquiry task two (plants in the tropical rainforest) at the small group level whilst the PIS classroom script students worked on the same inquiry task but at the individual level. They had about 15 minutes to work on the task: list, interpret and analyse the evidences. Finally, they were to indicate if they considered the evidence relevant, irrelevant or questionable with a tick, a cross or a question mark respectively.

The guided tour of the cactus hall followed after the students completed inquiry task two. Similarly, prior to the tour, students are asked to review the questions, the hypothesis and the data collection plan they had developed for inquiry task three. The same botanist, Dr. Kurbasik conducted the 30 minutes tour of the cactus hall. After the tour, students went through the same transformative processes: generated ideas and evidences, and put a tick, a cross or a question as they assessed these evidences for source and relevance. Students in the PSI condition then worked on this task individually and vice versa, students in the PIS condition undertook the task at small group level. Students had about 15 minutes for this task.

5.3.4 Post-field Trip

In the post-field, the teacher began the lesson with a brief recap of the field trip and moved on to model the transformative processes of evaluating evidence and drawing conclusions using the inquiry task on plants in the dark as an example. The teacher demonstrated how evidence evaluation is scientifically carried out using evidence to support a claim in the reasoning process. Next, the teacher modeled the formulating of a scientific conclusion using claim, evidence and reasoning.

Thereafter, again students in the PSI script condition worked on inquiry task two at the small group level before proceeding to work on inquiry task three at the individual level. The reverse is true for students in the PIS script condition. Again, students had about 15 minutes for each inquiry task.

5.3.5 Post-tests & Debrief

In the final learning phase, students first sat for the post-test on individual inquiry skills (see section 5.5.3). After the scheduled 10 minutes, students moved into their assigned small groups to do the same pre-test on inquiry skills at the small group level where they were supposed to consolidate their ideas and presented a group response. Next, the students undertook a 10 minutes post-test on individual domain-specific knowledge. Finally, the teacher gave a debriefing of the learning journey and thanked the students for their participation.

5.4 Experimental Conditions

This section describes the simple design with two experimental conditions. The implementation of the two differently sequenced classroom scripts in the inquiry process will be illustrated. The treatment commenced only after the introductory lesson on photosynthesis and cellular respiration was carried out. Each of the three phases from pre- to post-field trip of the inquiry process begins with plenary and followed by the different script transitions in PSI and PIS classroom scripts respectively.

5.4.1 Classroom Script: Plenary - Small Group - Individual (PSI)

Following the introductory lesson, the entire inquiry process spanned three phases from pre-field trip to post-field trip. Each phase began with plenary session for modeling of the transformative processes specific to that phase, e.g., orienting, asking questions, generating and testing hypothesis during pre-field trip. Important to note too that inquiry task one is consistently used for all modeling sessions from pre-to-post field trip. After the modeling session at each plenary phase, students in the PSI condition then worked on inquiry task two at the small group level before working on inquiry task three at the individual level. This script sequence is strictly adhered to from pre-to post-field trip.

5.4.2 Classroom Script: Plenary - Individual - Small Group (PIS)

The reverse applies to the students in the PIS script condition. After the modeling session at each plenary phase, students in the PIS condition first worked individually on inquiry task two before working on inquiry task three in small groups. Again, this sequence is observed from pre- to post-field trip. The time alotted for each phase of the inquiry processes was the same as in the PSI script condition. Table 8 provides a comprehensive overview of the execution of the PSI vs. PIS classroom scripts and the designated duration.

Table 8: *Overview of the execution of the PSI vs. PIS classroom scripts*

Scripts & Social Levels		Inquiry Task(s) & Transformative Processes	Duration
		Pre-field Trip	
PSI	PIS		
Plenary (P) (Teacher modeling)		Inquiry Task 1: orienting, asking questions, generating & testing hypothesis	15 min
Small Group (S)	Individual (I)	Inquiry Task 2: orienting, asking questions, generating & testing hypothesis	15 min
Individual (I)	Small Group (S)	Inquiry Task 3: orienting, asking questions, generating & testing hypothesis	15 min
		Field Trip	
Plenary (P)		Guided Tour of the Rainforest Hall	30 min
Plenary (P) (Teacher modeling)		Inquiry Task 1: generating evidence	15 min
Small Group (S)	Individual (I)	Inquiry Task 2: generating evidence	15 min
Plenary (P)		Guided Tour of the Cactus Hall	30 min
Individual (I)	Small Group (S)	Inquiry Task 3: generating evidence	15 min
		Post-field Trip	
Plenary (P) (Teacher modeling)		Inquiry Task 1: evaluating evidence & drawing conclusion	15 min
Small Group (S)	Individual (I)	Inquiry Task 2: evaluating evidence & drawing conclusion	15 min
Individual (I)	Small Group (S)	Inquiry Task 3: evaluating evidence & drawing conclusion	15 min

5.5 Operationalization of Dependent Variables

The goal of the empirical study was to measure the effects of the differently sequenced classroom scripts PSI and PIS (the independent variables) on the transformative and regulative processes, as well as outcomes (the dependent variables) of both the individuals and the small groups in collaborative inquiry learning. This section will present all dependent variables including the transformative and regulative processes and outcomes, as well as the social levels. Data sources and instruments of measure will also be presented.

5.5.1 Process Data and Instrument of Measures

The data for both the transformative and regulative processes of the individuals and the small groups were collected during the inquiry learning process from pre-to-post field trip. Table 9 provides an overview of the data collection process and the data sources for both the individuals and the small groups.

For the individuals, the data source for the transformative processes is derived from the individual written tasks and the data source for the regulative processes is the audio recordings of the individual responses to the reflection questions at the end of the activities from pre-to post-field trip (every student was given a digital audio recorder).

For the small groups, the data source for the transformative processes is derived from the small group written tasks and the data source for the regulative processes and the social levels is the audio recordings of the discourse during the small group work.

Table 9: *Overview of data collection process and data source*

Data Source (Individual)	Data Source (Group)
Pre-field Trip	
Transformative Processes Individual written tasks for orienting, asking question, generating hypothesis and testing hypothesis.	*Transformative Processes* Small group written tasks for orienting, asking question, generating hypothesis and testing hypothesis.
Regulative Processes Individual responses to two reflection questions: What did you already know and what must you know to develop your inquiry plan? How did you go about planning your inquiry procedure?	*Regulative Processes and Social Levels* Group discourse during small group work
Field Trip	
Transformative Processes Individual written tasks for generating evidence	*Transformative Processes* Small group written tasks for generating evidence
Regulative Processes Individual responses to two reflection questions: What other questions and/or issues surface when you think about your hypothesis and your inquiry plan? What changes would you make if your inquiry plan does not work out?	*Regulative Processes and Social Levels* Group discourse during small group work
Post-field Trip	

Transformative Processes Individual written tasks for evaluating evidence and drawing conclusions.	*Transformative Processes* Small group written tasks for evaluating & drawing conclusions
Regulative Processes Individual responses to two reflection questions: What difficulties and challenges did you encounter during the inquiry process? And how did you resolve them? Were you able to carry out your inquiry as planned? If yes, why? And if no, why not?	*Regulative Processes and Social Levels* Group discourse during small group work

The transformative and regulative processes were analyzed using the coding categories adapted from De Jong et al. (2005) and Saab et al. (2007). The descriptor for each category of the transformative processes was further adapted from the National Research Council (2012) and Fischer et al.'s (2014) work on epistemic activities in scientific reasoning and argumentation. The coding category and descriptor for the three social levels was adapted from Järvelä and Hadwin (2013). Further, these two processes were also coded on a high or low quality level. Examples of statements that illustrate the quality level (written work for transformative) and utterances (audio recordings for regulative) will be surfaced in the section labelled categorization (see section 5.5.2).

Unit of analysis

In the quantitative analysis, each idea in the individual and small group written tasks form a unit of analysis (Chi, 1997) and was coded for transformative processes. Each idea may contain one or more sentences. For the regulative processes and social levels, every five seconds of the audio recordings for both individual and group was coded for regulative processes and social levels.

Rater training

Overall, there were 61 individuals' written work and 20 small groups' written work for transformative processes. As for regulative processes, there was approximately 600 minutes of audio recodings for the individuals' reflections and 800 minutes for small groups' discourse from pre-to-post field trip. There was no sampling and all collected data was analysed. Two independent raters were trained to code for transformative and regulative by processing the written work and audio recordings of eight individuals and two small groups together, which constitutes 10% of the total data. Any disagreements between the coders were resolved by means of collective review of students' written work for transformative processes and collective listening to the audio footages for regulative processes and social levels. One of the raters then coded the rest of the data independently.

5.5.2 Categorisation

The simultaneous coding of the regulative processes, high and low regulative processes, as well as the three social levels of regulation (self, co- & shared applied to small group work only) was made possible with a multimedia player system, videograph. Videograph affords the construction of multiple categories for concurrent multiple codings. The audio footage was coded per five seconds for the regulative processes and social levels. Frequencies of each type of regulative processes at both quality levels (high- and low-level), as well as the social levels as dependent variables were used in the analyses.

(1) *Transformative processes in inquiry learning*

Students' written work at the individual and group level was coded for transformative processes that constitute the scientific practices in inquiry learning: (a) orienting; (b) asking question; (c) generating hypothesis, (d) testing hypothesis; (e) generating evidence; (f) evaluating evidence and (g) drawing conclusion. Each idea was also coded for high- or low-level. We define a high-level transformative statement, e.g., evaluating evidence (high), as one that contains scientific reasoning for a claim made and a low-level statement would be one without any scientific explanation. Cohen's Kappa as indicator of inter-rater reliability was satisfactory with $\kappa = .70$ for individual transformative processes, $\kappa = .72$ for high- and low-level individual transformative processes. For group written work, Cohen's Kappa as indicator of inter-rater reliability was satisfactory with $\kappa = .83$ for group transformative processes, $\kappa = .78$ for high- and low-level group transformative processes. For each of the transformative processes, an example from students' written work will be presented to illustrate its accorded quality: high or low.

(a) ***Orienting.*** An idea which demonstrated the activation of prior knowledge or retrieval of available information from the learning materials to identify parameters and variables on the subject of inquiry, e.g., bamboo plants in tropical rainforest, was coded as orienting. Students who were able to make interpretive connections of the pieces of information, e.g., between structure of a plant and its functions would get a high for orienting and those who purely reproduced information from given learning materials would get a low for orienting (see table 10).

Table 10: *Examples of high- and low-level orienting*

Orienting (High)	Kakteen haben keine Blätter, in denen sie Chloroplasten haben.
Orienting (Low)	Kakteen leben in der Wüste. Sie brauchen extrem wenig Wasser.

(b) ***Asking questions.*** An idea was coded as asking question when students displayed the scientific habit of mind to critique information and the need to pursue evidences for further reasoning. In this instance where the topic of inquiry was on plant adaptation, a high-level question was one that probes the structure of a species, whereas, a low-level question was one that remained general and/ or lacks depth. The examples below were taken from students who chose cactus as the plant of their inquiry in dry places (see table 11).

Table 11: *Examples of high- and low-level questions*

Asking questions (High)	Wo haben Kakteen Chloroplasten? Wo Kakteen ihre Glukose herstellen?
Asking questions (Low)	Kann zuviel Wasser schädlich sein?

(c) ***Generating hypothesis.*** For biology, a hypothesis would be one that could be supported by further investigation or verification of evidences, rather than through a methodological experiment. Here, students had to formulate hypothesis on how the plants they had chosen survived in their respective living environments (tropical rainforest or desert). A high-level hypothesis was one that inferred relations between variables and a low-level hypothesis was one that was too simplistic, obvious or derives from pure guesses, which often required no effort of further scientific inquiry nor possible investigation (see table 12).

Table 12: *Examples of high- and low-level generating of hypothesis*

Generating Hypothesis (High)	Kakteen haben Chloroplasten in ihrem Stamminneren und speichern dort (in der Zelle) das Wasser.
Generating Hypothesis (Low)	Der Kugelkaktus speichert Wasser.

(d) ***Testing hypothesis.*** An idea was coded as testing hypothesis high when it developed an inquiry plan that considered the type of data and method of data collection that was able to test the hypothesis formulated. A low-level testing of hypothesis was one where the data collection method nor type of data was neither able to prove or disprove the formulated hypothesis in a scientific manner (see table 13).

Table 13: *Examples of high- and low-level testing of hypothesis*

Testing Hypothesis (High)	Information zum Aufbau der Kakteen, wie sie Wasser speichern: recherchieren, mikroskopieren.
Testing Hypothesis (Low)	Einen Kaktus nicht Giessen…

(e) ***Generating Evidence.*** A piece of evidence was considered high-level when it demonstrated observations, comparisons and descriptions to make valid inferences. For instance, how the structure of a cactus adapts to the living environment to produce glucose. A low-level evidence was one that contained a claim without any scientific verification (see table 14).

Table 14: *Examples of high- and low-level generating of evidence*

Generating Evidence (High)	Der Kugelkaktus ist rund, um wenig Oberfläche zu haben, um wenig Wasser zu verlieren.
Generating Evidence (Low)	Kakteen sind rund. Sie können Wasser speichern.

(f) ***Evaluating Evidence.*** An idea was coded as evaluating evidence when students were able to analyse and interpret the data/ observations to construct scientific explanations of a phenomenon. In high-level evaluating of evidence, students were able to use evidence to support their claim in the scientific reasoning process to make connections between evidence and pre-existing ideas. A low-level evaluating of evidence was one where students made claims without scientific evidences or show gaps or weaknesses in explanatory account to support a claim (see table 15).

Table 15: *Examples of high- and low-level evaluating of evidence*

Evaluating Evidence (High)	Behauptung(en): Der Kugelkaktus versucht, den Wasserverlust zu minimieren. Beleg(e): Sie sind so gebaut, dass sie wenig Oberfläche haben. Begründung: Bei einer grossen Oberfläche trifft das Sonnenlicht mehr, und das Wasser wird stärker erhitzt, was zu Wasserverlust führt.
Evaluating Evidence (Low)	Behauptung(en): Kakteen leben in der Wüste. Beleg(e): Wir haben Kakteen in der Wüste gesehen. Begründung: Kakteen haben sich mit ihrem Äusseren an die Bedingungen in der Wüste angepasst.

(g) ***Drawing Conclusion.*** An idea was coded as developing scientific conclusion when it was able to use evidence to support a claim in the scientific reasoning process. A high-level scientific conclusion contained the three core features in constructing scientific argument: claim, evidence and reasoning. A low-level conclusion was one which lacked substantial evidence in the reasoning process to support its claim or contained flaws in making valid scientific inferences (see table 16).

Table 16: *Examples of high- and low-level drawing of conclusions*

Drawing Conclusion (High)	Der Kugelkaktus kann in einer trockenen Umgebung überleben, da er Wasser in seinem Gewebe speichern kann und sie versucht, den Wasserverlust zu minimieren. CO_2 und Licht kriegt er tagsüber im Überfluss.
Drawing Conclusion (Low)	Der Kugelkaktus hat sich mit seiner runden Form und seinen Stacheln statt Blättern an die Wüste angepasst.

(2) ***Regulative processes in inquiry learning.***

The regulative processes were coded per five sec. for both the individuals and the group. As mentioned, data for the individuals' regulative processes was derived from the individuals' responses to the reflection questions and data for the groups' regulative processes and social levels was taken from the group's discourse during the small group collaborative work. Rater also differentiated between high- and low-level regulative processes. Non-regulative processes include silence, casual conversations, writing and reading of reflection questions (for the individuals). Cohen's Kappa as indicator of inter-rater reliability was κ = .82 for individual regulative processes, κ = .74 for high and low individual regulative processes. For the group regulative processes, Cohen's Kappa as indicator of inter-rater reliability was satisfactory with κ = .78 for group regulative processes, κ = .73 for high and low group regulative processes and κ = .70 for social levels. Sample utterances of each of the high- and low-level regulative processes will be illustrated.

(a) ***Orienting.*** Students indicated preparation for task at hand: expressed one's own opinion, activated prior knowledge and mentioned possible strategies. A high-level orienting showed perceptiveness of task requirements, awareness of task goals, keen awareness of knowledge gaps and possible learning strategies. Conversely, a low-level orienting occured where students showed lack of awareness of task characteristics; unable to formulate good questions nor mobilize the necessary information during the pre-field phase (see table 17).

Table 17: *Examples of high- and low-level orienting*

	Individual Reflections	Group Discourse

Orienting (High)	Ich weiß, dass sie Glukose benötigen, die sie einspeichern können, wenn sie kein Licht haben.	N: Ja, ich nehme an, das Licht nehmen sie tagsüber auf und die S: Und wo tun sie es hin? So: Sie speichern sie. N: Im Chlorophyll.
Orienting (Low)	Ich weiß, der Kaktus mit extremem Klima … mit extremen Klima überleben kann.	J: Und was ist denn so besonders am tropischen Wald? L: Weil die so wenig Sonne kriegen und es fast nicht regnet. P: Er wird Regenwald genannt, weil es so feucht ist.

(b) ***Planning.*** Utterances that displayed attempts to coordinate the planning, sequencing and execution of activities in the inquiry process were coded as planning. A high-level planning showed systematic organisation for execution of the inquiry plan and documenting of progress, while a low-level planning displayed lack of coherence in the inquiry plan, e.g., the method and mode of data collection is unclear or not viable (see table 18).

Table 18: *Examples of high- and low-level planning*

	Individual Reflections	Group Discourse
Planning (High)	Erstmal schreibe ich auf, was ich weiß, dann, was ich wissen will. Das Dritte ist, was ich folgern werde, dann, was ich testen werde.	L: Ja… hmm…warte, welche Art von Daten werden wir jetzt… P: Messungen… N: Wachstum des Bambus…
Planning (Low)	Nach einem Monat werde ich dann das richtiges zweimal oder dreimal durchführen.	Sh: Wie werden wir die Daten sammeln? N: einem Kaktus lange kein Wasser geben… S: ok …

(c) ***Instructing*** (Applicable only for small group collaboration). Utterances that were instructive or directive: asking fellow group members to carry out a task. A high-level instructing demonstrated good communication skills which fostered team spirit and a low-level instructing statement often showed dominance and assertions which could cause conflicts or acceptance of instructions without amiable discussions (see table 19).

Table 19: *Examples of high- and low-level instructing*

	Individual Reflections	Group Discourse
Instructing (High)	N. A.	L: Gruppenrätsel…das sollen wir zusammen machen… dann werden wir vorlesen…
Instructing (Low)	N. A.	V: Ich hab' hier schon. Mach du einfach 01, 02, 03.

(d) ***Grounding*** (Applicable only for small group collaboration). Utterances that sought clarification by posing verification questions to arrive at a consensus, to dispute and/ or to modify a contribution were coded as grounding. A high-level grounding showed students pose sound verification questions to arrive at shared understanding or to bring the group's contributions to a higher platform in the process of affirming or constructing scientific explanations. A low-level grounding occurred when students showed immediate agreement without further probes or disagreement without sound scientific reasoning (see table 20).

Table 20: *Examples of high- and low-level grounding*

	Individual Reflections	Group Discourse
Grounding (High)	N. A.	J: Wie kommen sie mit der Hitze klar? M: Sie besitzen einen anderen Aufbau. L: Sie besitzen einen anderen Aufbau, einen anderen Stoffwechsel.
Grounding (Low)	N. A.	V: Also ... schreib mal die Stichpunkte, oder? gegen Trockenheit ... ja T: Ok ... fertig ... bereits ... wieso ist es?

(e) ***Testing.*** Utterances that showed students providing summary, checking of comprehension and checking for sufficiency and accuracy of information were coded as testing. Testing usually occurred during and after the data collection process, here, it was during and after the field trip. Thinking of problems, posing of questions, drawing conclusions and comparisons during this phase were also coded as testing. A high-level testing occurred when students displayed the above-mentioned features in their discussion and assessment of the evidence collated during the construction of scientific explanation. Conversely, low-level testing utterances merely summarised without demonstrating critical thinking: showed weak or no attempts to verify data and/ or to identify possible issues or gaps in providing scientific explanations (see table 21).

Table 21: *Examples of high- and low-level testing*

	Individual Reflections	Group Discourse
Testing (High)	Ich werde wahrscheinlich die Fragen ein bißchen vereinfachen, ein bißchen aufbauen, und dann gucken.	L: Pflanzen, die über dem Boden leben, haben meist Luftwurzeln, damit sie Nahrstoffen aus der Luft entnehmen, z.B. Orchideen… J: Was können wir noch dazu sagen? M: Pflanzen versuchen schnell ans Licht zu gelagen...ja, wegen der Dunkelheit…

Testing (Low)	Ich hab' das auch gemessen, aber ich meine, es gibt verschiedene...	V: Ok, Leute, ich hab' ganz viele Notizen gemacht. Der Kugelkaktus hat die perfekte Form S: Er hat also…nachts...verliert er weniger Wasser… V: Also, ich würde sagen, wir nehmen die Form, die Nahrungsaufnahme, das Wasser und das Licht.

(f) ***Monitoring.*** Utterances that showed active tracking and discussion of task progress were coded as monitoring. High-level monitoring of learning activities showed reflection and comparison on the progress of the inquiry plan and the set goals. Importantly, learners were able to propose measures to renegotiate direction to arrive at intended goals if misalignment arose. Low-level monitoring displayed weak judgements or evaluation of task progress and work processes; unable to suggest viable solutions to address the situation (see table 22).

Table 22: *Examples of high- and low-level monitoring*

	Individual Reflections	Group Discourse
Monitoring (High)	Dann werde ich versuchen, es von anderen Perspektiven zu betrachten und andere Möglichkeiten da einzubeziehen.	V: Dann Toleranz gegen Trockenheit… das können wir nehmen … oder dickere äussere Schaft reduziert Wasserverlust. Dazu haben wir auch viele Informationen.
Monitoring (Low)	Falls es nicht klappt, werde ich keine Änderungen vorfürhren, weil es klappen wird…ich weiß es	N & L: Wissenschaftlich?... Aber wir haben auch sonst nichts mehr, das wisst ihr? Wir haben keine Behauptungen mehr, keine Begründungen.

(f) ***Evaluating.*** Utterances that contained comments and feedback on the execution of the inquiry task, as well as on the learning process at the individual and small group level. High-level evaluating demonstrated critical thinking and reflection on the learning process and progress; able to comment on areas that need improvement and/ or even suggest measures to address those issues. Low-level evaluating showed lack of meta-cognitive and/or sociocognitive knowledge to assess the effectiveness of the learning strategies employed (see table 23).

Table 23: *Examples of high- and low-level evaluating*

	Individual Reflections	Group Discourse

Evaluating (High)	J: Ja, ich konnte den Plan durchführen weil ich dafür geplant habe und auch weiss...	M: Wir haben den Untersuchungsplan eigentlich richtig durchführen können, aber wir müssen ...extra Zeit und wir müssen aufmerksamer zuhören...und ein bisschen nachdenken.
Evaluating (Low)	F: Wenn das nicht funktioniert, dann ist das kaputt, oder? Glaube ich…	G: keine Frage und keine Veränderung…

(3) ***Social levels in inquiry learning.***

Three forms of regulation occur in any collaborative work. Utterances that indicated an intrapersonal process where a student externalised his or her opinion or contribution during the collaborative inquiry process was coded as self-regulation. However, where he or she sought an affirmation or assistance from a peer and /or a discussion ensued between the two, it was coded as co-regulation. Shared-regulation occurred when members of the group worked together to assist one another in the regulation of meta-cognition. Examples of utterances showcasing these three social levels are illustrated in table 24.

Table 24: *Examples of self-, co- and shared regulation at the small group level*

	Group Discourse
Self-regulation	L: Ja, ich würde erstmal die erste Seite lesen, dann die zweite
Co-regulation	J: Willst du vorlesen? L: Nein, ich glaube, wir können anfangen zu lesen
Shared-regulation	J: Ok… Wir haben zwei Sachen. L: Wir haben gesagt, Pflanzen brauchen Sonnenlicht, um Glukose herzustellen, und das steht hier… er versucht, möglich schnell... J: …ans Licht zu kommen…wächst schnell… N: Also, er braucht Licht. L: Genau. N: Behauptungen. Er braucht Sonnenlicht, um Glukose herzustellen.

5.5.3 Outcome Measures

The acquisition of domain-specific knowledge and domain-specific inquiry skills were considered as learning outcomes: the former was measured only at the individual level and the latter at both the individual and the group level. These two dimensions of outcomes were assessed during the pre-post tests, i.e., before and after the treatment.

For the domain-specific knowledge test, there was a total of 13 items (see appendix B): eight items on factual knowledge, five items on conceptual knowledge. The items were adapted from WISE library of online resources (Linn et al., 2014) to test the Webb's depth-of-knowledge (DOK): factual and conceptual (Hess, 2006). An exemplary item of the conceptual test items was “5.2. Welche Rolle spielt Kohlendioxid bei der Fotosynthese und der Zellatmung?”. The domain specific knowledge test was reliable with Cronbach’s α = .71. A scoring rubric of 3 levels (‘0’ for no answer, unclear or incorrect, ‘1’ for partial understanding and ‘2’ for full understanding) was applied to assess students’ performance. Cohen’s Kappa as indicator of inter-rater reliability was κ = .87 for pre-test and κ = .88 for post-test.

The domain-specific inquiry test aimed to assess students’ inquiry skills at the individual, as well as group level. The inquiry task for pre-test was, “How much water is enough for my green bean plant?” (see appendix C) and for the post-test was, “Which colour of light do you think is most beneficial for the growth of the green bean plant?” (see appendix D). The topic for the pre- and post-test was different, but the same set of skills was tested. Students were assessed for three core elements in inquiry: aim of experiment and development of hypothesis, variable identification and experiment methods. Owing to curriculum time constraints, not all transformative outcomes could be tested in the pre-post test, only four transformative processes in the hypothesis space (Klahr & Dunbar, 1988) could be tested: orienting, asking question, genenerating and testing hypothesis. For both the pre-and post-inquiry tests, students first worked individually before proceeding to work in their small groups on the same inquiry tests. To ensure that there was no compromise of written responses, individual tests were collected before students moved into groups and group inquiry test papers were then distributed for group written responses. A scoring rubric ranging from 1 to 3 (adapted from Van Horne, Bricker, & Bell, 2013) was used to assess students inquiry skills in three core elements (see table 25 for an overiew and appendix E for the detailed description of scoring elements and scoring rubric). Next, two raters were trained to assess the inquiry tests of seven individuals and two groups. Cohen’s Kappa as indicator of inter-rater reliability was κ = .70 for pre-test and κ = .85 for post-test.

Table 25: *Overview of scoring elements and scoring rubric for pre- and post-inquiry test*

Scoring Elements
1. Aim of the Experiment and Development of Hypothesis 2. Identifying Variables 3. Discussion of Methods / Procedure
Scoring Rubrics

<table>
<tr><td>Does not reach a standard described by any of the descriptors given below</td><td colspan="2">Not Yet</td><td colspan="2">Approaches Expectations</td><td>Meets Expectations</td></tr>
<tr><td>0</td><td>1</td><td>1.5</td><td>2</td><td>2.5</td><td>3</td></tr>
</table>

5.6 Control Variables

Control variables were assessed using online questionnaires of multiple choice items. The data for control variables were collected prior to the experiment. The individual control variables included:

(1) ***Demographic data.*** Several demographic variables, namely, gender, age and first language (and years speaking German as a foreign language) were assessed by means of an online questionnaire (see table 5).

(2) ***Prior domain-specific knowledge and inquiry skills.*** Prior knowledge and inquiry skills were assessed with two tests: multiple choice and short-answer questions, and inquiry test respectively. These were analogous test to the post-tests. The reliability of the pre/post knowledge tests and the Cohen's Kappa for inter-rater reliability were sufficient (see section 5.5.3).

(3) ***Interest.*** The interest in domain knowledge, learning with media and learning with others was measured with a self-developed scale of 15 items (see appendix F). It was measured prior to the experiment. Cronbach's α = .88.

(4) ***Metacognitive awareness.*** Metacognitive awareness was measured with the help of Schraw and Dennison's (1994) scale prior to the experiment (see appendix G). The 16 items covered three core areas of metacognition: planning, monitoring and evaluation. Cronbach's α = .93.

(5) ***Epistemological beliefs***. Epistemological beliefs were measured with the instrument from Urhanne and Hopf (2004). The 26 items aim to assess students' motivation, self-perception and learning strategies relating to the learning of science (see appendix H). It was measured before the experiment. Cronbach's α = .77.

5.7 Statistical Analyses

With respect to the research questions on the effects of the two differently sequenced classroom scripts on individual and group engagement in transformative and regulative processes (at both quality levels: high and low), absolute frequencies of each type of the transformative and the regulative processes was used as dependable variables in the analyses. Owing to the skewness and broad distribution of variables, independent-samples T-test was used to detect possible significant differences between the effects of the two differently sequenced classroom scripts. Next, Bonferroni correction was considered as a number of independent-Samples T-test was conducted on the same data set. However, an alpha level of .05 was used for all statistical tests for this study owing to the small sample size. Descriptive statistics and effect sizes of variables with no statistical significance will also be presented for discussion of the findings.

For research questions on the effects of the two script conditions on the outcomes of inquiry learning, Repeated Measures ANOVA analyses were conducted for the pre/post domain-specific knowledge tests and inquiry tests for individuals, as well as small groups.

5.8 Case Studies

In addition to the quantitative analyses, case studies with detailed description and interpretation of four discourses will be presented: one individual and one group for each of the two script conditions. The case studies aim to illustrate the actual verbal protocol of the two individuals (responses to the reflection questions) and the two small groups (group discourse during collaborative inquiry). The presentation of the discourse trends and moves in the case studies will afford a visual comprehension of the quantitative findings (Chi, 1997). The case studies serve further to evaluate the discourse structures in the two differently sequenced classroom scripts and how the two differently sequenced classroom scripts affect the specific transformative and regulative processes at the individual and group level. In order to illustrate the discourse structures and moves, the case studies presents an overview of complete discourses with the help of a graphical coding analysis with coarser granularity of the units of analysis than in the quantitative studies.

5.8.1 Procedures of the Case Studies

First, two individuals' reflection responses and two groups' discourse during collaboration will be presented as they appeared in the order of the inquiry process: pre-field trip, field trip and post-field trip. For the PSI classroom script, the data of the small group discourse, followed by the individual reflections (one of the members of the group) will be presented in this order. Conversely, for the PIS classroom script, the data of the individual reflections (one of the members of the group), followed by the small group discourse will be presented. Next, the reflections and discourse will be analysed with respect to the transformative and regulative processes (at both quality level: high and low). Finally, the transformative and regulative processes as indicated in the discourse structures (individual and the group) will be interpreted with the help of a graphical coding analysis, transformative and regulative processes, as well as their quality levels (high and low) will be allocated in the respective discourse structures. Further Chi's ICAP framework describing the activity type will be applied to each unit of analysis

Data of the individual reflections and group's discourse

The case studies are based on the complete discourse of the small groups and the individual reflections from pre- to post-field trip. The data of the discourse and individual reflections include the student codes, group codes and lines to indicate order of the utterances. The two students and the two groups in the two differently sequenced classroom scripts will be identified by their codes. For example, group 2 in the PSI classroom script consists of S04, S05, S06 and S07, and group 6 in the PIS classroom script consists of I19, I20, I21 & I22. Lines of utterances are numbered and then clustered as each unit of analysis, for instance, L1 to L7 form one unit of analysis, followed by L8 to 10 another unit of analysis.

Transformative and regulative processes

After presenting the data of the group discourse and individual reflection, the data will be interpreted based on the theoretical framework of this research study. First, the regulative processes at both levels (high- and low-level) will be analysed. Next, individual and small group written work will be presented and analyed for transformative processes (high and low-level).

Graphical Coding Analysis

The case studies will be illustrated with the help of a graphical coding analysis (Keefer, Zeitz & Resnick, 2000). The graphical coding analysis aims to present an overview of the high- and low-level transformative and regulative processes in the two differently sequenced classroom scripts. In the case studies, the unit of analysis is 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 (and not per five sec. as in the quantitative analysis).

The labels for high- and low-level transformative and regulative activities will be abbreviated (see table 26). Apart from the high- and low-level transformative and regulative processes, Chi's ICAP framework (2009) will also be applied to each unit of analysis to indicate if the activity is active, constructive or interactive. Figure 10 illustrates the symbols representing each activity type. Green triangle indicates that the activity is interactive, inverted triangle represents not interactive but rather constructive, rectangle means activity is constructive and circle represents active. Further, for the PSI classroom script, a red arrow bow indicates instances where individuals show integration of collaborative ideas into his or her own work, and for the PIS classroom script, a blue arrow bow indicates integration of individual idea into collaborative work (see figure 10).

Table 26: *Abbreviations for all transformative and regulative processes*

Regulative Processes		Transformative Processes	
OH	Orienting High	OH	Orienting High
OL	Orienting Low	OL	Orienting Low
PH	Planning High	AQH	Asking Question High
PL	Planning Low	AQL	Asking Question Low
IH	Instructing High	GHH	Generating Hypothesis High
IL	Instructing Low	GHL	Generating Hypothesis Low
GH	Grounding High	THH	Testing Hypothesis High
GL	Grounding Low	THL	Testing Hypothesis Low
MH	Monitoring High	GEH	Generating Evidence High
ML	Monitoring Low	GEL	Generating Evidence Low
TH	Testing High	EEH	Evaluating Evidence High
TL	Testing Low	EEL	Evaluating Evidence Low
EH	Evaluating High	DCH	Drawing Conclusions High
EL	Evaluating Low	DCL	Drawing Conclusions Low

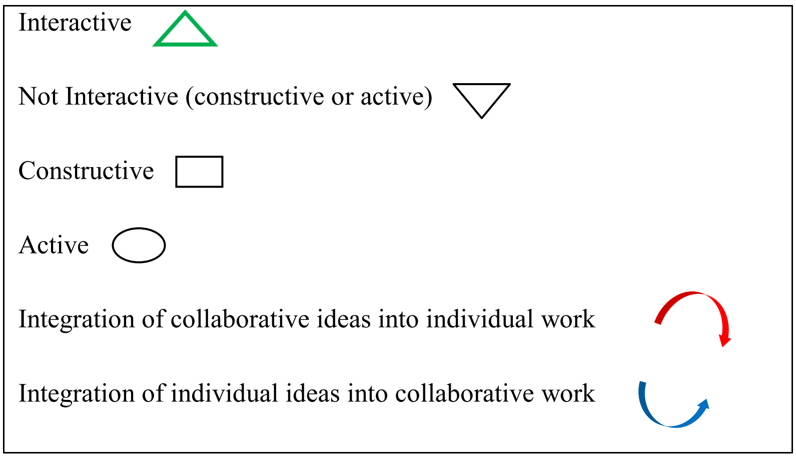


Figure 10: *Graphical coding symbols and their representations*

Interpretation of the case studies

The case studies will be interpreted with respect to the research questions. The discourse structures will be identified with reference to the graphical coding analysis. Based on the theoretical framework of this study, the high- and low-level transformative and regulative processes together with the activity type of the ICAP framework will be discussed to illustrate how the differently sequenced classroom scripts PSI vs. PIS have affected the inquiry learning processes for the individual and the small group.

5.8.2 Selection of the Individual Reflections and Small Group Discourse for the Case Studies

The case studies aim to illustrate the quantitative results. The cases studies 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 of all the 10 groups in each experimental condition. Other criteria for selection of discourse include similar group size and attendance for the three phases of inquiry from pre-to-post field trip. The selected discourse for the two case studies met these important criteria. They had similar group size of members in each of the script condition and their length of discourse best mirrored the average length of the twenty groups of students in this study.

6 Results

In this chapter, the results of the study on the 61 students and 20 small groups will be presented. The experimental conditions will be abbreviated with PSI for Plenary-Small Group-Individual classroom scripts and PIS for the Plenary-Individual-Small Group script sequence. This chapter begins with a comparison of the individual learning pre-requisites in the two differently sequenced script conditions. Next, the results of each of the research questions will be reported. Finally, two case studies (one from each of the two experimental conditions) will be presented to provide an in-depth explanation of the results of the quantitative analyses.

6.1 Comparison of the Learning Pre-requisites

(1) *Prior domain-knowledge and inquiry skills*

Prior domain-knowledge and inquiry skills were assessed with two tests (domain-knowledge test on photosynthesis and cell respiration, and inquiry test on amount of water for green bean plant growth). The domain-knowledge test was done individually and the inquiry test was conducted first individually, then in small groups.

The descriptive raw data indicated that there were no large differences between the students in the two experimental conditions regarding prior domain-knowledge on photosynthesis and cellular respiration, as well as individual inquiry skills and group inquiry skills in the two script conditions (see table 27).

Table 27: *Mean and (SD) of individuals' domain-specific knowledge, individuals' and small groups' inquiry skills*

	PSI Script M *(SD)*	**PIS Script** M *(SD)*
Individual domain-specific knowledge	9.25 *(4.14)*	10.68 *(2.85)*
Individual inquiry skills	2.76 *(2.59)*	2.46 *(2.54)*
Small group inquiry skills	5.15 *(2.56)*	5.56 *(2.27)*

Next, to determine whether individuals and small groups differ significantly in their learning prerequisites, three separate ANOVAs were conducted for the three tests respectively. The results showed that there was no significant difference for domain-specific knowledge (*F*(1,47) =1.99; *n.s*.). Likewise, there were no significant differences for individual inquiry skills (*F*(1,53) =2.90; *n.s*.) and for group inquiry skills (*F*(1,18) =0.08; *n.s*.).

(2) *Interest in domain knowledge, learning with media and learning with others; metacognitive awareness and epistemological beliefs*

The descriptive raw data indicated that there were no large differences between the students in the two experimental conditions regarding their interest in domain knowledge, learning with media and learning with others, metacognitive awareness and epistemological beliefs (see table 28). ANOVA test was conducted and results showed that there was no significant differences in the individuals' interest in these three areas: interests (*F*(1,53) =2.81; *n.s*.), metacognitive awareness (*F*(1,53) =2.81; *n.s*.) and epistemological beliefs (*F*(1,39) =0.08; *n.s*.) respectively.

Table 28: *Mean and (SD) of the individuals' interest, metacognitive awareness and epistemological beliefs*

	PSI Script M *(SD)*	**PIS Script** M *(SD)*
Interest	3.29 *(0.74)*	3.19 *(0.56)*
Metacognitive awareness	3.38 *(0.78)*	3.35 *(0.48)*
Epistemological beliefs	3.61 *(0.36)*	3.64*(0.39)*

6.2 Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on Individual's and Small Group's Transformative and Regulative Processes in Inquiry Learning

In this section, the effects of the two script conditions on the individual and small group engagement in transformative and regulative processes during inquiry learning will be reported. First the effects of differently sequenced classroom scripts on the individual inquiry learning will be presented in section 6.2.1, followed by small group inquiry learning in section 6.2.2. A brief summary and discussion of the results will be provided at the end of each research question. This section will conclude with an overall summary before the discussion of the case studies.

6.2.1 Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on Individuals' Transformative and Regulative Processes in Inquiry learning

The data on the transformative processes is derived from the individual students' written work and the data for the regulative processes came from students' responses to the individual reflection questions.

The **first part of the first research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individuals' transformative processes, as well as high- and low-level transformative processes in inquiry learning? **(RQ 1a)**

Hypotheses:
The PSI script facilitates more occurrences of transformative processes than the PIS script.
The PSI script facilitates more occurrences of high-level transformative processes than the PIS script.
The PSI script facilitates fewer occurrences of low-level transformative processes than the PIS script.

For all the analyses, absolute frequencies were used and independent-Samples T-tests were conducted to investigate the effects of the PSI vs. PIS scripts on the overall frequencies of transformative processes, as well as on the frequencies for high- and low-level transformative processes. The descriptive statistics are illustrated using bar graph with the *p*-value and the effect size of each of the transformative processes and its quality level (high and low) (see figure 11). Owing to the multiple T-tests conducted, a Bonferroni correction was considered. Bonferroni correction showed that effects were only significant at $p \leq .007$ for overall transformative processes and $p \leq .003$ for high and low-level transformative processes. However, owing to the small sample size, the significance level will be observed at $p \leq .05$.

The PSI classroom script: The PSI script facilitated significantly more occurrences of high-level orienting ($F(1,57) = 7.23$, $p = .01$, $d = .67$), generating evidence ($F(1,57) =$

3.89 , $p = .05$, $d = .51$), high-level generating of evidence ($F(1,57) = 5.77$, $p= .02$, $d = .62$) and significantly reduced the frequency of low-level orienting ($F(1,57) = 5.01$, $p= .03$, $d = .58$). Although there was no statistical significance for evaluating evidence ($F(1,57) = 2.38$, $p = .13$, $d = .41$), high-level evaluating evidence ($F(1,57) = 2.52$, $p= .12$, $d = .43$) and drawing conclusions ($F(1,57) =1.95$, $p = .17$, $d = .38$), the PSI script still yielded medium to strong effects for these transformative processes.

The PIS classroom script: The PIS script facilitated the testing of hypothesis ($F(1,57) =1.30$, $p = .25$, $d = .30$) and reduced the frequency of low-level drawing of conclusions ($F(1,57) = 1.84$, $p= .18$, $d = .38$) with medium to strong effects but no statistical significance for these two variables.

For the remaining transformative processes, no substantial differences were detected in the two script conditions ($F(1,57) < 1$, *n.s.*, $d < 0.3$).

Brief summary and discussion of results for RQ 1a

Overall, the results provided partial support for the hypotheses. More specifically, as compared to the PSI script facilitated more occurences of only some specific transformative processes, as well as some high-level transformative processes with medium to strong effects. These transformative processes were orienting, generating of evidence, evaluating of evidence and drawing of conclusions. Noteworthy is that the latter three transformative processes occurred in an outdoor learning setting, i.e., during the field trip. The provision of plenary level modeling and small group apprenticeship (Collins et al., 1989) could explain this phenomenon. The individuals were able to enact and emulate these transformative processes through observation (Palinscar & Brown, 1986). Further, in an outdoor learning setting where leveraging the rich physical affordances of the environment plays a pivotal role, the teacher and peer support and feedback at the plenary and small group level respectively could have enabled him or her to interact with the physical and material resources more effectively. As hypothesized, students in the PIS script condition did not engage as effectively in transformative, as well as high-level transformative processes owing to possible ‘desireable difficulties’ in the *generation and exploration* phase (Kapur, 2012). Moreover, students in the PIS script condition did not experience interactive activity prior to individual work. The lack of mutual generative activites (Chi, 2009) is one possible explanation for the results.

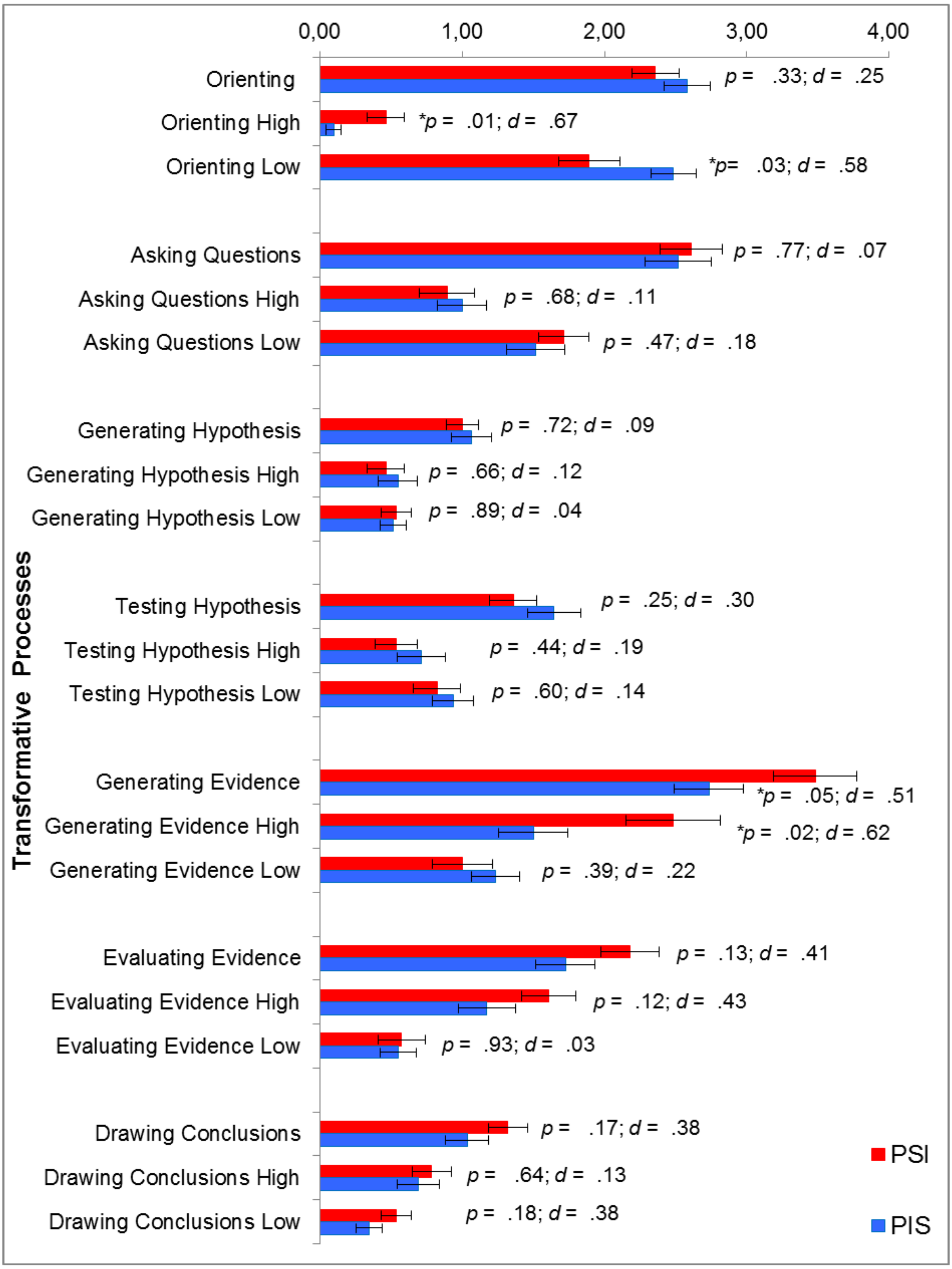


Figure 11: *Effects of PSI vs. PIS on individual engagement in transformative processes, as well as high- and low-level transformative processes*

Note. $^*p \leq .05$

The **second part of the first research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individuals' regulative processes, as well as high- and low-level regulative processes in inquiry learning? **(RQ 1b)**

Hypotheses:

The PSI script facilitates more occurrences of all regulative processes than the PIS script.

The PSI script facilitates more occurrences of high-regulative processes than the PIS script.

The PSI script facilitates fewer occurrences of low-regulative processes than the PIS script.

Likewise, independent-samples T-tests for the regulative processes were conducted. The descriptive statistics are depicted with bar graphs showing the p-value and the effect size of each of the regulative processes and its quality level (high and low) (see figure 12). Bonferroni correction showed that the effects were only significant at $p \leq .001$ for overall regulative processes and $p \leq .005$ for high and low-level regulative processes. Owing to the small sample size, the significance level will be observed at $p \leq .05$.

The PSI classroom script: The PSI script yielded more occurrences of evaluating ($F(1,59) = 2.22$, $p = .14$, $d = .38$), reduced the occurrences of low-level orienting ($F(1, 59) = 1.74$, $p = .19$, $d = .34$) and low-level monitoring ($F(1, 59) = 2.71$, $p = .09$, $d = .42$) with medium to strong effects but no statistical significance for these regulative processes.

The PIS classroom script: The PIS script led to higher frequency of orienting ($F(1,59) = 4.17$, $p = .04$, $d = .53$) and high-level orienting ($F(1,59) = 3.78$, $p = .05$, $d = .49$) with statistical significance. Although the PIS script descriptively facilitated more occurrences of planning ($F(1,59) = 1.90$, $p = .17$, $d = .35$), high-level planning ($F(1, 59) = 1.23$, $p = .27$, $d = .29$), testing ($F(1,59) = 1.98$, $p = .15$, $d = .37$), high-level testing ($F(1, 59) = 2.31$, $p = .12$, $d = .40$) and reduced the frequency of low-level evaluating ($F(1, 59) = 2.05$, $p = .16$, $d = .37$), there were no statistical significance for these regulative processes.

For the remaining regulative processes, no substantial differences were detected in the two script conditions ($F(1,59) < 1$, *n.s.*, $d < .3$).

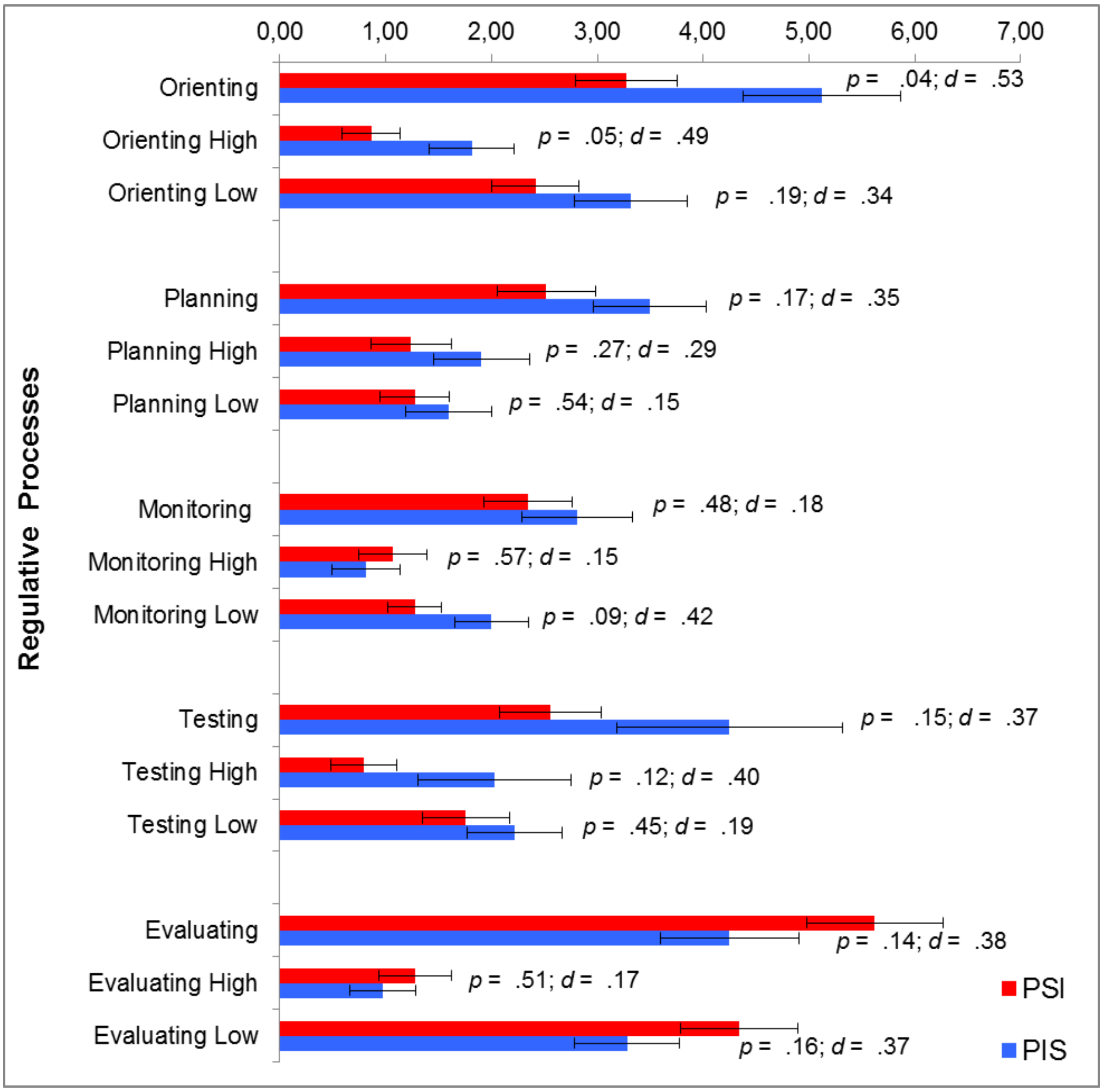


Figure 12: *Effects of PSI vs. PIS on individual engagement in regulative processes, as well as high- and low-level regulative processes*

Note. * p ≤ .05

Brief summary and discussion of results for RQ 1b

Overall, the results only partially supported the hypotheses on regulative processes. The PSI script did reduce the frequencies of low-level regulative processes, but only in low-level orienting and low-level monitoring. It did not facilitate any high-level regulative processes. This results is intriguing considering that the individuals did engage relatively well in the transformative processes, but similar performance did not show up in the regulative processes. It could be a situation where students were only beginning to acquire metacognitive experiences (Favell, 1979) especially in changing learning contexts from indoor to outdoor inquiry learning. According to Favell (1979), metacogntive experiences are likely to occur in situations that demand more critical thinking and reflection; and metacognitive experiences can inform metacognitive knowledge. This theoretical explanation should likewise apply to the individuals in the PIS script condition. However, contrarywise, students in the PIS script condition showed better engagement in regulative processes, as well as high-level regulative processes. One possible explanation could be that the PIS script condition affords the students the space for individual critical reflection, instead of assuming and applying a collective view without processing one's own. On the same note, the small group engagement in regulative processes could have shaped the individual enagement for students in the PSI script condition, i.e., *socially constructed self-regulation* (Järvelä & Järvenoja, 2011). This shall be taken up in the overall summary of the findings after reviewing the effects of both PSI vs. PIS on small group engagement in regulative processes.

6.2.2 Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Small Groups' Transformative Processes, as well as High- and Low level- Transformative Processes in Collaborative Inquiry Learning

The data on the small group transformative processes is derived from the small groups' written work and the data for the regulative processes came from the group discourse during the inquiry tasks.

The **first part of the second research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small groups' transformative processes, as well as high- and low-level transformative processes in collaborative inquiry learning? **(RQ 2a)**

Hypotheses:

The PIS script facilitates more occurrences of transformative processes than the PSI script.

The PIS script facilitates more occurrences of high-level transformative processes than the PSI script.

The PIS script facilitates fewer occurrences of low-level transformative processes than the PSI script.

Independent-samples T-tests were conducted and the effects of the PSI vs. PIS scripts on the transformative processes, as well as high- and low-level transformative processes are illustrated using bar graph (see figure 13). Descriptive statistics showed that there were no substantial differences in most of the transformative processes and the quality levels in the two script conditions. Bonferroni correction was considered and effects were only significant at $p \leq .007$ for overall tranformative processes and $p \leq .003$ for high and low-level tranformative processes. Likewise, for this study, owing to the small sample size, the significance level will be observed at $p \leq .05$.

The PSI classroom script: The PSI script descriptively facilitated more occurrences of high-level asking questions ($F(1,18) = .60$, $p = .46$, $d = .33$), fewer occurrences of low-level asking questions ($F(1,18) = .54$, $p = .47$, $d = .33$), more occurrences of generating hypothesis ($F(1,18) = .81$, $p = .41$, $d = .41$), fewer occurrences of low-level generating of evidences ($F(1,18) = 1.30$, $p = .27$, $d = .51$) and fewer occurrences of low-level drawing of conclusions ($F(1,17)= .42$, $p = .52$, $d = .30$) with medium to strong effects but no statistical significance for these transformative processes.

The PIS classroom script: The PIS script led to significantly more occurrences of generating evidence ($F(1,18) = 7.94$, $p = .01$, $d = 1.26$). Although there was no statistical significance, the PIS script yields medium to strong effects for high-level orienting ($F(1,18) = 1.0$, $p = .33$, $d = .45$), high-level generating of evidence ($F(1,18) = 2.14$, $p = .16$, $d = .65$), more occurrences of drawing conclusions ($F(1,18) = 1.33$, $p = .26$, $d = .52$), and reduced the frequency of low-level orienting ($F(1,18) = 1.14$, $p = .30$, $d = .48$).

For all remaining transformative processes, there were no substantial differences in the two script conditions ($F(1,18) < 1$, *n.s.*, $d < .3$).

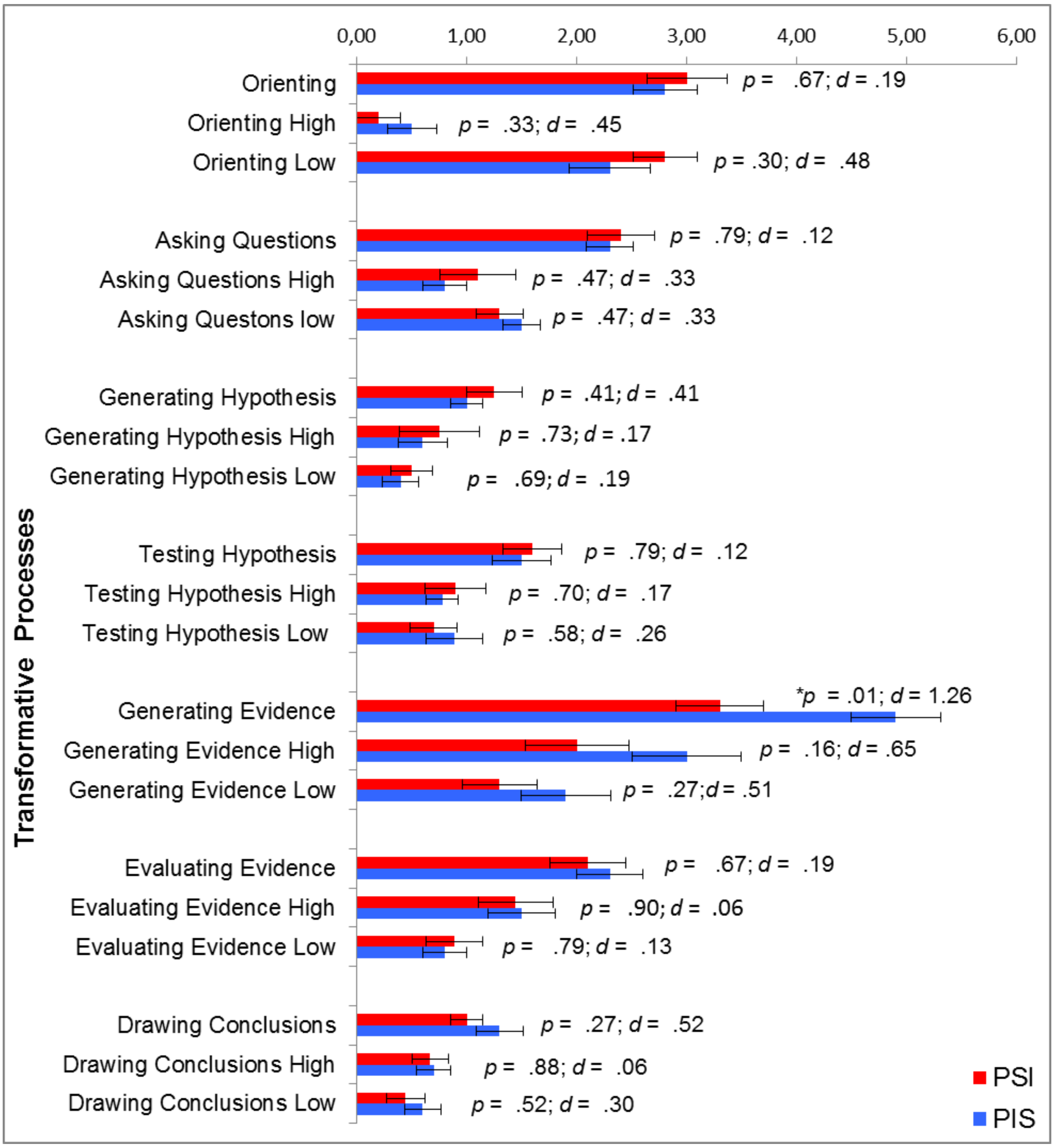


Figure 13: *Effects of PSI vs. PIS on small group engagement in transformative processes, as well as high- and low-level transformative processes*

*Note. *p ≤ .05*

Brief summary and discussion of results for RQ 2a

The results only partially supported the hypotheses. The PIS script did facilitate more occurrences of transformative processes but only the specific few such as generating of evidence and drawing of conclusions, and facilitated more occurrences of high-level orienting and high-level generation of evidence. Whereas, it was the PSI script that reduced frequencies of transformative processes such as low-level asking question, low-level generating of evidence and low-level drawing of conclusions.

Similarly, the provision of apprenticeship (Collins et al., 1989) at both plenary and small group level in the PSI script condition could explain the trend of results for the small group collaborative inquiry. They were able to externalize and appropriate the transformative processes and reduced the occurrences of low-level transformative processes. However, the occurrence of high-level transformative processes in collaborative inquiry is contingent on 'common grounds' (Clark & Brennan, 1991; Koschmann & LeBaron, 2003) to coordinate both the content and the process, as well as posing of good verification questions (De Jong et al., 2005). On this note, what could have affected the coordination and communication could be the absence of individual phase prior to collaboration (Rummel & Spada, 2005). This also explains why the small groups in the PIS script condition showed better engagement in high-level transformative processes.

The **second part of the second research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small groups' regulative processes, as well as high- and low-level regulative processes in collaborative inquiry learning? **(RQ 2b)**

Hypotheses:

The PSI script facilitates more occurrences of regulative processes than the PIS script.

The PIS script facilitates more occurrences of high-level regulative processes, in particular, more occurrences of high-level grounding and high-level testing than the PSI script.

The PIS script facilitates fewer occurrences of low-level regulative processes than the PSI script.

Similarly, independent-samples T-tests were conducted and the effects of the PSI vs. PIS scripts on the small group regulative processes, as well as high- and low-level regulative processes are illustrated using bar graph (see figure 14). Bonferroni correction was not considered here as there was no statistical significance on any of the variables in both script conditions.

The PSI classroom script: The PSI script facilitated more occurrences of orienting ($F(1,18) = 4.03$, $p = .06$, $d = .89$), planning ($F(1,18) = 0.57$, $p = .46$, $d = .34$), instructing ($F(1,18) = 2.18$, $p = .16$, $d = .66$) and monitoring ($F(1,18) = 1.17$, $p = .29$, $d = .48$) with medium to strong effect size although there was no statistical significance. And for high-level orienting and high-level evaluating, descriptive statistics showed that the PSI script yielded more occurrences for both these processes with medium to large effects ($F(1,18) = 1.14$, $p = .30$, $d = .48$) and ($F(1,18) = 1.00$, $p = .33$, $d = .44$) respectively.

The PIS classroom script: The PIS script facilitated more occurrences of high-level grounding ($F(1,18) = .75$, $p = .39$, $d = .39$) and high-level testing ($F(1,18) = .59$, $p = .45$, $d = .33$) and reduced the occurrences of low-level orienting ($F(1,18) = 3.50$, $p = .08$, $d = .84$). low-level planning ($F(1,18) = 2.08$, $p = .17$, $d = .65$), low-level instructing ($F(1,18) = 2.21$, $p = .16$, $d = .66$), low-level monitoring ($F(1,18) = 1.96$, $p = .18$, $d = .63$) and low-level testing ($F(1,18) = 1.10$, $p = .31$, $d = .47$). Although there was no statistical significance, the PIS script yielded medium to large effects for these regulative processes.

There were no substantial differences in the two script conditions for the remaining regulative processes ($F(1,18) < 1$, *n.s.*, $d < .3$).

Brief summary and discussion of results for RQ 2b

For the overall regulative processes, the results did support the hypothesis that the PSI script would facilitate more occurences than the PIS script, but not in grounding. Again, the theory of *cognitive apprenticeship* (Collins et al., 1989) and *fading* (Pea, 2004) could explain this trend of results. As for the small groups in the PIS script condition, they showed more high-level regulative processes in grounding and testing which could explain the occurrences of the high-level transformative processes. As aforementioned, 'grounding' is instrumental for *group knowledge* (Stahl, 2005) and substantive contribution in interactive activities (Chi, 2009) could bring about emergent knowledge and new perspectives. As hypothesized, the PIS script led to a reduction of most low-level regulative processes such as planning, testing, instructing and monitoring. Again, this could be attributed to better coordination and communication (Rummel & Spada, 2005) when sufficient individual time is allotted prior to collaborative effort.

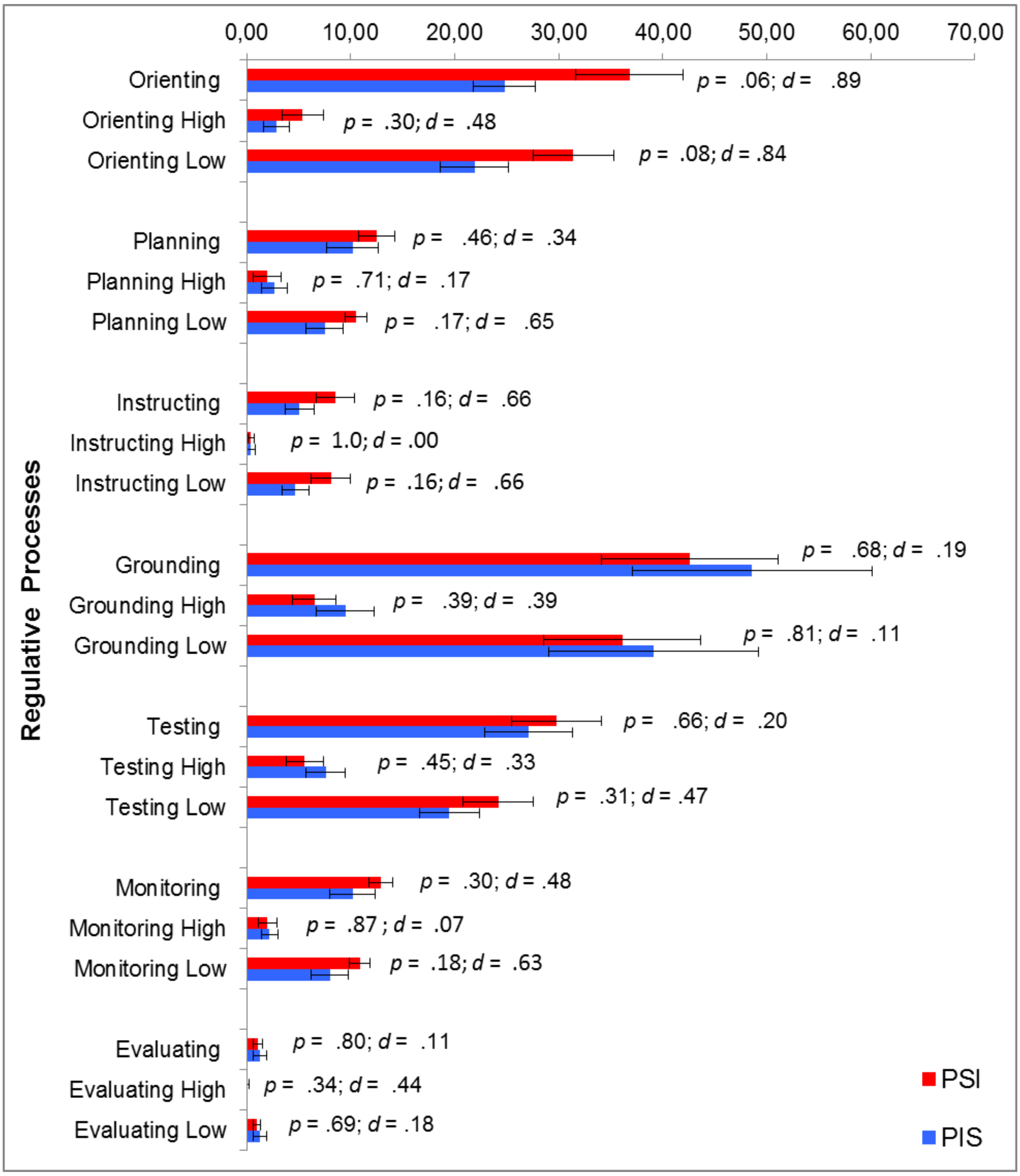


Figure 14: *Effects of PSI vs. PIS on small group engagement in regulative processes, as well as high-and low-level regulative processes*

Note. * $p \leq .05$

The **third part of the second research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the three social levels of regulation, i.e., self-, co- and shared-regulation in collaborative inquiry learning? **(RQ 2c)**

The data for this research question is derived from the group discourse.

Hypothesis:

The PSI script will see more activities (both transformative and regulative) occurred at the self-, co- and shared-level, as compared to the PIS script.

To test this hypothesis, independent-samples T-tests were conducted (see figure 15). The PSI script facilitated significantly more co-regulatory activities ($F(1,18) = 7.21$, $p = .01$, $d = 1.20$) than the PIS script. Although there was no statistical significance for self- and shared-regulation, the PSI script still yielded medium to strong effects ($F(1,18)=1.46$, $p = .24$, $d =.54$) and ($F(1,18) = .42$, $p = .53$, $d = .29$) respectively. Bonferroni correction was considered; the effects were significant at $p \leq .017$ for social levels. Likewise, the significant level will be observed at $p \leq .05$ owing to the small sample size.

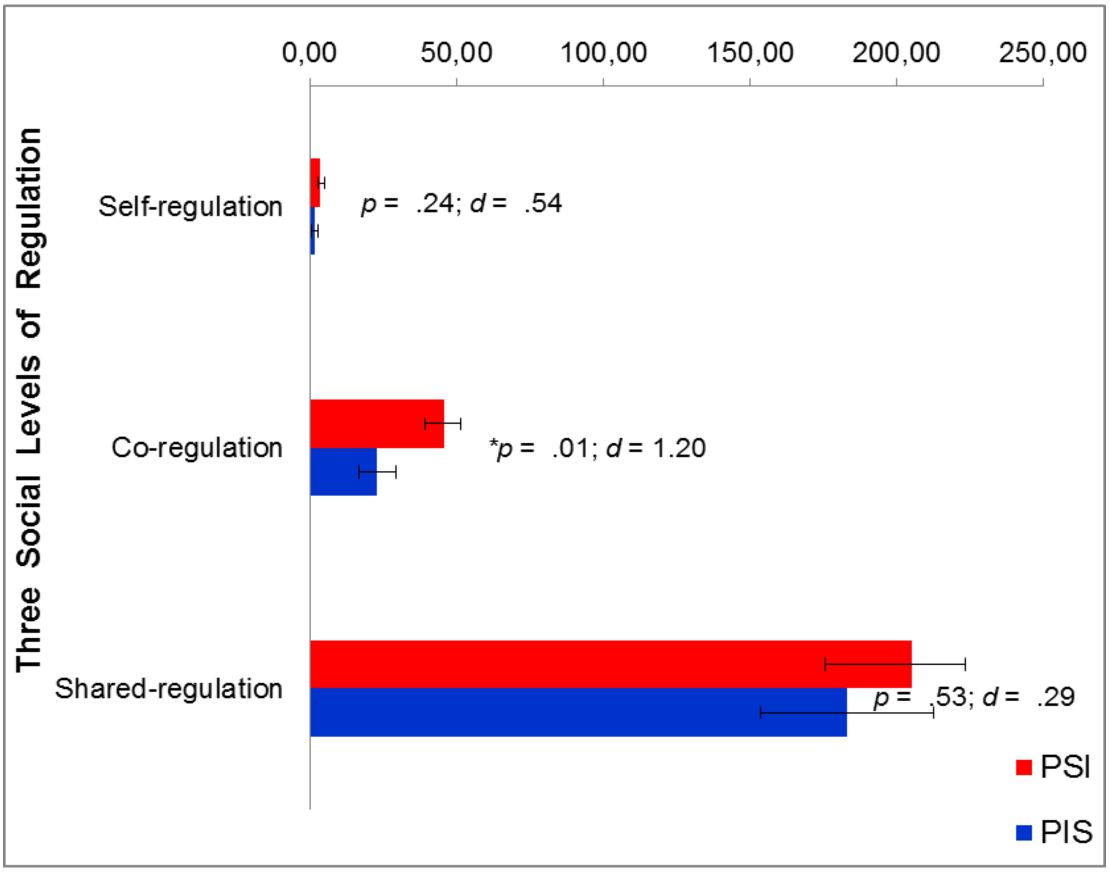


Figure 15: *Effects of PSI vs. PIS on the three social levels of regulation during the small group Inquiry task*

Note. $*p \leq .05$

Brief summary and discussion of results for RQ 2c

As hypothesized, the PSI classroom script did facilitate more regulative activities for all three social levels than the PIS script. The immediate collaborative inquiry following the modeling at the plenary could result in the occurences of more regulative processes to coordinate the interactive phase in joint work. Roschelle and Teasley (1995) liken collaboration to a *coordinated activity* which requires continued effort to maintain shared perception of the task to construct a joint problem space (Teasley & Roschelle, 1993). However, the above results on regulative processes seemed to indicate that more occurences of regulative processes did not imply better coordination nor interaction, i.e., more regulative processes do not mean better group regulation. The PIS classroom script facilitated fewer occurences of regulative processes at all three social levels as compared to the PSI classroom script. This should not be concluded that regulative processes generated were of a lower quality in the PIS small groups. The individual time before joint work (Rummel & Spada, 2005) for the PIS classroom script might explain that better coordination (as evidenced in the results on PIS small group regulative processes) lessened the need for more regulative activities for all three social levels.

6.3 Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Individual Domain-Specific Knowledge, as well as Individual and Small Group Inquiry Skills

This section presents the effects of the two differently sequenced classroom scripts on the individual acquisition of domain-specific knowledge and inquiry skills, as well as the acquisition of inquiry skills at the small group level.

The **first part of the third research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individual acquisition of domain-specific knowledge? **(RQ 3a)**

Hypothesis:
Both PSI and PIS scripts facilitate individual acquisition of domain-specific knowledge.

The descriptive raw data showed that both classroom scripts facilitated the acquisition of domain-specific knowledge (see table 29). Students in the PIS script condition performed only slightly better than those in the PSI script condition.

Table 29: *Means and (SD) of individuals' domain-specific knowledge in the pre- and post-tests*

	PSI Script M *(SD)*	**PIS Script** M *(SD)*
Pre-test domain-specific knowledge	9.25 *(4.14)*	10.68 *(2.85)*
Post-test domain-specific knowledge	15.46 *(5.12)*	16.92 *(5.99)*

To ensure there were no significant difference in the pre-test and no interaction effect, an ANCOVA test for homogeneity of regression was carried out. Results showed that there was no significance differences in the students' pre-test knowledge ($F(1,47) = 2.53$, $p = .07$).

With respect to the effects of the two differently sequenced classroom scripts on the individual acquisition of domain-specific knowledge, Repeated Measures ANOVA with the two classroom scripts as fixed factor, the pre-test as measurement point one and the post-test as measurement point two was carried out. Results indicated that there was significant learning gains in domain-specific knowledge ($F(1,47) = 56.43$, $p = .00$) but there were no differential effects of the two scripts on the individual acquisition of the domain-specific knowledge: ($F(1,47) = .00$, $p = .98$) (see figure 16).

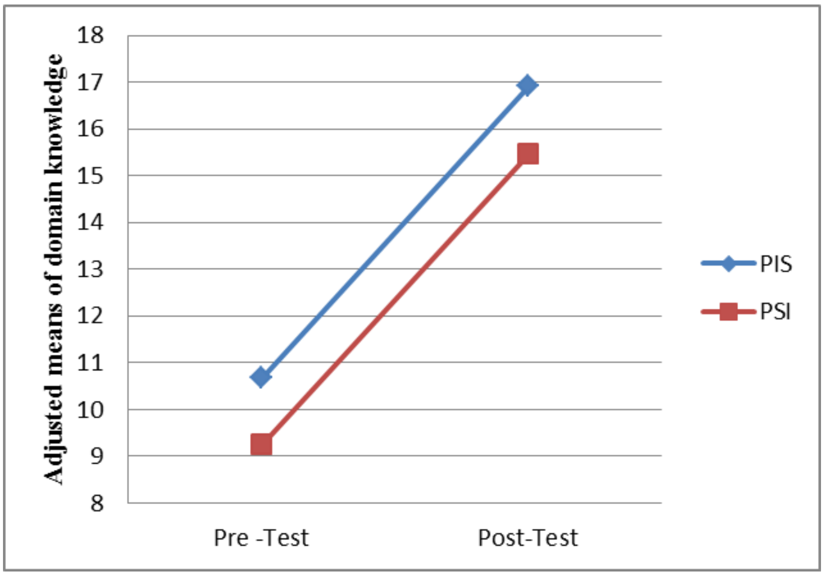


Figure 16: *Effects of the PSI & PIS scripts on individual acquisition of domain-specific knowledge*

Note. *p < .05

The **second part of the third research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the individual acquisition of inquiry skills? **(RQ 3b)**

Hypothesis:
The PSI script facilitates better individual acquisition of inquiry skills than the PIS script.

The descriptive raw data showed that the two classroom scripts facilitated the acquisition of inquiry skills with students in the PIS script condition performing slightly better than those in the PSI script (see table 30).

Table 30: *Means and (SD) of individuals' inquiry skills in the pre- and post-tests*

	PSI Script M *(SD)*	**PIS Script** M *(SD)*
Pre-test inquiry skills	2.76 *(2.59)*	2.46 *(2.54)*
Post-test inquiry skills	3.92 (*1.95)*	3.83 *(1.81)*

An ANCOVA (for homogeneity of regression) with the post-test as dependent variable and pre-test as covariate was conducted to check for significant differences and interaction effect in pre-test inquiry skills. Results showed that there were no significant differences in the pre-test inquiry skills in the two script conditions: ($F(1,49) = 2.59$, $p = .44$). Next, to determine the effects of the two differently sequenced classroom scripts on the individual acquisition of inquiry skills, Repeated Measures ANOVA with the two classroom scripts as fixed factor, the pre-test as measurement point one and the post-test as measurement point two was carried out. Results indicated that there was significant increase in inquiry skills from pre- to post-test ($F(1,49) = 9.13$, $p = .00$) but there were no differential effects of the two scripts on the individual acquisition of the domain-specific knowledge: ($F(1,49) = .06$, $p = .81$) (see figure 17).

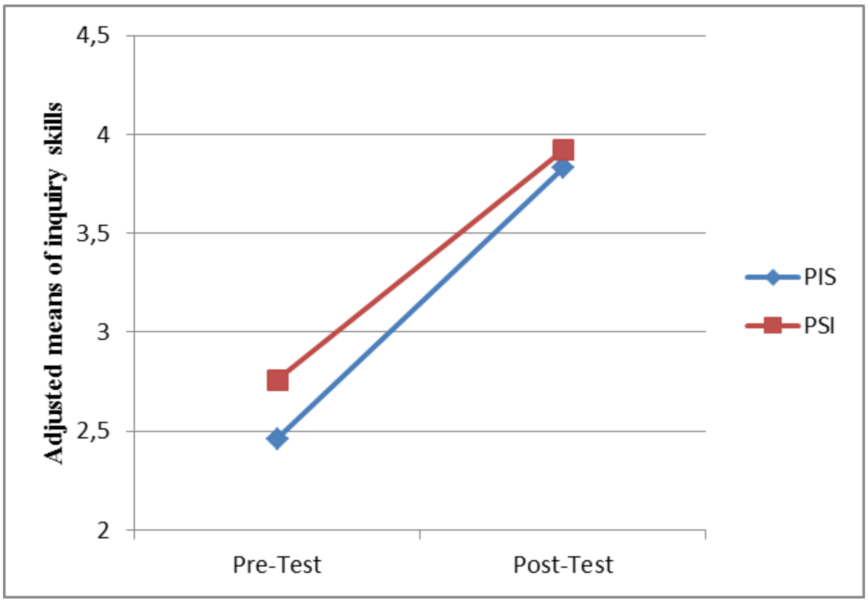


Figure 17: *Effects of the PSI & PIS scripts on individual acquisition of inquiry skills*

*Note. *p < 0.05*

The **third part of the third research question** was: What are the effects of the differently sequenced classroom scripts (PSI vs. PIS) on the small group acquisition of inquiry skills? **(RQ 3c)**

Hypothesis:

The PIS script facilitates better acquisition of inquiry skills than the PSI script.

The descriptive raw data showed that there is little increase in skills gain for the small groups in both script conditions (see table 6.3c).

Table 31: *Means and (SD) of small groups' inquiry skills in the pre- and post- tests*

	PSI Script M *(SD)*	**PIS Script** M *(SD)*
Pre-test inquiry skills	5.15 *(2.56)*	5.56 *(2.27)*
Post-test inquiry skills	5.20 *(2.78)*	5.67 *(1.58)*

An ANCOVA (for homogeneity of regression) with the post-test as dependent variable and pre-test as covariate was conducted to check for significant differences and interaction effect in pre-test inquiry skills at the small group level. Results showed that there were no significant differences in the group inquiry skills ($F(1,17) = 1.95$, $p = .18$). Next, to determine the effects of the two differently sequenced classroom scripts on the small group acquisition of inquiry skills, Repeated Measures ANOVA with the two classroom scripts as fixed factor, the pre-test as measurement point one and the post-test as measurement point two was carried out. Results indicated that there was no significant learning gains in inquiry skills ($F(1,17) = .02$, $p = .89$) nor was there any script effects on the small group acquisition of inquiry skills: ($F(1,17) = .00$, $p = .96$) (see figure 18).

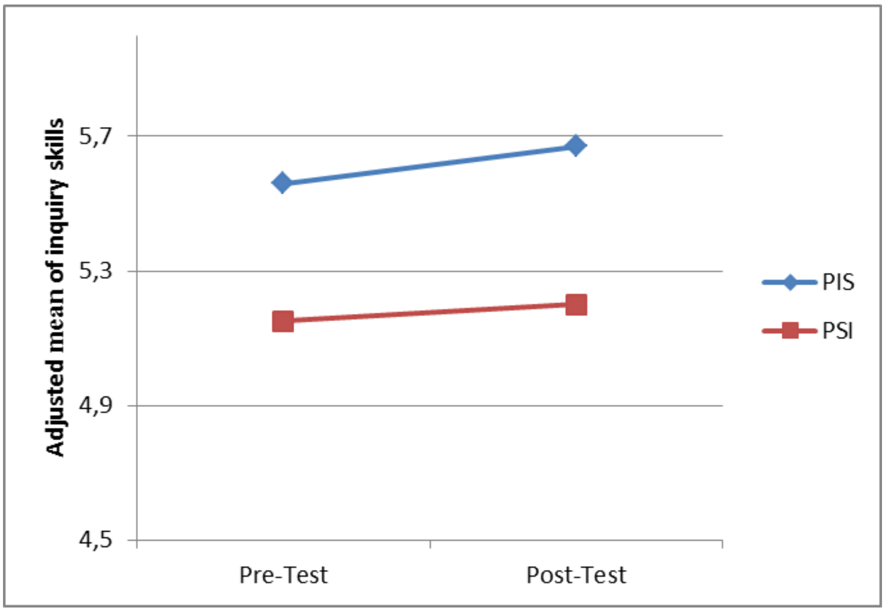


Figure 18: *Effects of the PSI & PIS scripts on small group acquisition of inquiry skills*

Note. *$*p < 0.05$*

Brief summary and discussion of results for RQ 3

As hypothesized, both classroom scripts should facilitate the individual acquisition of domain-specific knowledge owing to the use of simulations in the introductory lessons. Studies showed that learners improved significantly in *definitional knowledge and intuitive knowledge* when learning with the simulation environments (Swaak & De Jong, 1996). Hence, differently sequenced classroom scripts are unlikely to play a major role here in acquisition of factual and conceptual knowledge.

The results of the individual inquiry and small group inquiry tests did not support the hypotheses at all. One main explanation could be the decline of motivation in the final experimental phase and time constraints in the post-inquiry test.

6.4 Summary of the Results

In sum, the two differently sequenced classroom scripts wrought not only differential effects for the individual and the small group, but also varying effects for transformative and regulative processes, as well as their quality (high- and low-level) during the inquiry learning process. Both scripts seemed to have rendered more effect on transformative processes in the field-trip and post-field trip. The following summarizes and highlights some of these key findings.

The *PSI* classroom script facilitated the individual transformative processes in generating evidence, evaluating evidence and drawing conclusions with statistical significance for generating of evidence and high-level generating of evidence. And for the small group, the PSI classroom script reduced the frequency of low-level generating of evidence and low-level drawing of conclusion. For the individual and small group regulative processes, the PSI script seemed to facilitate more regulative processes at the start and end of the inquiry task such as orienting, monitoring and evaluating but with no statistical significance.

The *PIS* classroom script reduced the frequency of low-level drawing of conclusions for the individual. For the small group, the PIS script facilitated generating of evidence, drawing of conclusions and with statistical significance for high-level generating of evidence. For the individual regulative processes, the PIS script facilitated regulative processes, as well as high level ones in orienting, planning and testing with only statistical significance for orienting and high-level orienting. For the small group regulative processes, the PIS script facilitated more occurrences of high-level grounding and high-level testing, which were instrumental in the higher occurrences of high-level generating of evidence, as well as overall generating of evidence and drawing of conclusions for the transformative processes.

Noteworthy too, for the small groups, the PSI script facilitated more occurrences of regulative processes (e.g., orienting, planning, instructing and monitoring) than the PIS script. This could possibly explain the higher occurrences of co- and shared- regulation as compared to the PIS script with significance for the co-regulation learning.

Notwithstanding the PSI script facilitated more regulative processes but fewer high-level ones as compared to the PIS script. There was an apparent lack of high-level regulative processes such as grounding and testing at the small group level in the PSI script which also accounted for the lack of high-level transformative processes.

The overall trend in the descriptive statistics suggests that there were no substantial differences in most of the transformative and regulative processes in the two differently sequenced classroom scripts for small group inquiry learning. The small sample size is one likely explanation. The succeeding case studies will explicate the results of the quantitative analyses by investigating the discourse structures and moves in these two script conditions.

6.5 Case Studies

In the following sections, one case study for each of the two experimental conditions will be presented. For the PSI script condition, the group discourse followed by the individual reflections (one of the group members) will be presented as students in this script condition first worked in small groups before working individually. Conversely, for the PIS script condition, the individual reflections (one of the group members), followed by the group discourse will be presented as the students in this script condition first worked individually before working in small groups. The discourse within each case study will be discussed and analyzed with respect to the regulative and transformative processes (both quality levels: high & low). For the transformative processes, statements from their written work will be surfaced. For clarity purpose, the discourse with analysis will be presented in three phases: pre-field trip, field trip and post-field trip respectively. Finally, the data of each case study will be interpreted with the help of graphical coding to visualize the effects of the two script sequences on the individuals' and the small groups' engagement in regulative and transformative processes.

6.5.1 Discourse with the PSI Classroom Script

Quantitative analysis showed that the PSI classroom script descriptively facilitated individual transformative processes, as well as high-level transformative processes for generating evidences, evaluating evidence and drawing conclusions. However, for the small group inquiry, the PSI script only reduced the frequencies of low-level transformative processes for generating of evidence and drawing of conclusions. As for regulative processes, the PSI script seemed to facilitate more regulative processes at the start and end of the inquiry task such as orienting, monitoring and evaluating for both the individual and the small group inquiry. The succeeding case study of the discourse will provide further insights into the individual and group inquiry in this script condition.

First, the group discourse of PSI group 2 will be discussed and analyzed followed by the individual reflection of student S07 a member of this group. This PSI group consists of four students from grade nine: two girls and two boys. For confidentiality, only students' code numbers will be used. Students in the PSI script condition first worked on inquiry task two, "plants in the tropical rainforest" in their small group before working individually on inquiry task three, "plants in the desert".

Data of small group discourse and individual reflection in the pre-field trip

Following is the complete small group discourse of group 2 (see table 32), followed by the individual reflection of student S07 (see table 33) during the pre-field trip. In the pre-field trip, students were engaged in task-orienting, asking questions, generating hypothesis and developing inquiry plan to test hypothesis which the students had generated prior to the visit to the Botanical Gardens for data collection.

Small group discourse of PSI group 2 in the pre-field trip

Table 32: *Discourse excerpt of PSI small group 2 in the pre-field trip*

Line	Student	Group Discourse
1	S04	Im tropischen Regenwald…
2	S06	Das wir später machen.
3	S04	Ja, dann fangen wir mal an.
4	S05	Nein, ich glaube, wir können anfangen zu lesen.
5	S07	Das ganze Jahr über...Regenmenge mindestens…
6	S04	Könnstest Du mal leise sein?
7	S05	Wir müssen uns eine Pflanze aussuchen, die wir irgendwie im Botanischen Garten untersuchen.
8	S04	Die Bambuspflanze…
9	S07	Die müssen wir dann auch im Botanischen Garten finden und bearbeiten, oder?
10	S04	Bambus, Bambus…
11	S06	Wir nehmen den Bambus.
12	S05	Was wir bereits wissen…
13	S04	Und was ist dann so besonders am tropischen Wald?
14	S05	Weil die kriegen so wenig Sonne und es regnet fast nicht.
15	S07	Das sind auch die besten…
16	S06	Es regnet fast nicht.
17	S07	Er wird Regenwald genannt, weil er so feucht ist.
18	S06	Es ist nur feucht. Was?

Line	Student	Group Discourse
19	S05	Ok, also wir wissen bereits, was wissen wir denn bereits? Die müssen sich einen ablachen, wenn sie das abhören. Wir wissen, dass…
20	S04	Pflanzen Wasser aus der Erde kriegen.
21	S05	Ok...wir wissen bereits, dass Pflanzen Wasser aus der Erde kriegen können.
22	S 05	Ok, was wissen wir noch?
23	S 07	Sie können auch ohne Sonnenlicht, fast ohne Sonnenlicht leben.
24	S 05	Ja, zumindest brauchen sie irgendwann mal Sonnenlicht, wenn sie ganz unten sind.
25	S 04	Aber da ist Sonne…
26	S 05	Ja, das ist aber auch in München und nicht im Regenwald.
27	S 04	Das ist der Botanische Garten. Woher soll ich das wissen, ganz ehrlich?
28	S 05	Ok, wozu haben wir noch Fragen?
29	S 04	Wie die ohne…wie die ohne Sonnenlicht…
30	S 06	Was, was verstehst du nicht?
31	S 04	Also, wie die mit nur so wenig Sonnenlicht überleben können?
32	S 05	Ok, also, wie, wie kann man…
33	S 04	Ok. Was genau wollen wir herausfinden?
34	S 06	Wir wollen herausfinden, wie sie ohne Sonnenlicht überleben.
35	S 05	Gut.
36	S 07	Was wollen wir herausfinden?
37	S 05	Hast du etwa nicht zugehört?
38	S 07	Ach so, doch, die Pflanzen ohne Sonnenlicht…
39	S 05	Eine Hypothese…
40	S 06	Hypothese, was für eine Hypothese?
41	S 04	Sie speichern die Lichtenergie.
42	S 07	Ja, wenn, manchmal kommt doch, manchmal kommt doch Licht sicher durch. Das haben wir davor…
43	S 04	Dann speichern sie halt…was?
44	S 07	Oder? Durch die Blätter oben speichern die Nahrung. Ja, sag‘ du jetzt mal…
45	S 07	Eine These! Ja? Ja?
46	S 06	Das ist eine Hypothese?
47	S 05	Eine These ist nämlich etwas, wo man sich sicher ist.
48	S 07	Ich habe das doch gerade schon oft gesagt, dass die Blätter vielleicht ziehen das Sonnenlicht auf, machen sie sowieso, aber vielleicht nur die... (interrupted by classroom instructions from the teacher)
49	S07	Wachsende Pflanzen der Erde: Holziger Bambus ist resistent und die Stängel sind hohl.
50	S04	Oh nee, wir hätten andere…
51	S05	(Steht da auch, warum) der Bambus so schnell wächst?
52	S07	Hast du nicht zugehört? Wieso wächst der Bambus am schnellsten?
53	S05	Das wollen wir auch herausfinden, nehme ich mal an.

Line	Student	Group Discourse
54	S05;S07	Ok, unsere These, Hypothese, Hypothese…
55	S05	Wieso wächst der Bambus so schnell?
56	S04	Weil der Bambus wenig Wasser und Sonnenlicht braucht…
57	S05	Perfekt, so schnell. da er nicht… da er am wenigsten Wasser und Sonnenlicht braucht…
58	S07	Um Glukose herzustellen ... ja... die sie zum…
59	S05	Wachsen brauchen…Sonnenlicht…
60	S05	Ok, welche Arten von Daten werden wir sammeln?
61	S07	In einen Topf tun und in einen dunklen Raum und…
62	S05	Ihm wenig Wasser geben…
63	S07	Ja…
64	S05	Und gucken, wie schnell er an einem Tag wächst…
65	S07	Ja, mit wenig Licht würde ich sagen.
66	S05	Ja…hmm…warte, welche Art von Daten werden wir jetzt sammeln?
67	S07	Messungen…
68	S06	Wachstum des Bambus…
69	S07	Messungen des Wachstums…
70	S07	Was können die Daten zur Aufklärung des Rätsels beitragen?
71	S05	Die Hypothese bestätigen oder wiederlegen. Ok. Was können wir noch machen?
72	S07	Ja, vielleicht nach Glukose durchsuchen…wie viel Glucose?
73	S05	Du meinst, du willst die Rinde aufschnitzen, diese harte, feste Rinde, und dann gucken?
74	S04	Du kannst ja hochklettern beim Bambusstamm und dann…oder du schneidest sie einfach runter…

Individual Reflection of Student S07 in the pre-field trip

Table 33: *Excerpt of the individual reflection of student S07 in the pre-field trip*

Reflection Questions:
1. Was weißt du bereits und was musst du wissen, um deinen Untersuchungsplan zu entwickeln?
2. Wie gehst du bei der Planung deiner Untersuchung vor?

Line	Individual Reflection
1	Ich weiß, dass ein Kaktus... mit extremem Klima…mit extremem Klima überleben kann.
2	Also, es ist so, das Kakteen sehr toll…weil sie sehr lange überleben.
3	Meine Untersuchung geht sehr gut voran. Es ist sehr toll, mir sind die Ideen sehr schnell gekommen.

Analysis of regulative and transformative processes in the pre-field trip

The small group discourse will first be presented and analysed for the regulative processes, followed by the small group transformative processes in the written work. Thereafter the individual reflection will be presented and analysed for regulative processes, followed by the individual transformative processes in the written work. Only high and low-level transformative and regulative processes will be explained and discussed.

Analysis of small group regulative processes in the pre-field trip

Table 34: *Discourse excerpt on task procedure*

Line	Student	Group Discourse	Code
1	S04	Im tropischen Regenwald…	Planning (Low)
2	S06	Das wir später machen.	Shared Regulation
3	S04	Ja, dann fangen wir mal an.	
4	S05	Nein, ich glaube, wir können anfangen zu lesen.	

The group discourse began with an attempt to plan task procedure (see table 34). This was coded planning low at shared regulation level owing to the lack of a group consensus and shared understanding of task strategies. There was no agreement reached and each proceeded with their own task strategies.

Table 35: *Discourse excerpt on group work regulation*

Line	Student	Group Discourse	Code
5	S07	Das ganze Jahr über...Regenmenge mindestens…	Instructing (Low)
6	S04	Könnstest Du mal leise sein?	Co- Regulation

There was an absence of coordination where student S07 was reading aloud, while the others were reading quietly and felt disturbed (see table 35). Student S07 was eventually asked to read quietly, which was coded instructing low at co-regulation. Further, there was no occurrence of any substantive interactive activity.

Table 36: *Discourse excerpt on task expectations*

Line	Student	Group Discourse	Code
7	S05	Wir müssen uns eine Pflanze aussuchen, die wir irgendwie im Botanischen Garten untersuchen.	Orienting (Low) Shared Regulation
8	S04	Die Bambuspflanze…	
9	S07	Die müssen wir dann auch im Botanischen Garten finden und bearbeiten, oder?	
10	S04	Bambus, Bambus…	
11	S06	Wir nehmen den Bambus.	

The group next discussed about the selection of the rainforest plant and task expectations (see table 36): coded as orienting low for the brevity of response and lack of shared meaning in the collaborative meaning making process. There was no attempt of providing an explanation for selecting the bamboo plant as their choice of inquiry: no collective sharing of prior knowledge about the bamboo plant. Although it was shared level regulation, it was more constructive than interactive to arrive at a shared decision.

Table 37: *Discourse excerpt on task goals*

Line	Student	Group Discourse	Code
12	S05	Was wir bereits wissen…	Grounding (Low)
13	S04	Und was ist dann so besonders am tropischen Wald?	Shared Regulation
14	S05	Weil die kriegen so wenig Sonne und es regnet fast nicht.	
15	S07	Das sind auch die besten…	
16	S06	Es regnet fast nicht.	
17	S07	Er wird Regenwald genannt, weil er so feucht ist.	
18	S06	Es ist nur feucht. Was?	

Student S05 next alerted everyone to the task on the worksheet where they were supposed to write down what they already knew, what questions they had and what they would like to find out (see table 37). The series of contributions was coded grounding low as the verification statements on the conditions of the rainforest were superficially dealt with and left unaddressed to some measure.

Table 38: *Discourse excerpt on task orientation*

Line	Student	Group Discourse	Code
19	S05	Ok, also wir wissen bereits, was wissen wir denn bereits? Die müssen sich einen ablachen, wenn sie das abhören. Wir wissen, dass…	Orienting (Low) Shared Regulation
20	S04	Pflanzen Wasser aus der Erde kriegen.	
21	S05	Ok... wir wissen bereits, dass Pflanzen Wasser aus der Erde kriegen können.	

The group engaged in low-level orienting statements at the shared regulation level where they merely retrieved given lead information without further reflection (see table 38). They did not mobilize prior knowledge and made connections with the given information in the learning materials. It was also non-interactive as student S05 seemed to engage in constructive activity to affirm her own knowledge.

Table 39: *Discourse excerpt on sunlight and plant growth*

Line	Student	Group Discourse	Code
22	S 05	Ok, was wissen wir noch?	Grounding (Low)
23	S 07	Sie können auch ohne Sonnenlicht, fast ohne Sonnenlicht leben.	Shared Regulation
24	S 05	Ja, zumindest brauchen sie irgendwann mal Sonnenlicht, wenn sie ganz unten sind.	
25	S 04	Aber da ist Sonne…	
26	S 05	Ja, das ist aber auch in München und nicht im Regenwald.	
27	S 04	Das ist der Botanische Garten. Woher soll ich das wissen, ganz ehrlich?	

Student S05 probed about the idea that the bamboo plant cannot survive without sunlight but there was no substantial follow-up from the other members in the reasoning process either owing to the lack of knowledge and/or depth in critical reflection, hence grounding remained at a low-level (see table 39).

Table 40: *Discourse excerpt on sunlight and plant adaptation*

Line	Student	Group Discourse	Code
28	S 05	Ok, wozu haben wir noch Fragen?	Grounding (Low)
29	S 04	Wie die ohne…wie die ohne Sonnenlicht…	Shared Regulation
30	S 06	Was, was verstehst du nicht?	
31	S 04	Also, wie die mit nur so wenig Sonnenlicht überleben können?	
32	S 05	Ok, also, wie, wie kann man…	
33	S 04	Ok. Was genau wollen wir herausfinden?	
34	S 06	Wir wollen herausfinden, wie sie ohne Sonnenlicht überleben.	

Again, as shown in table 40, student S04 attempted to re-surface the issue about sunlight which was an important contribution, but her query was dismissed. Grounding was coded low.

Table 41: *Discourse excerpt on inquiry task goals*

Line	Student	Group Discourse	Code
35	S 05	Gut.	Orienting (Low)
36	S 07	Was wollen wir herausfinden?	Co- Regulation
37	S 05	Hast du etwa nicht zugehört?	
38	S 07	Ach so, doch, die Pflanzen ohne Sonnenlicht…	

Orienting remained at a low-level as it became a case of quick confirmation of idea without further probes (see table 41). It was co-regulation as student S07 was seeking help about task goals. It was also non-interactive; more a constructive activity for student S07.

Table 42: *Discourse excerpt on hypothesis for inquiry task*

Line	Student	Group Discourse	Code
39	S 05	Eine Hypothese…	Grounding (Low)
40	S 06	Hypothese, was für eine Hypothese?	Shared Regulation
41	S 04	Sie speichern die Lichtenergie.	

The group engaged in a brief grounding statement on hypothesis for inquiry task from student S05 and S06 (see table 42). This was coded grounding low as it was abrupt, directive and requesting for responses and ideas without provision of context or connections. It was not as interactive as each of the group member seemed to be engaged in seeking affirmation from one another about their own perceptions about what a possible hypothesis could be.

Table 43: *Discourse excerpt on development of hypothesis*

Line	Student	Group Discourse	Code
42	S 07	Ja, wenn, manchmal kommt doch, manchmal kommt doch Licht sicher durch. Das haben wir davor…	Grounding (High) Shared Regulation
43	S 04	Dann speichern sie halt…was?	
44	S 07	Oder? Durch die Blätter oben speichern die Nahrung. Ja, sag‘ du jetzt mal…	

The verification questions and statements to clarify the earlier hypothesis made by S04 were coded grounding high as it showed reflective thinking to probe further if bamboo plants needed to save light energy for photosynthesis (see table 43).

Table 44: *Discourse excerpt on possible hypotheses*

Line	Student	Group Discourse	Code
45	S 07	Eine These! Ja? Ja?	Orienting (High)
46	S 06	Das ist eine Hypothese?	Shared Regulation
47	S 05	Eine These ist nämlich etwas, wo man sich sicher ist.	
48	S 07	Ich habe das doch gerade schon oft gesagt, dass die Blätter vielleicht ziehen das Sonnenlicht auf, machen sie sowieso, aber vielleicht nur die...(interrupted by classroom instructions from the teacher)	

The group continued to build on earlier grounding statements to formulate their hypothesis (see table 44). This was coded orienting high at the shared regulatory level for they negotiated shared understanding on the definition of hypothesis and also displayed an awareness of possible knowledge gaps or missing links about sunlight and plants in the rainforest.

Table 45: *Discourse excerpt on verification of hypothesis*

Line	Student	Group Discourse	Code
49	S07	Wachsende Pflanzen der Erde: Holziger Bambus ist resistent und die Stängel sind hohl.	Grounding (Low) Shared Regulation
50	S04	Oh nee, wir hätten andere…	
51	S05	(Steht da auch, warum) der Bambus so schnell wächst?	
52	S07	Hast du nicht zugehört? Wieso wächst der Bambus am schnellsten?	
53	S05	Das wollen wir auch herausfinden, nehme ich mal an.	

The group attempted to mobilize given information to confirm their hypothesis (see table 45). This was coded grounding low as queries posed were not adequately dealt with and the lower quality of communication seemed to have hindered deeper discourse.

Table 46: *Discourse excerpt on confirmation of hypothesis*

Line	Student	Group Discourse	Code
54	S05;S07	Ok, unsere These, Hypothese, Hypothese…	Orienting(Low)
55	S05	Wieso wächst der Bambus so schnell?	Shared Regulation
56	S04	Weil der Bambus wenig Wasser und Sonnenlicht braucht…	
57	S05	Perfekt, so schnell. da er nicht… da er am wenigsten Wasser und Sonnenlicht braucht…	
58	S07	Um Glukose herzustellen ... ja... die sie zum…	
59	S05	Wachsen brauchen…Sonnenlicht…	

The group confirmed their hypothesis based on assumptions (see table 46). This was coded orienting low for they were not able to make sound connections of information on rainforest and the bamboo plant they had chosen.

Table 47: *Discourse excerpt on development of inquiry plan*

Line	Student	Group Discourse	Code
60	S05	Ok, welche Arten von Daten werden wir sammeln?	Planning (Low)
61	S07	In einen Topf tun und in einen dunklen Raum und…	Shared Regulation
62	S05	Ihm wenig Wasser geben…	
63	S07	Ja…	
64	S05	Und gucken, wie schnell er an einem Tag wächst…	
65	S07	Ja, mit wenig Licht würde ich sagen.	

Next, the group discussed the inquiry plan to test their hypothesis (see table 47). This was coded as planning low as it showed a lack of reflection about the nature of their inquiry and the experiment planned was not feasible for a field trip.

Table 48: *Discourse excerpt on different data types and their uses*

Line	Student	Group Discourse	Code
66	S05	Ja… hmm…warte, welche Art von Daten werden wir jetzt sammeln?	Planning (High) Co- Regulation
67	S07	Messungen…	
68	S06	Wachstum des Bambus…	
69	S07	Messungen des Wachstums…	

The subsequent ideas were coded as planning high at the co-regulation level between student S07 and S06 as they indicated the awareness of having evidences and reliable measures in their data collection to prove their hypothesis (see table 48).

Table 49: *Discourse excerpt on possible use of data*

Line	Student	Group Discourse	Code

70	S07	Was können die Daten zur Aufklärung des Rätsels beitragen?	Grounding (Low) Shared Regulation
71	S05	Die Hypothese bestätigen oder wiederlegen. Ok. Was können wir noch machen?	

The discussion on the purpose of data collection was coded grounding low as the response to the query was brief and partially dismissed without further reflection (see table 49). It was also not interactive as it was reduced to a case of eliciting ideas instead of dialoging to arrive at shared meaning.

Table 50: *Discourse excerpt on data type and data collection plan*

Line	Student	Group Discourse	Code
72	S07	Ja, vielleicht nach Glukose durchsuchen…wie viel Glucose?	Grounding (Low) Shared Regulation
73	S05	Du meinst, du willst die Rinde aufschnitzen, diese harte, feste Rinde, und dann gucken?	
74	S04	Du kannst ja hochklettern beim Bambusstamm und dann…oder du schneidest sie einfach runter…	

Grounding was low at the shared regulatory level as the idea proposed by student S07 was not seriously addressed nor reflected upon (see table 50). There was no attempt to pose verification questions to seek clarification and/ or to advance the idea to examine the glucose level.

Analysis of small group transformative processes (written work) in the pre-field trip

PSI Group 2 had two orienting statements: (1) “Pflanzen konnen Wasser aus der Erde kriegen” and (2) “Pflanzen brauchen Sonnenlicht, um Glukose herzustellen”. These two orienting statements were coded low as they were purely activating prior knowledge without any critical thinking or reference to the living environment for the bamboo plant they had chosen for their inquiry task. Next, they indicated in the written work that they had questions for: (1) “Wie können Pflanzen ohne oder mit wenig Sonnenlicht überleben?” and (2) “Wieso wächst der Bambus so schnell?” Both were coded low as the first question was very general and the second question did not show any attempt to make any inferences about the bamboo plant structure for its fast growth.

The group next formulated their hypothesis as “Der Bambus braucht wenig Wasser und Sonnenlicht, um Glukose herzustellen, was er zum Wachsen braucht”. Generating of hypothesis was coded low as the hypothesis was not substantiated with any scientific reasoning or reference to the structure of the bamboo plant nor the tropical rainforest. For the testing of hypothesis, they wrote, (1)“Wachstum des Bambus” as the data they would like to collect and for method, they would (2) “Den Keim des Bambus in einen Topf in einen dunklen Raum mit wenig Wasser tun und nach einem Tag sehen, wie weit er gewachsen ist”. Both statements were considered as one idea for testing hypothesis and was coded as testing hypothesis low for the lack of coherence. Further, their inquiry plan for data collection did not seem viable for a field trip study.

Analysis of individual regulative processes in the pre-field trip

In the individual reflection, students S07’s response to the first question was coded orienting low (see table 51: line 1 & 2) as he merely reproduced given information. There was no indication of awareness of knowledge gap, neither was there an attempt to further discuss his opinion or desired learning goals. His self-regulatory process seemed to mirror the group’s regulative processes: learning goals and learning strategies were not clear. S07 responses to the question on the planning of the inquiry task, was somewhat superficial but he seemed to display metacognitive awareness of his strength areas and how he had progressed. This was coded monitoring high (line 3).

Table 51: *Student S07’s responses to the reflection questions in the pre-field trip*

Reflection Questions:
1. Was weißt du bereits und was musst du wissen, um deinen Untersuchungsplan zu entwickeln?
2. Wie gehst du bei der Planung deiner Untersuchung vor?

Line	Individual Reflection	Code
1	Ich weiß, das ein Kaktus...mit extremem Klima…mit extremem Klima überleben kann.	Orienting (Low)
2	Also, es ist so, das Kakteen sehr toll…weil sie sehr lange überleben.	Orienting (Low)
3	Meine Untersuchung geht sehr gut voran. Es ist sehr toll, mir sind die Ideen sehr schnell gekommen.	Monitoring (High)

Analysis of individual transformative processes (written work) in the pre-field trip

Although S07 appeared seemingly uncertain or superficial in his self-regulation, his individual written work showed otherwise. There was one orienting low for (1) “Pflanzen brauchen Wasser, Kohlenstoff und Lichtenergie” and one orienting high for (2)“Sie benötigen Glukose, um zu wachsen und überleben”. The orienting statement was coded high for he showed an attempt to go beyond given information; linking ideas to the structure of the kaktus and its living environment. He listed three questions. Two asking questions were coded low: (1) “Wie kann ein Kaktus mit extrem niedriger Wasserversorgung überleben?” and (2) “Wie lange können Kakteen ohne Wasser überleben?" as they remained at a superficial level. The third question, (3) "Wie speichern Kakteen ihr Wasser?" was coded high for he was able to raise queries about the structure of the cactus for storing water.

For hypothesis, S07 wrote, "Ein Kaktus produziert durch die Chlorophasten, die im Stamminneren sind, seine Glukose, die er zum Weiterleben benutzt". This hypothesis was coded high as he showed the ability to make inferences between science information and the function of the structure in the Kaktus. However, for the testing of hypothesis, he wrote, "Wasserspeicher eines Kaktus" as data type and "kaum Wasser tun" as his method of collecting the data without any elaboration. Both statements were considered as one idea for testing hypothesis and was coded low as there was lacked of coherence from the hypothesis he formulated and the method in which he planned his data collection.

Interpretation of the discourse data for pre-field trip

The analysis of the regulative processes of the group 2 and student S07 in the PSI case provide an insight to the discourse patterns at the small group level and how this might have an effect on the individuals as they emerged from collaborative inquiry to engage in individual work. Graphical coding analysis enables an overview of the type of activity at the small group and individual level, together with the occurences of the high and low-level transformative (see figure 19). The activity type could explain the quality of the regulative processes and how they might have implications on the transformative processes.

In the pre-field trip, the group discourse showed 14 instances of low-level regulative processes and three instances of high-level regulative processes as shown in figure 19. The numerous occurrences of low-level regulative processeses could have affected the transformative processes where the group written work had two low-level orienting ideas, two low-level asking of questions, one low-level hypothesis and one low-level testing of hypothesis. There are two possible explanations. First, most of the grounding statements occurred at low-level (seven instances of low-level grounding) with no emergence of new shared knowledge or perspectives and where the verification questions posed were either dismissed or superficially responded. Moreover, where good contributions were made by members of the group, for instance, on the measurement of the Bamboo plant's growth (See table 48: line 66 to 69) as part of the inquiry plan for data collection, insufficient thoughts were given to further develop this idea. Hence, though there were occurrences of attempts at establishing common grounds through grounding, the posing of verification questions and statements were superficial and lacking in critical thinking. These diverse contributions of ideas were not given justice at the group level.

Legend							
Interactive △ Constructive □				Not Interactive (constructive or active) ▽ Active ○			
Integration of collaborative ideas into individual work ↷							
Regulative Processes				Transformative Processes			
OH	Orienting High	IH	Instructing High	OH	Orienting High	GHH	Generating Hypothesis High
OL	Orienting Low	IL	Instructing Low	OL	Orienting Low	GHL	Generating Hypothesis Low
PH	Planning High	GH	Grounding High	AQH	Asking Qns. High	THH	Testing Hypothesis High
PL	Planning Low	GL	Grounding Low	AQL	Asking Qns. Low	THL	Testing Hypothesis Low

	Lines			Regulative Processes	Transformative Processes
Small Group	L 1-4	△		PL	
	L 5&6	▽		IL	
	L 7-11	▽		OL	
	L 12-18	△		GL	
	L 19-21	▽		OL	OL
	L 22-27	△	↷ L23-27	GL	OL
	L 28-34	△		GL	AQL
	L 35-38	▽		OL	
	L 39-41	▽		GL	
	L 42-44	△	↷ L44	GH	
	L 45-48	△		OH	
	L 49-53	△		GL	AQL
	L 54-59	△	↷ L57-59	OL	GHL
	L 60-65	△		PL	THL
	L 66-69	△	↷ L69	PH	
	L 70-71	▽		GL	
	L 72-74	△		GL	
Individual	L1		○	OL	OL
	L 2		○	OL	AQL(2); THL
	L 3		□	MH	OH; AQH; GHH

Figure 19: *Graphical coding analysis of the PSI discourse in the pre-field trip*

Second, there were several occurrences where the group discourse was not interactive, but rather active or constructive. It was reduced to a case of accepting, eliciting or verbalizing one's ideas (table 41; table 42; table 49). Reiterating Chi's (2009) postulation that the substantive contributions foster *mutually generative processes,* which is instrumental for emergence of new knowledge and advancing knowledge. The discourse at the small group level in the pre-field trip at times did not see the desired cognitive processes during collaboration (Cohen, 1994; Dillenbourg, 1999) to converge differing views through reasoning and argumentation (Amigues, 1988; Osborne, 2010).

At the individual level, student S07 appeared to have still benefitted from the collaborative interaction at the small group level. His individual reflection showed one occurrence of constructive activity where he showed metacognitive skill in monitoring his progress and how he had performed. However, he also displayed more constructive activities in his transformative processes: he had one high-level orienting idea, one high-level asking of question and one high-level generating of hypothesis. This could be attributed to the effects of *fading-out* at the small group level where he incorporated and advanced these 'not-dealt with' ideas at the individual level (see figure 19: indicated with red bow arrow). The group's discussion on the importance of sunlight (see table 39; table 40; table 41) and the production of glucose (see table 46: line 57 to 59) was taken up in his own individual written work. Also, at the group level, he was able to leverage on fellow group member's contribution to advance his own knowledge and improve on his initial idea about taking measurement of the bamboo plant (see table 48: line 69). The effects of scaffolding were evident at the individual engagement in transformative processes. However, at the group level, his self-regulation at the group level seemed constrained by the group coordination and interaction (Järvelä & Järvenoja, 2011). He showed compliance to group decision and did not successfully integrate his idea into the collaborative space (e.g., see table 44, line 48 on the light through the leaves; table 47, line 65 on light as a variable in the inquiry plan and table 50, line 72 on measuring of glucose level). All these ideas and contributions either ended abruptly or were not taken up at the group level.

Data of small group discourse and individual reflection in the field trip

The small group discourse took place at the field trip after the guided tour of the rainforest hall. They generated possible evidences, and thereafter, they had to put a tick, a cross or a question mark next to evidences. In the following, the complete small group discourse of group 2 (see table 52) will be first presented, followed by the individual reflection of student S07 respectively during the field trip (see table 53).

Small group discourse of PSI group 2 in the field trip

Table 52: *Discourse excerpt of PSI small group 2 in the field trip*

Line	Student	Group Discourse
1	S05	Erstmal, was wir über den Bambus wissen …
2	S07	Er wächst ziemlich schnell. Er wächst den ganzen Tag.
3	S05	40 bis 50 cm am Tag…
4	S04	Maximal am Tag…
5	S07	Sagen wir 20 bis 50 cm einfach…
6	S06	20 bis 50 cm?
7	S05	Er hat Hohlräume zur Stabilität.
8	S05	Im Stamm…
9	S06	Er hat was?
10	S07; S05	Hohlräume.
11	S07	Er versucht, ziemlich schnell ans Licht zu kommen.
12	S04	Also…er versucht…
13	S07	Ja… versucht so schnell wie möglich zum Licht…
14	S07	Ja…wo werden die…welche Temperatur?
15	S05	Hmm…mit 28 Grad…
16	S04	75…
17	S07	Er lebt in einem Umfeld von…
18	S04	Mit 28 Grad und 75 Prozent Luftfeuchtigkeit…
19	S05	Ok… mehr Ideen ...es gibt noch eine Rückseite…
20	S04	Wir können auch schreiben, dass er resistent gegen Kälte und Frost ist.
21	S05	Es steht hier, dass er am schnellsten wächst und dass die Stängel hohl sind.
22	S06	Wir haben noch – was relevant ist?
23	S05	Ok, was war unsere Frage…
24	S07	Das mit dem Regenwald…mit dem...also…wie können Regenwaldpflanzen unter derart warmen und feuchten Lebensbedingungen überleben?
25	S05	Ok, dass er so schnell wächst, ist, glaube ich, nicht wirklich relevant.
26	S04	Naja, weil er so groß wird, aber dann hat sich eigentlich…
27	S05	Fragezeichen?
28	S07	Er versucht so schnell. ..
29	S04	Ok. Er versucht möglicht schnell, ins Licht zu kommen.
30	S05	Und dass er resistent gegen Frost und Kälte ist…in unserem Umfeld ist irgendwie nicht…
31	S07	Ja?...(nicht überzuegt davon)
32	S05	Also nicht relevant…also nicht.

Individual Reflection of Student S07 in the field trip

Table 53: *Excerpt of the individual reflection of student S07 in the field trip*

Reflection Questions: 1. Welche anderen Fragen tauchen auf, wenn du an deine Fragestellung, deine Hypothese und die Durchführung der Untersuchung denkst? 2. Falls es nicht geklappt hat, welche Veränderungen würdest du beim Entwurf des Untersuchungsplans machen?	
Line	Individual Reflection
1	Bei mir tauchen keine anderen Fragen auf. Ich weiß, was man machen soll…Keine anderen Fragen…
2	Wie groß an sich der Temperaturunterschied.
3	Ja…ich habe das auch gemessen, aber ich meine, es gibt verschiedene…
4	Falls es nicht klappt, ich werde keine Änderungen vorführen, weil es klappen wird…ich weiß es… Ich bin ein großes Genie.

Analysis of regulative and transformative processes in the field trip

The small group discourse will first be presented and analysed for the regulative processes, followed by the small group transformative processes in the written work. Thereafter the individual reflection will be presented and analysed for regulative processes, followed by the individual transformative processes in the written work. Only high and low-level transformative and regulative processes will be explained and discussed.

Analysis of small group regulative processes in the field trip

Table 54: *Discourse excerpt on growth of the bamboo plant*

Line	Student	Group Discourse	Code
1	S05	Erstmal, was wir über den Bambus wissen …	Grounding (High)
2	S07	Er wächst ziemlich schnell. Er wächst den ganzen Tag.	Shared Regulation
3	S05	40 bis 50 cm am Tag…	
4	S04	Maximal am Tag…	
5	S07	Sagen wir 20 bis 50 cm einfach…	
6	S06	20 bis 50 cm?	

The group discourse began with grounding statements on the data gathered which were coded grounding high as they displayed metacognitive awareness to check emerging comprehension of the information and to control for correctness (see table 54). They also showed good team regulation at the shared level to reflect upon one another’s idea and to further advance the idea as a collective unit.

Table 55: *Discourse excerpt on stability of the bamboo plant*

Line	Student	Group Discourse	Code
7	S05	Er hat Hohlräume zur Stabilität.	Testing (High)
8	S05	Im Stamm…	Shared Regulation
9	S06	Er hat was?	
10	S07; S05	Hohlräume.	

The brief affirmation about the structure of the bamboo and its stability was coded testing high for they showed critical reflection and went beyond the information collected (see table 55).

Table 56: *Discourse excerpt on sunlight and growth of the bamboo plant*

Line	Student	Group Discourse	Code
11	S07	Er versucht, ziemlich schnell ans Licht zu kommen.	Testing (Low)
12	S04	Also…er versucht…	Co- Regulation
13	S07	Ja… versucht so schnell wie möglich zum Licht…	

In table 56, the statements from students S04 and S07 at the co-regulation level were coded testing low as they merely reiterating earlier claim that the bamboo plant try to reach the sunlight as quickly as possible without making comparisons nor think about possible issues.

Table 57: *Discourse excerpt on temperature and moisture*

Line	Student	Group Discourse	Code
14	S07	Ja…wo werden die…welche Temperatur?	Testing (High)
15	S05	Hmm…mit 28 Grad…	Shared Regulation
16	S04	75…	
17	S07	Er lebt in einem Umfeld von…	
18	S04	Mit 28 Grad und 75 Prozent Luftfeuchtigkeit…	

In table 57, the group's discussion on the humidity level was coded testing high at the shared regulation level as they again, showed critical reflection and were able to make connections and inferences from pieces of science. They made visible attempts to compare and contrast the pieces of information to form a coherent whole.

Table 58: *Discourse excerpt on monitoring of work progress*

Line	Student	Group Discourse	Code
19	S05	Ok… mehr Ideen ..es gibt noch eine Rückseite…	Monitoring (Low) Shared Regulation

The brief directional monitoring statement made by student S05 was coded low (see table 58). Though at a shared regulation level, she dominated and decided the direction for the group.

Table 59: *Discourse excerpt on the structure of the bamboo plant*

Line	Student	Group Discourse	Code
20	S04	Wir können auch schreiben, dass er resistent gegen Kälte und Frost ist.	Testing (Low) Co-regulation
21	S05	Es steht hier, dass er am schnellsten wächst und dass die Stängel hohl sind.	

The discussion about the resistance of bamboo plant against cold and frost (see table 59; line 20 & 21) was coded as testing low as they merely summarizing given information. It was also not interactive, more a situation of constructive to affirm information in the learning materials.

Table 60: *Discourse excerpt on group work regulation*

Line	Student	Group Discourse	Code
22	S06	Wir haben noch – was relevant ist?	Instructing (Low) Shared Regulation

Student S06 next instructed group members to the next task where they had to evaluate the claims and evidences (see table 60). This was coded as instructing low as she 'ordered' the group to populate the table with ideas without visible attempts to contribute her own.

Table 61: *Discourse excerpt on monitoring of work progress*

Line	Student	Group Discourse	Code
23	S05	Ok, was war unsere Frage…	Monitoring (High) Co-Regulation
24	S07	Das mit dem Regenwald…mit dem..also…wie können Regenwaldpflanzen unter derart warmen und feuchten Lebensbedingungen überleben?	

Students S05 and S07 statements to check for understanding of their inquiry task and hypothesis were coded as monitoring high as they showed awareness to align the learning activities and strategies with their earlier set goals (see table 61). At the co-regulation level, there was a display of good support for one another in tracking their task progress and in maintaining the shared knowledge in the collaborative space.

Table 62: *Discourse excerpt on evidence evaluation - growth of the bamboo plant*

Line	Student	Group Discourse	Code
25	S05	Ok, dass er so schnell wächst, ist, glaube ich, nicht wirklich relevant.	Testing (Low) Shared Regulation
26	S04	Naja, weil er so groß wird, aber dann hat sich eigentlich…	
27	S05	Fragezeichen?	
28	S07	Er versucht so schnell...	
29	S04	Ok. Er versucht möglicht schnell, ins Licht zu kommen.	

The group was unable to leverage the earlier data collected on the measurement of daily growth of a bamboo plant to rightly evaluate their evidences (see table 62). This was coded as testing low at the shared regulation level as there was lack of depth in critical reflection.

Table 63: *Discourse excerpt on evidence evaluation – bamboo's resistance against cold*

Line	Student	Group Discourse	Code
30	S05	Und dass er resistent gegen Frost und Kälte ist…in unserem Umfeld ist irgendwie nicht…	Grounding (Low) Shared-regulation
31	S07	Ja?...(nicht überzuegt davon)	
32	S05	Also nicht relevant…also nicht.	

The final part of the discussion to decide if 'resistance against cold and frost' was a piece of valid evidence to support their hypothesis was coded grounding low as there was no attempt to address the query posed (see table 63). Student S07 expressed doubt about the group's decision (line 31) but he conceded with the majority's idea. It was also not interactive as student S05 seemed to be seeking affirmation of her idea.

Analysis of small group transformative processes (written work) in the field trip

The group's written work showed that they had a total of five ideas for generating of evidences. Two cases of generating evidence were coded high: (1) "Er lebt in einem Umfeld mit 28 Grad und 75 Prozent Lüftfeuchtigkeit" and (2) "Er hat Hohlräume zur Stabilität im Stamm". Here, they were able to link the claims to the structure of the bamboo plant and the living environment. There were three cases of generating evidence low. Two of which were: (3) "Er versucht, möglichst schnell ans Licht zu kommen-wächst schnell" and (4) "Er wächst maximal 40 bis 50 cm am Tag". It was coded generating evidence low they were not able to see the link between the pieces of evidences; the special stem (rhizome system) of the bamboo that explains its fast growth. For the fifth evidence, they wrote: (5) "Er ist resistent gegen Frost und Kälte". This was coded low as the group dismissed this as not quite relevant to their context though it was a good piece of information about the hardiness of the bamboo plant.

Analysis of individual regulative processes in the field trip

In the individual reflection (see table 64), student S07's monitoring statement on his task progress was coded high as he showed metacognitive knowledge of which learning activities to employ (line 1). He showed an awareness of the task goals and the appropriation of the learning activities to reach his goal. Similarly, his reflection on his inquiry plan (line 2) was coded testing high as he displayed knowledge on the data type for his hypothesis. However, he expressed uncertainty about how he could manage some of the queries arising from his data (line 3). This was coded testing low as he neither provided further critical reflection nor posing of relevant questions to check for understanding. His final reflection statement (line 4) was coded monitoring low as he did not state why he was sure his inquiry plan would be successful nor suggest change if it did not work though he displayed confidence. He did not attempt to surface any contingency plan nor gave any thought to it.

Table 64: *Student S07's responses to the reflection questions in the field trip*

Reflection Questions:
1. Welche anderen Fragen tauchen auf, wenn du an deine Fragestellung, deine Hypothese und die Durchführung der Untersuchung denkst?
2. Falls es nicht geklappt hat, welche Veränderungen würdest du beim Entwurf des Untersuchungsplans machen?

Line	Individual Reflection	Code
1	Bei mir tauchen keine anderen Fragen auf. Ich weiß, was man machen soll…Keine anderen Fragen…	Monitoring (High)
2	Wie groß an sich der Temperaturunterschied.	Testing (High)
3	Ja…ich habe das auch gemessen, aber ich meine, es gibt verschiedene…	Testing (Low)
4	Falls es nicht klappt, ich werde keine Änderungen vorführen, weil es klappen wird…ich weiß es… Ich bin ein großes Genie.	Monitoring (Low)

Analysis of individual transformative processes (written work) in the field trip

In the individual work, student S07 wrote four ideas for evidences. Three were coded high: (1) "Der Kaktus speichert das Wasser im Stamm und hat somit ein Wasserworrat". (2) "Die Kugelform ist die beste Form, Wasser zu speichern, durch das grosse Volumen". (3) "Guter Stoffwechsel, bei Nacht öffnen sich kleine Spalten (Stomata) wo CO_2 gespeichert wird. Diese schliessen sich am Tag, und das gesamelte CO_2 kann in dem Prozess gebraucht werden". These were coded high for he was able to relate the evidence to the structure of the cactus plant, its functions, as well as the living environment of the cactus.

One evidence was coded low: (4) “Dornen sind Überreste von Blättern. Abwehrreaktion. Revolution der Kakteen”. Here, he did not make concrete inference to his hypothesis nor build on this evidence to construct new knowledge about the cactus’ need for defense in the desert environment.

Interpretation of the discourse data for field trip

In the field-trip, the group discourse showed six instances of low-level regulative processes (two low-level grounding; one low-level monitoring; two low-level testing; one low-level instructing) and four instances of high-level regulative processes (one high-level grounding; two high-level testing; one high-level monitoring) as shown in figure 20. There was a marked reduction of low-level regulative processes which could account for the two instances of generating evidence high. There was also a decline in the occurrences of non-interactive activities: only three occurrences. It is noticeable that where there was high-level grounding, the group was able to co-construct new knowledge and shared understanding was well-negotiated (see table 54, table 55 & table 57) with the posing of good verification questions or statements. Explanatory activities during interaction and consolidation of ideas through reciprocal questioning (King, 1990; Webb, Troper, & Fall, 1995) have evidently seen an improvement in the discourse moves. For instance, the group leveraged on one another’s contribution to affirm shared understanding on the humidity level and moisture in the air to infer connections about the temperature and adaptation of the tropical rainforest plant (see table 57).

At the individual level, student S07 showed some improvement in his regulative and transformative processes (see figure 20: indicated with red bow arrow). The improvement in group regulation had effect a positive change in his self-regulation of task. It resonates with the notion that self-regulation is a social process (Meyer & Turner, 2002). His regulative processes had moved from active to show some constructive activities where he showed deeper awareness of how he could have approached his inquiry plan (one high-level monitoring and one high-level testing). As aforementioned, there were a few instances where good ideas from fellow members were only dealt with superficially, these ideas were adapted and applied in his individual inquiry task. For his transformative processes, he had three high-level evidences where he was able to infer connections between the plant structure and its function for adaptation. The group’s discussion on the specific conditions of the living environment and function of the specific plant parts (see table 55, line 7 to 10) and use of measurement to support their claim (see table 57, line 15 to 17) was applied in his generating of evidence for the cactus's adaptation to the desert condition.

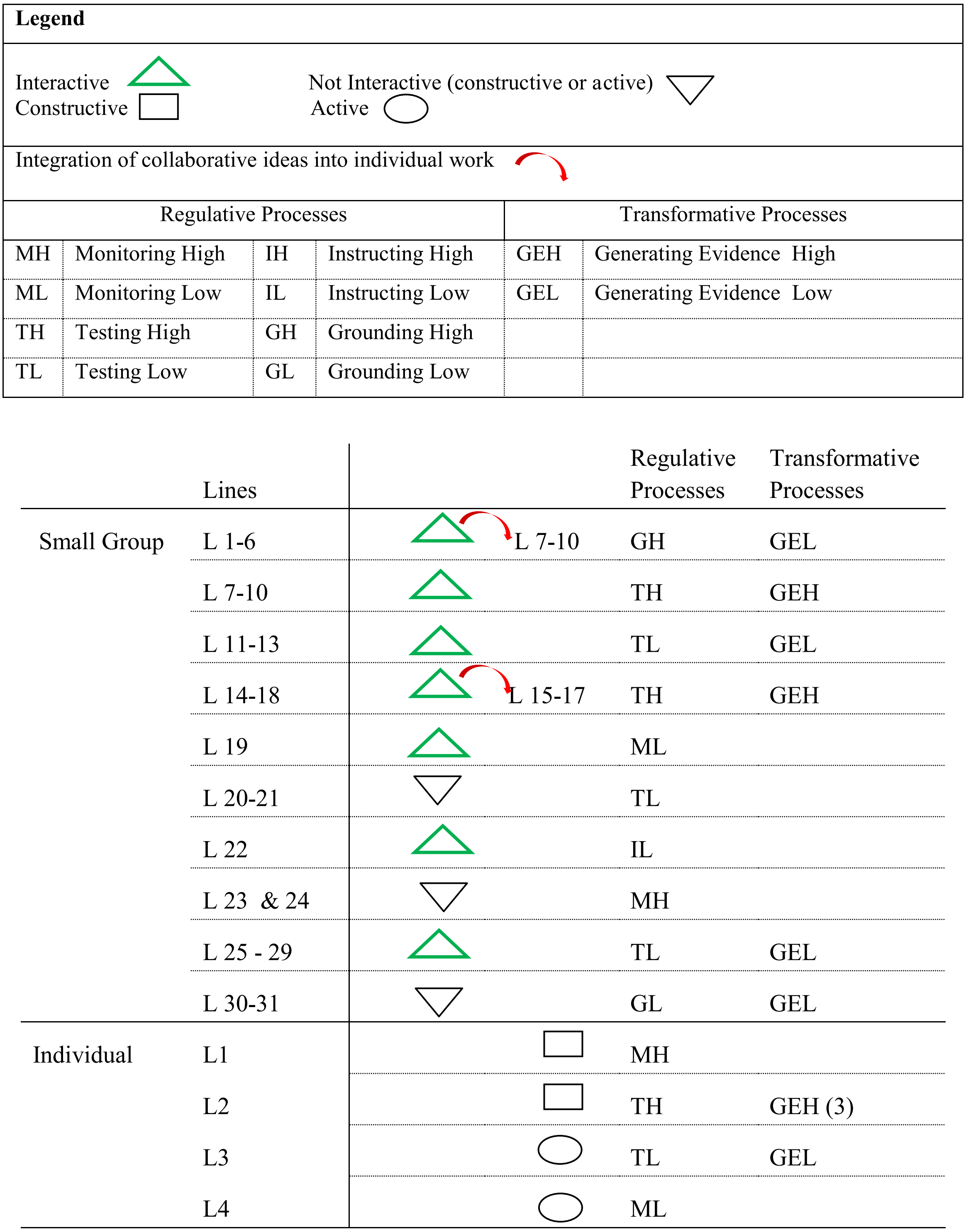


Figure 20: *Graphical coding analysis of the PSI discourse in the field trip*

Data of small group discourse and individual reflection in the post-field trip

In the post-field trip, students had to evaluate the evidences using the given scaffolds: claim, evidence and reasoning. Their final task was to write a scientific conclusion for the inquiry task. In the following, the complete small group discourse of group 2 (see table 65) will be first presented, followed by the individual reflection of student S07 (see table 66) respectively during the post-field trip.

Small group discourse of PSI group 2 in the post-field trip

Table 65: *Discourse excerpt of PSI small group 2 in the post-field trip*

Line	Student	Group Discourse
1	S05	Wir haben gesagt…Pflanzen brauchen Sonnenlicht um Glucose herzustellen und das steht hier…er versucht, möglich schnell ans Licht zu kommen…wächst schnell…
2	S06	Also, er braucht Licht.
3	S05	Genau.
4	S06	Behauptungen. Er braucht Sonnenlicht, um Glucose herzustellen.
5	S07	Begründung…
6	S04	Was habt ihr jetzt als Begründung?
7	S06	Wissenschaftlich!
8	S05	Aber wir haben auch sonst nichts mehr, das wisst ihr? Wir haben keine Behauptungen mehr, keine Begründungen, äh, keine Belege mehr…
9	S07	Ich weiß, das ist wie blöde.
10	S05	Wir haben…wie schnell er wächst, das ist unsere Behauptung, dass er schnell wachsen…dann Luftfeuchtigkeit…und also…die resistent gegen Frost und Kälte ist…
11	S05	Ok. Begründung. Was für eine Begründung?
12	S06	Was?
13	S05	Sagt mal eine Idee für eine Begründung.
14	S05	Vielleicht wenn er eine kleine Pflanze ist...genügend Sonnenlicht bekommt. Dann, wenn er größer ist, wächst er schnell zum Sonnenlicht.
15	S06	Aber hat der Bambus ehh… der Bambus genügend Wasser…
16	S05	Doch…Der Bambus braucht das Wasser. Wahrscheinlich kommt es aus der Erde oder der Luft.
17	S05	Ich glaube, dass die Dozentin hat gesagt, dass der Bambus so schnell wächst, weil er alles hat was er braucht, und das er soviel davon hat.
18	S06	Das auch. Oder dass er viel Sonnenlicht?
19	S05	Kann sein. Also, wir können schreiben, dass der Bambus wächst so schnell, weil er genügend Mineralstoffe…

Line	Student	Group Discourse
20	S04	Ja, aber wir haben hier jetzt nur noch: wie Pflanzen holen Wasser aus der Erde…
21	S05	Ja…vielleicht noch…Pflanzen können mit wenig Licht überleben.
22	S04	Also dann als Behauptung, Pflanzen können auch…
23	S05	Pflanzen können mit wenig Licht überleben.
24	S04	Pflanzen können mit wenig Licht überleben, dann die Belege…
25	S05	Pflanzen passen sich an ihre Lichtverhältnisse an.
26	S05	Und als Begründung, Pflanzen wachsen so, dass sie möglichst viel Licht bekommen…z.B. haben riesige Blätter.
27	S06	Hatten wir das?
28	S04	Ich habe nicht die Begründung.
29	S07	Ich habe meine eigene Begründung…dass sie möglicht viel Licht…
30	S05& S07	Abzufangen, z.B. mit riesigen Blättern.
31	S04	Aber das ist zu Stoff für die…
32	S05	Du kannst zum Beispiel schreiben, wachsen extrem schnell.
33	S04	Ok…
34	S05	Wir müssen endlich noch diese Dinge machen.
35	S07	Wissenschaftliche Erklärung!
36	S04	Der Bambus. Schreib: durch das starke Wachstum…Dass der Bambus viel Licht hat, dass er so schneller viel Licht hat…er kann besser Wasser auf...wie heißt…
37	S05	Aufnehmen und...
38	S04	Kann er mehr Licht aufnehmen, sowie Wasser…
39	S05	Und CO_2…

Individual Reflection of Student S07 in the post-field trip

Table 66: *Excerpt of the individual reflection of student S07in the post-field trip*

Reflection Questions:
1. Welche Schwierigkeiten und Herausforderungen sind dir während deiner Untersuchung begegnet? Wie hast du sie überwunden?
2. Konntest Du Deine Untersuchung wie geplant durchführen? (Wenn ja, warum? Falls nein, warum nicht?)

Line	Individual Reflection
1	Während meiner Untersuchung sind mir ein paar Baustellen in den Weg gefallen. Es war schwer, sie aus dem Weg zu schaffen, aber ich hab‘ es geschafft.
2	Ich finde, alleine war es ein bisschen schwerer als mit der Gruppe, ich musste mehr nachdenken.

Analysis of the small group discourse and individual reflection in the post-field trip

The small group discourse will first be presented and analysed for the regulative processes, followed by the small group transformative processes in the written work. Thereafter the individual reflection will be presented and analysed for regulative processes, followed by the individual transformative processes in the written work.

Analysis of small group regulative processes in the post-field trip

Table 67: *Discourse excerpt of evidence evaluation – glucose production*

Line	Student	Group Discourse	Code
1	S05	Wir haben gesagt…Pflanzen brauchen Sonnenlicht um Glucose herzustellen und das steht hier…er versucht, möglich schnell ans Licht zu kommen…wächst schnell…	Grounding (Low) Shared-regulation
2	S06	Also, er braucht Licht.	
3	S05	Genau.	
4	S06	Behauptungen. Er braucht Sonnenlicht, um Glucose herzustellen.	

The group discourse began with grounding to establish shared understanding by reviewing what they had discussed at the field trip (see table 67). The utterances were coded grounding low as there were neither verification questions nor seeking of further opinion, it was more a brief and quick consensus that plants need sunlight to produce glucose. It was not as interactive as there were no substantial contributions to generate new knowledge.

Table 68: *Discourse excerpt on monitoring of task progress*

Line	Student	Group Discourse	Code
5	S07	Begründung…	Monitoring (Low) Shared-regulation
6	S04	Was habt ihr jetzt als Begründung?	
7	S06	Wissenschaftlich!	
8	S05	Aber wir haben auch sonst nichts mehr, das wisst ihr? Wir haben keine Behauptungen mehr, keine Begründungen, äh, keine Belege mehr…	
9	S07	Ich weiß, das ist wie blöde.	

In table 68, the students monitored their progress and commented that they did not have any other claims, evidences nor reasoning to substantiate how the bamboo plant produce glucose other than what they had just discussed. Although the group noted that there was some missing information but they took no measures to address the situation e.g. by reviewing what they had written to tease out what they could have overlooked, monitoring was thus coded low.

Table 69: *Discourse excerpt on verification of evidence*

Line	Student	Group Discourse	Code
10	S05	Wir haben…wie schnell er wächst, das ist unsere Behauptung, dass er schnell wachsen …dann Luftfeuchtigkeit…und also…die resistent gegen Frost und Kälte ist…	Testing (Low) Shared-regulation

Student S05 got the group to move on to evaluate the evidences by summarizing what they had collated (see table 69). It was coded testing low at shared regulation as there were no connections made between the pieces of evidences and no contributions /queries from the other group members. It was evident that it was more constructive than interactive.

Table 70: *Discourse excerpt on substantiating a claim with evidence*

Line	Student	Group Discourse	Code
11	S05	Ok. Begründung. Was für eine Begründung?	Grounding (Low)
12	S06	Was?	Co-regulation
13	S05	Sagt mal eine Idee für eine Begründung.	

Student S05 asked student S06 for an idea on a scientific explanation to support their claim (see table 70). This was coded grounding low as it chiefly seeks to get idea or solution. It was also not interactive.

Table 71: *Discourse excerpt on verification of scientific reasoning*

Line	Student	Group Discourse	Code
14	S05	Vielleicht wenn er eine kleine Pflanze ist...genügend Sonnenlicht bekommt. Dann, wenn er größer ist, wächst er schnell zum Sonnenlicht.	Grounding (Low) Co-regulation
15	S06	Aber hat der Bambus ehh…der Bambus genügend Wasser…	
16	S05	Doch…Der Bambus braucht das Wasser. Wahrscheinlich kommt es aus der Erde oder der Luft.	

In table 71, the exchange between student S05 and S06 were coded grounding low as the verification statements and questions remained at low-level logical deduction on how the bamboo plant obtains sufficient sunlight and water for its growth in the rainforest. There was no attempt to provide nor seek scientific explanations for the claim made.

Table 72: *Discourse excerpt on source of evidence*

Line	Student	Group Discourse	Code

17	S05	Ich glaube, dass die Dozentin hat gesagt, dass der Bambus so schnell wächst, weil er alles hat was er braucht, und das er soviel davon hat.	Testing (Low) Co-regulation
18	S06	Das auch. Oder dass er viel Sonnenlicht?	
19	S05	Kann sein. Also, wir können schreiben, dass der Bambus wächst so schnell, weil er genügend Mineralstoffe…	

The continued discourse between both of them was also coded testing low as it did not reflect higher critical reflection, but merely cited the tour guide as their reference point for checking of relevance (see table 72).

Table 73: *Discourse excerpt on consolidation of evidence*

Line	Student	Group Discourse	Code
20	S04	Ja, aber wir haben hier jetzt nur noch: wie Pflanzen holen Wasser aus der Erde…	Testing (Low) Shared-regulation
21	S05	Ja …vielleicht noch…Pflanzen können mit wenig Licht überleben.	
22	S04	Also dann als Behauptung, Pflanzen können auch…	
23	S05	Pflanzen können mit wenig Licht überleben.	
24	S04	Pflanzen können mit wenig Licht überleben, dann die Belege…	
25	S05	Pflanzen passen sich an ihre Lichtverhältnisse an.	

The same situation applies here to the discourse between student S05 and S04 where testing remained at a low level for there was an apparent absence of reflective thinking of possible issues or new questions (see table 73). It was more a case of going through the list of collated evidences and reproducing them for the worksheets. Thus, the interaction was not substantive as most of the time, the two students seemed to engage in affirming the information they had generated and repeated the same information.

Table 74: *Discourse excerpt on confirmation of scientific reasoning*

Line	Student	Group Discourse	Code
26	S05	Und als Begründung, Pflanzen wachsen so, dass sie möglichst viel Licht bekommen…z.B. haben riesige Blätter.	Grounding (Low) Shared-regulation
27	S06	Hatten wir das?	
28	S04	Ich habe nicht die Begründung.	
29	S07	Ich habe meine eigene Begründung…dass sie möglicht viel Licht…	
30	S05& S07	Abzufangen, z.B. mit riesigen Blättern.	
31	S04	Aber das ist zu Stoff für die…	
32	S05	Du kannst zum Beispiel schreiben, wachsen extrem schnell.	
33	S04	Ok…	

The series of grounding statements was coded low as the verification questions posed were not aptly dealt with (see table 74). For instance, student S07 said that his reasoning was different but it was dismissed by student S05 who interrupted that the bamboo plant could absorb lots of light owing to the huge size of the leaves (line 29). Student S04 disagreed that the size of the leaves to absorb light (line 31) was a relevant argument for the case of the bamboo plant, but her argument was not taken up.

Table 75: *Discourse excerpt on monitoring of task progress*

Line	Student	Group Discourse	Code
34	S05	Wir müssen endlich noch diese Dinge machen.	Monitoring (Low)
35	S07	Wissenschaftliche Erklärung!	Shared-regulation

Monitoring of their task progress was coded low for they appeared to have overlooked the sequence of activities and task expectations (see table 75).

Table 76: *Discourse excerpt on drawing of scientific conclusion*

Line	Student	Group Discourse	Code
36	S04	Der Bambus. Schreib: durch das starke Wachstum…Dass der Bambus viel Licht hat, dass er so schneller viel Licht hat…er kann besser Wasser auf...wie heißt…	Testing (Low) Shared-regulation
37	S05	Aufnehmen und...	
38	S04	Kann er mehr Licht aufnehmen, sowie Wasser…	
39	S05	Und CO_2...	

The group discourse ended with another round of low-level testing for the attempt to sum up the core information and draw conclusions was superficial and lack deep reflection (see table 76). It could be that owing to low-level monitoring, they were in a bid for time and were unable to engage in deep discourse on developing a scientific conclusion using the claims, the evidences and the reasons they had earlier generated.

Analysis of small group transformative processes (written work) in the post-field trip

The group's written work for evaluating of evidences was coded low for both statements and so was the final scientific conclusion formulated (see table 77). It was apparent that the group failed to leverage on the data they had collected to make sound evaluation of their claims which eventually shaped their scientific reasoning process and the conclusion they made. There was no mention of the measurement on the growth of the bamboo plant nor the structure of the bamboo plant that made it resistant to the weather condition in the tropical rainforest and its fast growth owing to the stem structure. Next, they mentioned in a general manner that plants were able to adapt to the various amount of light and that big leaves enabled the plants to absorb more light. Although they were implicitly referring to the bamboo plant on light adaptation (corresponding to their group discourse), the reasoning about having big leaves was totally irrelevant for the bambus plant they had chosen. Hence, the eventual scientific conclusion was inevitably affected by the low-level evaluation of evidences and was coded low.

Table 77: *Small group written work in the post-field trip*

Evaluating Evidence		
Behauptung (en)	Beleg (e)	Begründung (en)
Pflanzen brauchen Sonnenlicht, um Glucose herzustellen	Der Bambus wachst schnell in Richtung Sonnenlicht, um das Licht zu absorbieren.	Der Bambus wächst so schnell, weil er genügend Mineralstoffe, CO_2, Wasser und Licht hat.
Pflanzen können mit wenig Licht überleben.	Pflanzen passen sich an ihre Lichtverhältnisse an.	Pflanzen wachsen so, dass sie möglichst viel Licht bekommen, z.B. haben riesige Blätter.
Drawing Conclusion		
Durch das schnelle Wachstum des Bambus kann er besser ans Licht kommen, CO_2 und Wasser aufnehmen.		

Analysis of individual regulative processes in the post-field trip

At the individual level after carrying out inquiry task three, student S07's reflection demonstrated high-level evaluation (see table 78). He displayed metacognitive awareness of his own learning process, in particular, the execution of the inquiry plan. He also appreciated collaboration in inquiry task two where he felt that the support from the group had made the inquiry process easier.

Table 78: *Student S07's responses to the reflection questions in the post-field trip*

Reflection Questions:
1. Welche Schwierigkeiten und Herausforderungen sind dir während deiner Untersuchung begegnet? Wie hast du sie überwunden?
2. Konntest Du Deine Untersuchung wie geplant durchführen? (Wenn ja, warum? Falls nein, warum nicht?)

Line	Individual Reflection	Code
1	Während meiner Untersuchung sind mir ein paar Baustellen in den Weg gefallen. Es war schwer, sie aus dem Weg zu schaffen, aber ich hab' es geschafft.	Evaluating (High)
2	Ich finde, alleine war es ein bisschen schwerer als mit der Gruppe, ich musste mehr nachdenken.	Evaluating (High)

Analysis of individual transformative processes (written work) in the post-field trip

Student S07 evaluation of evidences was coded as high for both statements as he was able to make valid inferences and connections between the claims and evidences: explaining the functions of the structures of the cactus in his reasoning process (see table 79). For the final scientific conclusions, one was coded high as he explained the function of the special structure that enabled the cactus to conduct transpiration in the night. The other was coded low for he did not mention the structure of the cactus on the storage of water in dry seasons.

Table 79: *Individual written work of student S07 in the post-field trip*

Evaluating Evidence		
Behauptung (en)	Beleg (e)	Begründung (en)
Der Kaktus braucht Wasser zum Überleben, was es in der Wüste wenig gibt.	Er speichert das Wasser gut.	Seine Kugelform ist die beste, um Wasser zu speichern.
Wie überlebt er so gut?	Er hat einen guten Prozess.	Nachts öffnet er seine Stomata, wo CO_2 gespeichert wird.
Drawing Conclusion		
Kakteen überleben durch den Prozess, der in der Nacht stattfindet. Es öffnet sich kleine Spalten, wo CO2 gespeichert wird. Dieses CO2 wird am Tag zum Überleben benötigt. Außerdem speichert er gut Wasser.		

Interpretation of the discourse data for post-field trip

In the post-field trip, the group discourse showed ten instances of low-level regulative processes (four low-level grounding; two low-level monitoring; four low-level testing) and no instances of high-level regulative processes (see figure 21). For the group transformative processes, they had two low-level evaluating of evidence and one low-level drawing of scientific conclusion (see figure 21). This is not surprising owing to the several occurrences of low-level grounding and testing where the interaction at the small group level was not as constructive and new perspectives surfaced by fellow group members was not critically dealt with. There was also an apparent lack of a scientific level discourse type, for instance, members leveraged on logical deduction rather than scientific reasoning for the fast growth of the bamboo plant, water intake and sunlight (see table 71).

However, student S07 was able to leverage some of the new knowledge and perspectives explored at the small group level and applied them at the individual level in the evaluating of evidence and drawing of conclusion. Student S07 adapted the group's ideas in his own inquiry task (see figure 21: indicated with red bow arrows) where the group spoke of a scientific explanation for the claims made (see table 68: line 5 to 7): the absorption of light (see table 70: line 26 to 30) and essential materials for survival (see table 76: line 37 to 39). He had two high-level evaluating of evidences and one high-level conclusion where he showed knowledge transfer in constructing explanations that are scientific with valid evidences (see figure 21). Likewise, there were also evidences of more constructive than active activities in his regulative processes. He displayed metacognitive awareness of the nature of the challenges at the individual level and appreciated collaborative work.

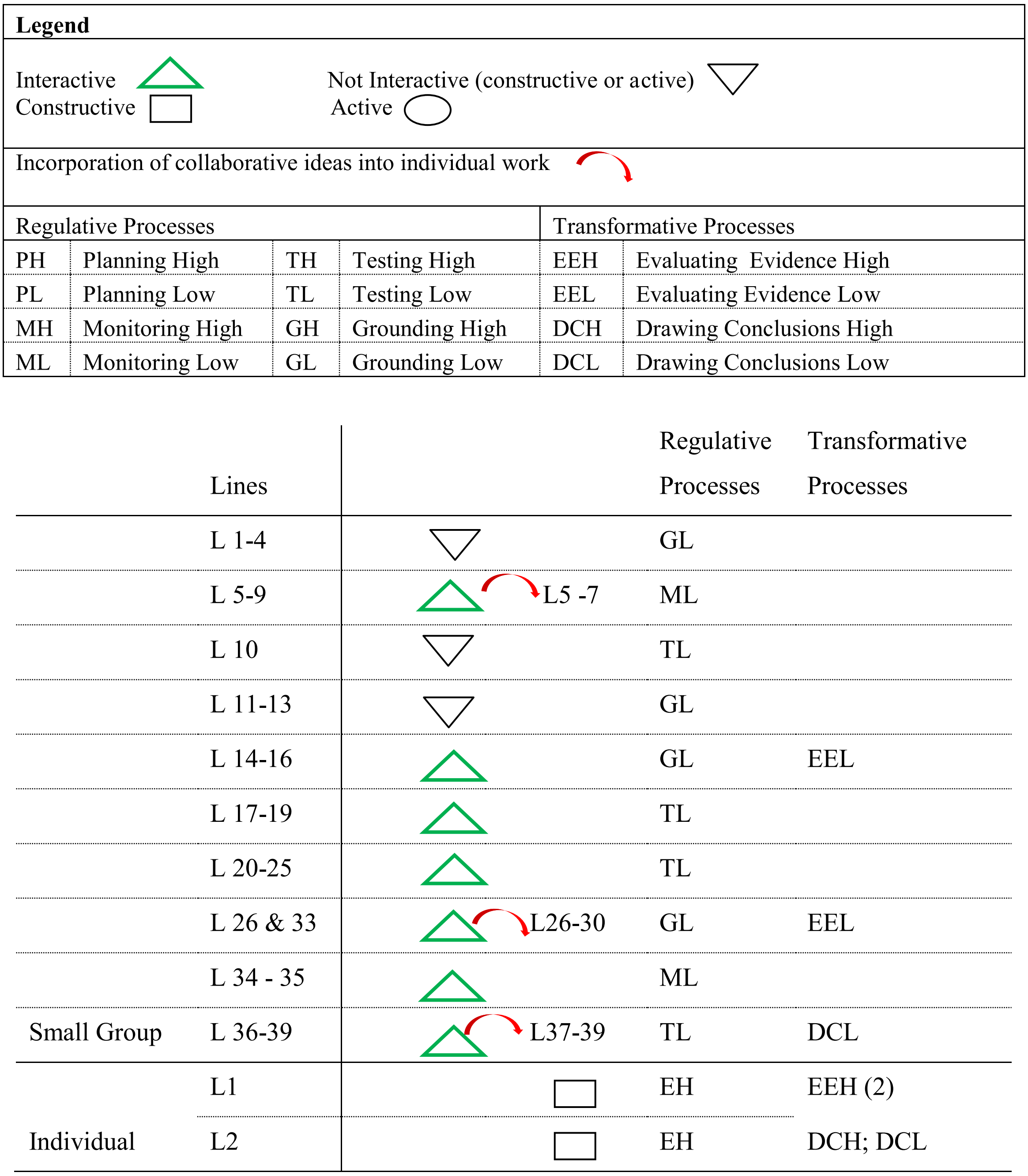


Figure 21: *Graphical coding analysis of the PSI discourse in the post-field trip*

Summary

Overall from the pre- to the post-field trip phase, the group discourse showed more instances of low-level regulative processes which apparently also led to more instances of low-level transformative processes. This is also aggravated by instances of no interactive activities in the group discourse where one or two dominated the 'collaboration' and no common grounds was negotiated to co-construct shared knowledge, for instance, line 18 to 20 (see table 38) and line 34 to 37 (see table 41) in the pre-field trip, as well as line 1 to 4 (see table 67) in the post-field trip. During these occasions, there was no interactive activity; it was more a situation where one member engaged in constructive activities to affirm his or her own understanding.

At the individual level, there were several evidences of the effects of 'gradual fading of the scaffolds' (Pea, 2004) where student S07 was able to leverage the range of ideas put forth at the group level, to readapt and to advance those ideas at the individual level which explained some instances of his high-level transformative processes. It is evident that he had more constructive than active activities in the field trip and post-field trip. This could be attributed to the effects of 'fading-out' as he moved from the small group level to work individually. In his individual reflection where he compared the small group to individual work, he acknowledged that it was more challenging thinking on his own feet.

6.5.2 Discourse with the PIS Classroom Script

The results of the quantitative analysis showed that the PIS script facilitated the following transformative processes: generating of evidence, drawing of conclusions and with statistical significance for high-level generating of evidence for the small group inquiry learning. As for the small group regulative processes, PIS script facilitated more occurrences of high-level grounding and high-level testing, which could be instrumental in the higher occurrences of high-level generating of evidence, as well as overall generating of evidence and drawing of conclusions for the transformative processes. However, for the individuals, the PIS script did not render noteworthy effects on transformative processes. It facilitated instead the regulative processes, as well as high levels ones in orienting, planning and testing with only statistical significance for orienting and high-level orienting. The analysis of the discourse structures in case study will afford us a better understanding of the quantitative results.

Students in the PIS script 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". As such, the individual reflection (student I21) will be discussed and analyzed, followed by the group discourse (group 2). This PIS group consists of four students from grade nine: three girls and one boy. For confidentiality, only students' code numbers will be used.

Data of the individual reflection and small group discourse in the pre-field trip

In the pre-field trip, students were engaged in orienting, asking questions, generating hypothesis and developing an inquiry plan to test hypothesis. Following is the complete individual reflection of student I21 (see table 80), followed by small group discourse of group 6 (see table 81) in the PIS script condition.

Individual Reflection of Student I21 in the pre-field trip

Table 80: *Excerpt of the individual reflection of student I21 in the pre-field trip*

Reflection Questions:
1. Was weißt du bereits und was musst du wissen, um deinen Untersuchungsplan zu entwickeln?
2. Wie gehst du bei der Planung deiner Untersuchung vor?

Line	Individual Reflection
1	Ich weiß, was sie benötigen: Licht, Wasser und CO_2, um zu leben.
2	Ich weiß, dass sie Glukose benötigen. Die sie einspeichern können, wenn sie kein Licht haben.
3	Die Pflanze in einen dunklen Raum stellen...und man muss den Versuch in verschiedenen Variationen ausführen, um zum einem Ergebnis zu kommen.

Small group discourse of PIS group 6 in the pre-field trip

Table 81: *Discourse excerpt of PIS small group 6 in the pre-field trip*

Line	Student	Group Discourse
1	I22	Jetzt müssen wir in Gruppen, oder?
2	I21	Ja
3	I19; I20	Ok. Gut.
4	I21	Ok. Was wollen wir jetzt machen?
5	I20	Ok. Falls jemand das interessiert. Die machen ihre Fotosynthese in der Nacht, um Wasserverlust zu verringern und können Wasser speichern.
6	I21 & I22	Aber wie macht man das ohne Licht? (zusammen gesprochen)
7	I22	Ja, wie ohne Licht?
8	I20	Ja, ich nehme an, das Licht nehmen sie tagsüber auf und die...

Line	Student	Group Discourse
9	I19	Und wo tun sie es hin?
10	I20	Sie speichern sie, Zsofia.
11	I22	In der Chlorophüsen…
12	I20	Chlorophyll…
13	I20	Nein, Chloroplast…nein Chlorophyll…
14	I22	Im Chlorophyll speichern sie es.
15	I21	Ok, was wissen wir…
16	I19	Eh…wir wissen…Ja…
17	I21	Kakteen brauchen extrem wenig Wasser.
18	I22	Brauchen sie wenig Wasser…
19	I19	Und sie können Wasser speichern.
20	122	Hab‘ Stacheln…
21	I21	Wo...
22	I20	Aber wofür sind die überhaupt?
23	I22	Also, bei den…
24	I21	Damit sie nicht gefressen werden.
25	I22	Und bei dem kann das nicht austrocknen.
26	I19	Kakteen speichern Lichtenergie, machen die Glukose...nee...die Fotosynthese in der Nacht, um Wasserverlust zu vermeiden.
27	I21	Yup…
28	I20	Ok. Fotosynthese in der Nacht…
29	I21	Damit sie den Wasserverlust verringern können.
30	I22	Wieso brauchen Kakteen wenig Wasser?
31	I21	Speichern können…
32	I22	Was wir herausfinden wollen?
33	I20	Wie lange überleben sie in einer anderen Vegetationszone?
34	I21	Ja...das ist gut!
35	I22	Eine Hypothese, wie ein Kaktus Nahrung…
36	I20	Er produziert Nahrung.
37	I21	Was für Nahrung denn?
38	I22	Er speichert Wasser.
39	I21	Was hast du geschrieben?
40	I22	Er speichert Wasser, macht Fotosynthese in der Nacht.
41	I19	Nee, er speichert Wasser und Lichtenergie und macht Fotosynthese in der Nacht.
42	I22	Machen wir mal, wie werden die Daten sammeln…
43	I21	Wie werden wir die Daten sammeln?
44	I22	Einem Kaktus lange kein Wasser geben…
45	I21	Wie wäre es damit, einen Kaktus so lange gießen, bis er zu viel Wasser hat?
46	I22	Und kein Wasser geben…

Line	Student	Group Discourse
47	I19	Aber es ist doch klar, dass er stirbt, weil wir ihm kein Wasser geben. Ja. Aber es ist auch klar, dass er stirbt, weil wir ihm zu viel Wasser geben.
48	I20	Das ist nicht klar, weil er so wenig Wasser braucht.
49	I22	Ach so…
50	I19	In der Wüste regnet es ja fast gar nicht.
51	I22	Weiß nicht, wann er nicht mehr genügend Wasser hat.
52	I20	Also…welche Arten von Daten werden wir sammeln?
53	I19	Ob ein Kaktus ohne Wasser gelebt hat…
54	I21	Und auch wie lange?
55	I20	Und bei den Stacheln, können wir die Stacheln ausschneiden und mit dem Mikroskop schauen.
56	I21	Ja…deswegen…
57	I22	Ja…die Stacheln…wie ist drin…
58	I20	Der Kaktus…weiß du wie klein die teilweise sind?
59	I21	Aber man kann ein Stück vom Kaktus abschneiden und gucken, wie er innen aussieht.

Analysis of regulative and transformative processes in the pre-field trip

Similar procedure is observed for the analysis of the PIS case study as per approach to the preceding case study of the PSI discourse. The responses to the individual reflection questions will first be presented and analysed for the regulative processes, followed by the individual transformative processes in the written work. Thereafter the small group discourse will be presented and analysed for regulative processes, followed by the small group transformative processes in the written work. Only high and low-level transformative and regulative processes will be explained and discussed.

Analysis of individual regulative processes in the pre-field trip

Table 82: *Student I21's responses to the reflection questions in the pre-field trip*

Reflection Questions:
1. Was weißt du bereits und was musst du wissen, um deinen Untersuchungsplan zu entwickeln?
2. Wie gehst du bei der Planung deiner Untersuchung vor?

Line	Individual Reflection	Code
1	Ich weiß, was sie benötigen: Licht, Wasser und CO_2, um zu leben.	Orienting (Low)
2	Ich weiß, dass sie Glukose benötigen. Die sie einspeichern können, wenn sie kein Licht haben.	Orienting (High)

3	Die Pflanze in einen dunklen Raum stellen...und man muss den Versuch in verschiedenen Variationen ausführen, um zum einem Ergebnis zu kommen.	Planning (High)

In the individual reflection (see table 82), student I21 initially merely reproduced given information about what plants need to grow and this was coded orienting low (line 1). However, she later expressed an awareness of some information gap and attempted to infer some scientific connections, this was coded as orienting high (line 2). She also displayed some critical reflection in planning and execution of her inquiry plan when she mentioned the need for different variations in the experiment, which was coded planning high (line 3).

Analysis of individual transformative processes (written work) in the pre-field trip

In her written work, she wrote two orienting ideas: (1) "Viele Pflanzen benötigen das warmfeuchte Klima zum Leben." and (2) "Die Pflanzen, die dort wachsen, sind alle voneinander abhängig". Both orienting statements remained relatively general about rainforest plants and were coded low as she did not state specific information about the bamboo plant she had chosen as her plant of inquiry. Next, she wrote that she had questions on,"Wie die kleinen Pflanzen, die weit unten wachsen, genug Licht bekommen", "Wie die verschiedenen Pflanzen voneinander abhängig sind" and "Warum so eine große Vielfalt an Pflanzen existieren kann, wenn einige offenbar nicht genug Licht bekommen". All three questions were coded as asking questions low as she did not list specific questions about the bamboo plant. Her hypothesis was, "Der Bambus braucht recht wenig Wasser und wächst sehr schnell in die Höhe, damit er genügend Sonnenlicht bekommt." It was coded high as she did try to go beyond given information to make scientific inferences about the fast growth of the bamboo plant and its reach for sunlight. For testing hypothesis, the idea, "Ich würde mehrere Tage eine Bambuspflanze beim Wachsen beobachten und messen" was coded high as she displayed the scientific knowledge for reliable evidence by observation and measurement. Her other idea, "Man müsste mehrere Bambuspflanzen mit verschiedenen großen Wassermengen gießen und beobachten" was coded low as it remained vague and superficial.

Analysis of small group regulative processes in the pre-field trip

Table 83: *Discourse excerpt on task orientation*

Line	Student	Group Discourse	Code

1	I22	Jetzt müssen wir in Gruppen, oder?	Orienting (Low)
2	I21	Ja	Shared-regulation
3	I19; I20	Ok. Gut.	
4	I21	Ok. Was wollen wir jetzt machen?	

The group discourse at the shared regulatory level began with orienting statements on task requirements and was coded orienting low for its brevity and lack of clear shared goals and task perceptions (see table 83). In fact, the group did not reach any shared understanding of how they should proceed with the task. There was also absence of a substantive interaction and was thus coded as non-interactive. It was more constructive than interactive as each of them was seemingly caught up with their own perception of the task and requirements. They did not voice their queries or seek clarifications at the group level.

Table 84: *Discourse excerpt on verification of orienting statements*

Line	Student	Group Discourse	Code
5	I20	Ok. Falls jemand das interessiert. Die machen ihre Fotosynthese in der Nacht, um Wasserverlust zu verringern und können Wasser speichern.	Grounding (High) Shared-regulation
6	I21 & I22	Aber wie macht man das ohne Licht? (zusammen gesprochen)	
7	I22	Ja, wie ohne Licht?	
8	I20	Ja, ich nehme an, das Licht nehmen sie tagsüber auf und die...	

Student I20 focused the group's attention to an important piece of the given information about on the process of photosynthesis in the cactus plant (see table 84: line 5). This also led to high grounding statements at the shared regulation level (line 6 to 8) where verification questions emerged on the process of photosynthesis in the night without sunlight. The group also showed good engagement as a collective unit; probed each other with pressing verification questions.

Table 85: *Discourse excerpt on integration of new knowledge*

Line	Student	Group Discourse	Code
9	I19	Und wo tun sie es hin?	Orienting (High)
10	I20	Sie speichern sie, Zsofia.	Shared-regulation
11	I22	In der Chlorophüsen…	
12	I20	Chlorophyll…	
13	I20	Nein, Chloroplast…nein Chlorophyll…	
14	I22	Im Chlorophyll speichern sie es.	

Following the above grounding statements, the group attempted to connect prior knowledge about the function of chlorophyll, the sunlight and the process of photosynthesis specific to the cactus plant (see table 85). Although the students had yet to fully understand that the transpiration process took place in the night for the cactus plants which enabled photosynthesis to complete in the daytime, this was coded orienting high for they displayed inclinations towards integrating new knowledge. There was good interaction with critical thinking and posing of clarification statements.

Table 86: *Discourse excerpt on task orientation*

Line	Student	Group Discourse	Code
15	I21	Ok, was wissen wir…	Orienting (Low)
16	I19	Eh…wir wissen…Ja…	Shared-regulation
17	I21	Kakteen brauchen extrem wenig Wasser.	
18	I22	Brauchen sie wenig Wasser…	
19	I19	Und sie können Wasser speichern.	

The group discussion here was more a situation of externalisation and affirmation, which led to low orienting statements about cactus storing water for use (see table 86). They did not generate any new knowledge during the orienting phase and merely replicated given information.

Table 87: *Discourse excerpt on verification of orienting statements*

Line	Student	Group Discourse	Code
20	122	Hab‘ Stacheln…	Orienting (High)
21	I21	Wo...	Shared-regulation
22	I20	Aber wofür sind die überhaupt?	
23	I22	Also, bei den…	
24	I21	Damit sie nicht gefressen werden.	
25	I22	Und bei dem kann das nicht austrocknen.	

In table 87, the discussion on the cactus's spikes as defense mechanism were coded high as they were able to go beyond the given information to construct new knowledge about conservation of water and prevention of drying up. The posing of questions led to a collaborative reflection and advancement of known knowledge.

Table 88: *Discourse excerpt on affirmation of orienting statements*

Line	Student	Group Discourse	Code
26	I19	Kakteen speichern Lichtenergie, machen die Glukose...nee...die Fotosynthese in der Nacht, um Wasserverlust zu vermeiden.	Orienting (Low) Co-regulation
27	I21	Yup…	
28	I20	Ok. Fotosynthese in der Nacht…	
29	I21	Damit sie den Wasserverlust verringern können.	

The group revisited some of the given information for affirmation: coded as orienting low because they did not show any awareness of information gap about photosynthesis taking place in the night (see table 88). There was inaccuracy in the conceptual knowledge.

Table 89: *Discourse excerpt on affirmation of orienting statements*

Line	Student	Group Discourse	Code
30	I22	Wieso brauchen Kakteen wenig Wasser?	Grounding (Low)
31	I21	Speichern können…	Co-regulation

Grounding at co-regulatory level occurred with I22 posing a verification question on the little water amount a cactus plant required (see table 89). This was coded grounding low as the response given was brief with no further scientific inferences. Also, it was non-interactive as it was reduced to a situation of externalizing a query and eliciting information.

Table 90: *Discourse excerpt on questions for the inquiry task*

Line	Student	Group Discourse	Code
32	I22	Was wir herausfinden wollen?	Orienting (High)
33	I20	Wie lange überleben sie in einer anderen Vegetationszone?	Shared-regulation
34	I21	Ja...das ist gut!	

The group discussed possible questions to address during the field trip which was coded orienting high (see table 90). They displayed an awareness of gap in prior knowledge and were able to go beyond given information to raise query about cactus in another vegetation zone.

Table 91: *Discourse excerpt on possible hypotheses for the inquiry task*

Line	Student	Group Discourse	Code
35	I22	Eine Hypothese, wie ein Kaktus Nahrung…	Grounding (High)
36	I20	Er produziert Nahrung.	Shared-regulation
37	I21	Was für Nahrung denn?	
38	I22	Er speichert Wasser.	
39	I21	Was hast du geschrieben?	
40	I22	Er speichert Wasser, macht Fotosynthese in der Nacht.	
41	I19	Nee, er speichert Wasser und Lichtenergie und macht Fotosynthese in der Nacht.	

The group began with grounding statements on a possible hypothesis for the cactus plant and its adaptation to its living environment (see table 91). The statements were coded grounding high as there were verification questions especially on the process of photosynthesis in the night which resulted in the emergent hypothesis that the cactus stored light energy. There was substantive interaction and the group showed good engagement in generating and constructing new knowledge.

Table 92: *Discourse excerpt on data collection plan*

Line	Student	Group Discourse	Code
42	I22	Machen wir mal, wie werden die Daten sammeln…	Grounding (Low)
43	I21	Wie werden wir die Daten sammeln?	Shared-regulation
44	I22	Einem Kaktus lange kein Wasser geben…	
45	I21	Wie wäre es damit, einen Kaktus so lange gießen, bis er zu viel Wasser hat?	
46	I22	Und kein Wasser geben…	

In table 92, the discussion and questions posed on the methods of data collection plan were coded grounding low as it remained at a very general level and attempts to establish shared understanding appeared weak. There was no identification of variables and no references made to the living environment.

Table 93: *Discourse excerpt on data type and its purpose – water quantity*

Line	Student	Group Discourse	Code
47	I19	Aber es ist doch klar, dass er stirbt, weil wir ihm kein Wasser geben.	Planning (Low) Shared-regulation
48	I20	Ja. Aber es ist auch klar, dass er stirbt, weil wir ihm zu viel Wasser geben.	
49	I22	Das ist nicht klar, weil er so wenig Wasser braucht.	
50	I19	Ach so…	
51	I22	In der Wüste regnet es ja fast gar nicht.	
52	I20	Weiß nicht, wann er nicht mehr genügend Wasser hat. Also…welche Arten von Daten werden wir sammeln?	
53	I19	Ob ein Kaktus ohne Wasser gelebt hat…	
54	I21	Und auch wie lange?	

The group surfaced the need for control on the length of time where the cactus could survive without water (see table 93). However, it was coded planning low as there was still no clear indication of a viable plan to test the hypothesis on a field trip study. The planning remained superficial though some of the group members had some good questions. These questions were not taken up for consideration during the development of an inquiry plan.

Table 94: *Discourse excerpt on data type and its purpose – function of spikes*

Line	Student	Group Discourse	Code

55	I20	Und bei den Stacheln, können wir die Stacheln ausschneiden und mit dem Mikroskop schauen.	Planning (High) Shared-regulation
56	I21	Ja…deswegen…	
57	I22	Ja..die Stacheln…wie ist drin…	
58	I20	Der Kaktus…weiß du wie klein die teilweise sind?	
59	I21	Aber man kann ein Stück vom Kaktus abschneiden und gucken, wie er innen aussieht.	

As shown in table 94, the group's discussion on data collection method to investigate the function of the spikes on the cactus plant was coded planning high, as they were able to employ a scientific method; use of a microscope to examine the inner tissue of the cactus. They displayed an awareness of the need for evidence. Contributions from some group members led to greater sense making in the planning process.

Analysis of small group transformative processes (written work) in the pre-field trip

The group had four orienting statements: (1) "Kakteen brauchen extrem wenig Wasser"; (2) "Kakteen können Wasser speichern"; (3) "Kakteen speichern Lichtenergie und machen Fotosynthese bei Nacht, um den Wasserverlust zu verringern"; (4) "Kakteen leben in der Wüste". The first orienting statement on the water amount a cactus plant would need was coded high as they were able to connect this idea to their question on vegetation zone. Another high orienting statement was number three where they spoke of the transpiration process in the night to reduce water loss. The other two statements were coded low as they were general knowledge statements without reference to the cactus plant structure, tissues nor functions. They had three ideas for asking questions. The question on "Wie lange überleben sie in anderen Vegetationszonen" was coded high as it showed critical thinking in probing further. The other two questions, "Wozu sind die Stacheln gut?" and "Ist zuviel Wasser schädlich?" were coded low as no elaboration and inferences were made.

The group formulated their hypothesis as "Er speichert Wasser und Lichtenergie und macht Fotosynthese in der Nacht." This was coded generating hypothesis high as they were able to specify the core elements needed for photosynthesis to take place though they had yet to realise that only transpiration process began at night. For the testing of hypothesis, they had two ideas, "wir würden einen Kaktus nicht giessen and einen Kaktus sehr oft giessen". This idea was coded testing hypothesis low as the method sounded superficial without mention of specific control measures for water quantity nor duration.
Further, the method of data collection was viable for a field trip study. However, the second idea, "Kaktus aufschneiden und mit Mikroskop untersuchen; sehen, wie sie Wasser

speichern" was coded high as they indicated an understanding for scientific evidence and the method was appropriate.

Interpretation of the discourse data for pre-field trip

At the individual level, student I21 showed high-level regulative processes in orienting and planning. She displayed potential to explore some new inferences but some of her ideas remained very general and vague. This could possibly explain the two low-level orienting ideas, three low-level asking of questions and one low-level testing of hypothesis in the transformative processes. However, at the group level, she performed better as she was able to explore some of her unpolished ideas with the fellow group members (see figure 22: indicated with blue arrows). In the process of negotiating shared understanding, new perspectives emerged when the group members co-constructed knowledge, queried new ideas and displayed critical thinking. This resonates with Kapur's (2012) idea of productive failure where the *consolidation* phase (here at the small group level) provides an avenue for student I21 to share some of her unexplored ideas. Student I21 integrated her idea of the need for sunlight in photosynthesis (see table 84: line 6) which led to the emergence of new knowledge and inferences at the group level. This was the same query she had in her inquiry task on rainforest plant at the individual level. Student I20 made further inferences based on her idea about the storage of sunlight (see table 84: line 8). Student I21 was able to leverage on the ideas of her group members and contributed to the collective advancement of ideas by posing her verification questions and surfaced her uncertain inferences or ideas (e.g., table 87: line 21 to 24, table 92: line 45, table 93: line 54 and table 94: line 56 to 59) during the collective reflection.

At the small group level, the group discourse showed six instances of low-level regulative processes and six instances of high-level regulative processes (see figure 22). There were five occurrences of high-level and five occurrences of low-level transformative processes There were two instances of no interactive activities where group members merely sought quick consensus and/or affirmation to proceed with task (see figure 22). Establishing common grounds with high-level grounding in the form of verification questions and statements facilitated better transformative processes where the group saw some high-level orienting ideas, asking of question, crafting of the hypothesis and development of inquiry plan to test hypothesis. This could be attributed to the *generation and exploration* phase (Kapur & Bielaczyc, 2012) in the PIS script sequence where the individuals were able to generate and explore new ideas. These raw ideas were more effectively built on during the collaborative interaction and co-construction of new knowledge and perspectives at the group level. The successful construction of this shared space can be likened to Levine, Resnick and Higgins's (1993) notion of *intersubjectvity*, which was pivotal to facilitate coordinated cognitive activity where group members achieved shared task perception, common goals and strategies.

Legend

Interactive △		Not Interactive (constructive or active) ▽	
Constructive □		Active ◯	
Integration of individual ideas into collaborative work ↪			

Regulative Processes				Transformative Processes			
OH	Orienting High	IH	Instructing High	OH	Orienting High	GHH	Generating Hypothesis High
OL	Orienting Low	IL	Instructing Low	OL	Orienting Low	GHL	Generating Hypothesis Low
PH	Planning High	GH	Grounding High	AQH	Asking Qns. High	THH	Testing Hypothesis High
PL	Planning Low	GL	Grounding Low	AQL	Asking Qns. Low	THL	Testing Hypothesis Low

	Lines		Regulative Processes	Transformative Processes
Individual	L1	◯	OL	OL(2); AQL(3)
	L2	□	OH	GHH
	L3	□	PH	THH ; THL
Small Group	L1-4	▽	OL	
	L5-8	L6 ↪ △	GH	OH
	L9-14	△	OH	
	L15-19	△	OL	OL (2)
	L20-25	L20-25 ↪ △	OH	AQL
	l26-29	L29 ↪ △	OL	
	L30-31	▽	GL	
	L32-34	△	OH	OH ; AQH
	L35-41	△	GH	GHH
	L42-46	L45 ↪ △	GL	THL ; AQL
	L47-54	L54 ↪ △	PL	
	L55-59	L56-59 ↪ △	PH	THH

Figure 22: *Graphical coding analysis of the PIS discourse in the pre-field trip*

Data of the individual reflection and small group discourse in the field trip

In the field trip, the discourse took place after the guided tour of the rainforest hall. They generated possible evidences, and thereafter, they had to put a tick, a cross or a question mark next to evidences. Following is the complete individual reflection of student I21 (see table 95), followed by small group discourse of group 6 (see table 96).

Individual Reflection of Student I21 in the field trip

Table 95: *Excerpt of the individual reflection of student I21 in the field trip*

Reflection Questions:
1. Welche anderen Fragen tauchen auf, wenn du an deine Fragestellung, deine Hypothese und die Durchführung der Untersuchung denkst?
2. Falls es nicht geklappt hat, welche Veränderungen würdest du beim Entwurf des Untersuchungsplans machen?

Line	Individual Reflection
1	Kein eigentlich...Warum keine Fragen…
2	Ich werde wahrscheinlich die Fragen ein bißchen vereinfachen.
3	Ein bißchen aufbauen und dann gucken…

Small group discourse of PIS group 6 in the field trip

Table 96: *Discourse excerpt of PIS small group 6 in the field trip*

Line	Student	Group Discourse
1	I21	Also, was wissen wir…
2	I19	Fangen wir mit dem Volumen.
3	I20	Oberfläche?
4	I19	Ja.
5	I20	Oberflächenverkleinerung, damit sie…
6	I21	Damit sie maximales Volumen mit der geringsten Oberfläche haben.
7	I20	Yup.
8	I22	Sie sind rund, damit sie wenig Oberfläche haben bei viel Volumen. Ist das relevant?
9	I21	Und sie haben die Blätter zu Stacheln verkleinert, damit das auch…
10	I20	damit, dass das Volumen kleiner ist. Das können wir noch dazu schreiben.
11	I21	Ja. Dann schreib unten darunter.
12	I20	Ist das relevant oder nicht?
13	I21	Ja schon.
14	I22	Ja oder?
15	I21	Zwei. Was wissen wir noch?
16	I22	Sie haben Rillen, damit sie Schatten sich selber machen.

Line	Student	Group Discourse
17	I22	Wo seid denn ihr? Ich hab‘ diesen Grund, warum wir sie beobachtet haben: sie haben Blätter, Stacheln und….
18	I21	Hmm...hmm…sie haben weiße Haare wegen der Sonnenwärme... Sonnenstrahlen…
19	I22	Manche haben weiße Haare, um das Sonnenlicht abzureflektieren.
20	I21	Das Sonnenlicht vom Körper wegzuhalten…
21	I21	Kakteen wachsen in Afrika, können wir auch aufschreiben.
22	I19	Stimmt gar nicht.
23	I21	Amerika, Entschuldigung. Falscher Kontinent.
24	I20	Aber Afrika auch.
25	I22	Ich bin schon fertig.
26	I19	Wir sind noch nicht fertig oder?
27	I20	Nein.
28	I20	Ja genau, Stomata bei der Nacht geöffnet…
29	All	Ok. Wir sind fertig.

Analysis of regulative and transformative processes in the field trip

Similarly, the responses to the individual reflection questions will first be presented and analysed for the regulative processes, followed by the individual transformative processes in the written work. Thereafter, the small group discourse will be presented and analysed for regulative processes, followed by the small group transformative processes in the written work.

Analysis of individual regulative processes in the field trip

In table 97, Student I21's brief response to the reflection questions about her hypothesis and the progress of inquiry plan was coded monitoring low (line 3). However, she showed some critical reflection about the possible improvement and changes she would make to the design of her inquiry plan, was coded high (line 4 & 5).

Table 97: *Student I21's responses to the reflection questions in the field trip*

Reflection Questions:
1. Welche anderen Fragen tauchen auf, wenn du an deine Fragestellung, deine Hypothese und die Durchführung der Untersuchung denkst?
2. Falls es nicht geklappt hat, welche Veränderungen würdest du beim Entwurf des Untersuchungsplans machen?

Line	Individual Reflection	Code

1	Keine eigentlich ... Warum keine Fragen…	Monitoring (Low)
2	Ich werde wahrscheinlich die Fragen ein bißchen vereinfachen.	Testing (High)
3	Ein bißchen aufbauen und dann gucken…	Testing (High)

Analysis of individual transformative processes (written work) in the field trip

In the individual written work, I21 wrote a total of four evidences. Three of which were irrelevant and not coded as they referred to rainforest plants at large. The only one she had about the bamboo plant, "Andere wachsen extrem schnell, um moglichst ans Licht zu kommen." was coded generating evidence low as there was no mention of the rhizome sytem to explain its fast growth.

Analysis of small group regulative processes in the field trip

Table 98: *Discourse excerpt on establishing common grounds – structure of cactus*

Line	Student	Group Discourse	Code
1	I21	Also, was wissen wir…	Grounding (High)
2	I19	Fangen wir mit dem Volumen.	Shared-regulation
3	I20	Oberfläche?	
4	I19	Ja.	
5	I20	Oberflächenverkleinerung, damit sie…	
6	I21	Damit sie maximales Volumen mit der geringsten Oberfläche haben.	
7	I20	Yup.	

The group discourse began with a discussion on water loss reduction and the structure of the cactus (see table 98). This was coded grounding high as the negotiation of shared understanding was achieved through posing of good verification questions and affirmation statements about the surface of a cactus. The group also leveraged on one another's ideas to further advance their new knowledge about the surface area of the cactus.

Table 99: *Discourse excerpt on testing evidence – spikes of the cactus*

Line	Student	Group Discourse	Code

8	I22	Sie sind rund, damit sie wenig Oberfläche haben bei viel Volumen.	Testing (High) Shared-regulation
9	I21	Ist das relevant?	
10	I20	Und sie haben die Blätter zu Stacheln verkleinert, damit das auch…damit, dass das Volumen kleiner ist. Das können wir noch dazu schreiben.	
11	I21	Ja. Dann schreib unten darunter.	
12	I20	Ist das relevant oder nicht?	
13	I21	Ja schon.	
14	I22	Ja oder?	

The group engaged in high-level testing: checking for emerging comprehension, reflecting and making comparisons in the construction of scientific evidences on how cactus conserved water (see table 99). At the shared level, the group members demonstrated good collaborative efforts to affirm knowledge.

Table 100: *Discourse excerpt on testing evidence – shelter from heat*

Line	Student	Group Discourse	Code
15	I21	Zwei. Was wissen wir noch?	Testing (High)
16	I22	Sie haben Rillen, damit sie Schatten sich selber machen.	Shared-regulation

The testing statements were coded high for the students were able to see the link between the special structure of the cactus plant to its function to provide shade (see table 100). However, there is admittedly a lack of rigorous discussion. It could be that there was mutual understanding on this idea and/or the explanation provided during the guided tour.

Table 101: *Discourse excerpt on establishing common grounds – function of the 'hair'*

Line	Student	Group Discourse	Code
17	122	Wo seid denn ihr? Ich hab' diesen Grund, warum wir sie beobachtet haben: sie haben Blätter, Stacheln und….	Grounding (High) Shared-regulation
18	I21	Hmm...hmm…sie haben weiße Haare wegen der Sonnenwärme...Sonnenstrahlen…	

The group moved on to surface the cactus' leaves/ spikes and hairs (see table 101). These were coded as grounding high for they were engaged in the checking and verifying of information to construct shared knowledge.

Table 102: *Discourse excerpt on testing evidence – function of the 'hair'*

Line	Student	Group Discourse	Code
19	I22	Manche haben weiße Haare, um das Sonnenlicht abzureflektieren.	Testing (High) Co-regulation
20	I21	Das Sonnenlicht vom Körper wegzuhalten…	

The above high grounding statements (see table 102) also provoked further development on the defense mechanism of the cactus's hair against heat and light which were coded testing high (see table 98). There was good support at the co-regulation level to ensure shared meaning-making.

Table 103: *Discourse excerpt on testing evidence – cactus in different continents*

Line	Student	Group Discourse	Code
21	I21	Kakteen wachsen in Afrika, können wir auch aufschreiben.	Testing (Low)
22	I19	Stimmt gar nicht.	Shared-regulation
23	I21	Amerika, Entschuldigung. Falscher Kontinent.	
24	I20	Aber Afrika auch.	

In table 103, the discussion about the continents and cactus was coded testing low as members were neither able to mobilise nor extract relevant information to draw comparison. The contribution was not sufficiently dealt with.

Table 104: *Discourse excerpt on monitoring of task progress*

Line	Student	Group Discourse	Code
25	I22	Ich bin schon fertig.	Monitoring (Low)
26	I19	Wir sind noch nicht fertig oder?	Shared-regulation
27	I20	Nein.	

Monitoring was coded low as the checking of task progress was briefly dealt with (see table 104). The group did not assess their progress but instead was more concerned as to whether they had finished up.

Table 105: *Discourse excerpt on monitoring of task progress*

Line	Student	Group Discourse	Code
28	I20	Ja genau, Stomata bei der Nacht geöffnet…	Testing (High)
29	All	Ok. Wir sind fertig.	Shared-regulation

The final lines were coded testing high as one of the group members made a check on their list of the evidences to ensure completion and the important evidence was reiterated though the interaction was weak to some measure (see table 105). It was possible that the audio could not capture the body language as I20's opening line seemed abrupt. Nonetheless, the group restated a piece of importance evidence for their inquiry task and the immediate mutual understanding warranted a high for testing.

Analysis of small group transformative processes (written work) in the field trip

The group wrote four evidences: (1) "Kakteen sind rund, um das größte Volumen mit der kleinsten Oberfläche zu haben. Blätter wurden zu Stacheln verkleinert, auch zur

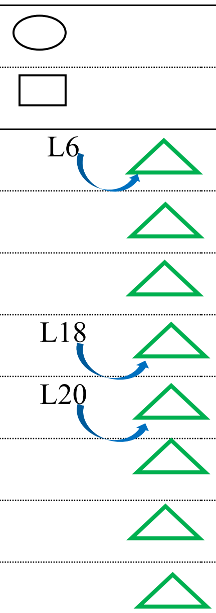
Oberflächenverkleinerung." (2) "Sie haben Rillen, um sich selbst abzuschatten, und dass weniger Wind über die Oberfläche weht." (3) "Sie haben weiße Haare, um das Sonnenlicht vom Körper wegzuhalten." (4) "Stomata sind während der Nacht geöffnet, damit wenig Wasser verdunstet." All were coded as generating evidence high as they evidently showed valid inferences between the plant parts, their functions and how the cactus survived in the desert.

Interpretation of the discourse data for field trip

In the field-trip, the similar discourse trend was true for both the individual and the group. At the individual level, student I21 showed high-level regulative processes in testing where she demonstrated good meta-cognitive awareness on how she could better her hypothesis and inquiry plan. However, this was not translated in her transformative processes. She had four evidences but only one was relevant. Her other three ideas were interesting but general; not related to her bamboo plant. She showed potential in generating diverse ideas and adopting multiple perspectives at the individual level. As evident in the pre-field trip, the consolidation phase afforded her the platform to develop and advance some of her raw ideas.

At the group level, instances of where I21 integrated her earlier ideas during individual work could be identified (see figure 23: indicated with blue bow arrows). Student I21 was able to make relevant connections between the structure of the plant and its functions (see table 98: line 6, table 101: line 18 & table 102: line 20) to co-construct knowledge by leveraging on the respective ideas from the other group members to reaffirm her own. It is apparent that where there were occurrences of high-level grounding statements and convergence of knowledge in the collaborative interaction; new perspectives emerged. As shown in figure 23, the group had five occurrences of high-level regulative processes (three high-level grounding and two high-level testing) and three instances of low-level regulative processes (one low-level monitoring and two low-level testing). The high-level grounding and testing facilitated high-level transformative processes in generating evidences. The group generated four high-level evidences. It was apparent that the two core regulative processes, namely, high-level grouding and high-level testing explained the quality of interactive activities at the small group level. This, in turn, facilitated better coordination and communication.

Legend					
Interactive			Not Interactive (constructive or active)		
Constructive			Active		
Integration of individual ideas into collaborative work					
Regulative Processes				Transformative Processes	
MH	Monitoring High	IH	Instructing High	GEH	Generating Evidence High
ML	Monitoring Low	IL	Instructing Low	GEL	Generating Evidence Low
TH	Testing High	GH	Grounding High		
TL	Testing Low	GL	Grounding Low		



	Lines		Regulative Processes	Transformative Processes
Individual	L 1		ML	
	L 2 & 3		TH	GEL
Small Group	L 1-7	L6	GH	GEH
	L 8-14		TH	
	L 15-16		TH	GEH
	L 17-18	L18	GH	
	L 19-20	L20	TH	GEH
	L 21-24		TL	
	L 25-27		ML	
	L 28-29		TH	GEH

Figure 23: Graphical Coding analysis of the PIS discourse in the field-trip

Data of the individual reflection and small group discourse in the post-field trip

In the post-field trip, students evaluted the evidences and drew conclusions. Here, they had to state evidence to support each claim before constructing a scientific reason. Following is the complete individual reflection of student I21 (see table 106), followed by small group discourse of group 6 (see table 107).

Individual Reflection of Student I21 in the post-field trip

Table 106: *Excerpt of the individual reflection of student I21in the post- field trip*

Reflection Questions:
1. Welche Schwierigkeiten und Herausforderungen sind dir während deiner Untersuchung begegnet? Wie hast du sie überwunden?
2. Konntest Du Deine Untersuchung wie geplant durchführen? (Wenn ja, warum? Falls nein, warum nicht?)

Line	Individual Reflection
1	Mir sind keine Schwierigkeiten bei meiner Untersuchung begegnet.

Small group discourse of PIS group 6 in the post-field trip

Table 107: *Discourse excerpt of PIS small group 6 in the post-field trip*

Line	Student	Group Discourse
1	I21	Machen wir unser Brainstorm … Belege... hmm…Behauptung…
2	I19	Ok…was waren unsere Ideen, Behauptungen?
3	I19	Das sind hier…Belege…
4	I21	Das waren unsere Hypothese, dass Kakteen Wasser speichern; ihre Fotosynthese nachts machen, um den Wasserverlust minimal zu halten.
5	I19	Ok…unsere Behauptung, dass Kakteen können Wasser speichern…
6	I19	Ich habe einen Beleg, dass sie so ein schwammiges Fleisch haben, wo Wasser…
7	I21	Eher schwammiges…ich wollte gerade schwammiges Innenleben sagen, aber Innenleben sagt man in Bezug auf Kakteen gar nicht.
8	I19	Inneres. Ja, ein schwammiger Aufbau…
9	I21	Dass sie innen schwammig sind…
10	I19	Ja, genau, machen wir innen schwammig…
11	I20	Ja, was denn?
12	I21	Ok. Was ist unsere Begründung dafür?
13	I19	Wenn sie Wasser speichern, können sie…machen sie überhaupt Fotosynthese in der Nacht?
14	I21	Ja…um ihren Wasserverlust zu minimieren… Wann kommen die überhaupt an Wasser?
15	I20	Das stimmt gar nicht, die machen es eigentlich bei Tag.
16	I21	Nee…
17	I20	Nee, die öffnen..die nehmen CO_2 in der Nacht auf. Aber Fotosynthese machen sie wegen dem Licht.
18	I21	Mir kommt irgendwie gerade nichts in den Sinn zu dem Wort - Begründung.
19	I19	Wasserspeichern ist nützlich, weil es sehr selten regnet und lange Trockenzeit herrscht.

Line	Student	Group Discourse
20	I21	Ok…was wissen wir noch? Ok…ok...jetzt..was für eine Behauptung?
21	I19	Keine Ahnung...was für eine Behauptung?
22	I21	Kakteen leben in der Wüste.
23	I19	Das schreiben wir auch: Kakteen leben in der Wüste. Also, Kakteen leben in der Wüste.
24	I19	Und speichern deswegen ihr Wasser, weil sie sonst sehr schnell austrocknen würden.
25	I20	Speichern ihr Wasser in dem schwammigen Inneren…

Analysis of the individual reflection and small group discourse in the post-field trip

Likewise, the responses to the individual reflection questions will first be presented and analysed for the regulative processes, followed by the individual transformative processes in the written work. Thereafter, the small group discourse will be presented and analysed for regulative processes, followed by the small group transformative processes in the written work.

Analysis of individual regulative processes in the post-field trip

Table 108: *Student I21's responses to the reflection questions in the post- field trip*

Reflection Questions:
1. Welche Schwierigkeiten und Herausforderungen sind dir während deiner Untersuchung begegnet? Wie hast du sie überwunden?
2. Konntest Du Deine Untersuchung wie geplant durchführen? (Wenn ja, warum? Falls nein, warum nicht?)

Line	Individual Reflection	Code
1	Mir sind keine Schwierigkeiten bei meiner Untersuchung begegnet.	Evaluating (High)

In the final reflection question on the learning process and the execution of the inquiry task (see table 108), student I21's response was brief on the task execution and learning process. It could be that she perceived no challenges and she was generally contented with her own progress. It was coded evaluation high for the confidence and the motivation she displayed in the individual reflection. Her perception of no significant challenges is also evident in the reasoning process in the transformative processes where she had to substantiate her claim with evidences. She showed confidence in her regulative-processes.

Analysis of individual transformative processes (written work) in the post-field trip

Student I21 wrote two pieces evidences (see table 109). The first was coded evaluating evidence high as she provided growth measurement of the bamboo plant to substantiate her claim. The second one was not coded as the claim, evidence and reasoning did not quite align. She made two points in her conclusions. The first one was not coded as the earlier evaluation of evidence was incorrect. The second conclusion about the fast growth of the bamboo and its reach for sunlight was coded high.

Table 109: *Individual written work on evaluating evidence and drawing conclusion*

Evaluating Evidence		
Behauptung (en)	Beleg (e)	Begründung (en)
1. Bambus wachst sehr schnell, um ans Licht zu kommen	Bambus wächst bis zu 40 cm am Tag, besonders in seinen 'Jugend'.	Viele Pflanzen im Regenwald haben sich gut angepasst. Manche wachsen so schnell wie möglich, um an Licht zu kommen
2. Bambus braucht eher wenig Wasser, zum Überleben.	Bambus hat recht kleine Blätter und keine "Luftwurzeln" wie Orchideen sie haben.	Er ist hohl und braucht deswegen nicht so viel Wasser.

Drawing Conclusion
Bambus braucht wenig Wasser, da er hohl ist und wächst sehr schnell (bis zu 40 cm pro Tag um ans Licht zu kommen.

Analysis of small group regulative processes in the post-field trip

Table 110*: Discourse excerpt on planning task progress*

Line	Student	Group Discourse	Code
1	I21	Machen wir unser Brainstorm…Belege...hmm… Behauptung…	Planning (High) Shared Regulation
2	I19	Ok…was waren unsere Ideen, Behauptungen?	

The group discourse began with student I21 planning their approach to evaluating the evidences and drawing conclusions (see table 110). It was coded as planning high as she proposed brainstorming which set the group in a good direction.

Table 111: *Discourse excerpt on monitoring of task progress*

Line	Student	Group Discourse	Code

3	I19	Das sind hier…Belege…	Monitoring (High)
4	I21	Das waren unsere Hypothese, dass Kakteen Wasser speichern; ihre Fotosynthese nachts machen, um den Wasserverlust minimal zu halten.	Shared-regulation
5	I19	Ok…unsere Behauptung, dass Kakteen können Wasser speichern…	

In table 111, the group reviewed their hypothesis before proceeding to evaluate their evidences, which was coded as monitoring high as they demonstrated good regulatory measures; reflecting and aligning their evidences with the hypothesis generated earlier.

Table 112: *Discourse excerpt on testing of evidence – structure of the cactus*

Line	Student	Group Discourse	Code
6	I19	Ich habe einen Beleg, dass sie so ein schwammiges Fleisch haben, wo Wasser…	Testing (High) Shared Regulation
7	I21	Eher schwammiges…ich wollte gerade schwammiges Innenleben sagen, aber Innenleben sagt man in Bezug auf Kakteen gar nicht.	
8	I19	Inneres. Ja, ein schwammiger Aufbau…	
9	I21	Dass sie innen schwammig sind…	
10	I19	Ja, genau, machen wir innen schwammig…	
11	I20	Ja, was denn?	

The evaluating of the evidences was coded testing high as they showed a keen awareness to check for emerging comprehension: critiqued their choice of word and drew comparisons (see table 112). They demonstrated good communication and interaction: especially in rendering support at the shared regulation level to ensure the group arrived at a shared consensus.

Table 113: *Discourse excerpt on verifying of evidence –photosynthesis for the cactus*

Line	Student	Group Discourse	Code
12	I21	Ok. Was ist unsere Begründung dafür?	Grounding (High)
13	I19	Wenn sie Wasser speichern, können sie…machen sie überhaupt Fotosynthese in der Nacht?	Shared Regulation
14	I21	Ja…um ihren Wasserverlust zu minimieren… Wann kommen die überhaupt an Wasser?	
15	I20	Das stimmt gar nicht, die machen es eigentlich bei Tag.	
16	I21	Nee…	
17	I20	Nee, die öffnen, Die nehmen CO_2 in der Nacht auf. Aber Fotosynthese machen sie wegen dem Licht.	

The grounding statements were coded high as the group posed verification questions, for instance on the misconception that photosynthesis took place in the night (see table 113). It 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 at shared knowledge.

Table 114: *Discourse excerpt on testing of evidence –water storage for cactus*

Line	Student	Group Discourse	Code
18	I21	Mir kommt irgendwie gerade nichts in den Sinn zu dem Wort - Begründung.	Testing (High) Co- Regulation
19	I19	Wasserspeichern ist nützlich, weil es sehr selten regnet und lange Trockenzeit herrscht.	

The exchange between students I21 and I19 was coded testing high as the pair showed awareness of possible issues in their attempt to construct an explanation on why the cactus stored water (see table 114). They also showed good co-regulation to tarry for one another and to offer transitional support to arrive at shared mean-making.

Table 115: *Discourse excerpt on substantiating a claim with evidence*

Line	Student	Group Discourse	Code
20	I21	Ok…was wissen wir noch? Ok… ok...jetzt..was für eine Behauptung? Keine Ahnung ... was für eine Behauptung?	Testing (Low) Shared Regulation
21	I19	Kakteen leben in der Wüste.	
22	I21	Das schreiben wir auch: Kakteen leben in der Wüste.	
23	I19	Also, Kakteen leben in der Wüste.	

This was coded testing low as the group did not show attempt to improve on the claim made; which remained very general (see table 115). There was no substantial contribution but more a case to seek a quick group consensus.

Table 116: *Discourse excerpt on drawing scientific conclusion*

Line	Student	Group Discourse	Code
24	I19	Und speichern deswegen ihr Wasser, weil sie sonst sehr schnell austrocknen würden.	Testing (High) Shared Regulation
25	I20	Speichern ihr Wasser in dem schwammigen Inneren…	

In the final discussion, the group sought to construct a scientific explanation for the cactus' adaptation to its living environment (see table 116). This was coded testing high as the group showed sound reflection on the evidences and the drawing of conclusions by making connections between plant parts and their functions.

Analysis of small group transformative processes (written work) in the post-field trip

The group wrote two pieces of evidences (see table 117). The first one was coded high as they were able to state the function of structure which supported water storage. The second evaluation of evidence was coded low as the evidence was not scientific but the reasoning on how the general structure of the cactus enabled it to adapt to the desert was sound. The group formulated two scientific conclusions. The first one was coded high as they stated the parts of the cactus that enabled it to adapt to the desert conditions. The second conclusion was coded low as there was no connection made to the water storage capacity.

Table 117: *Discourse excerpt on drawing scientific conclusion*

Evaluating Evidence		
Behauptung (en)	Beleg (e)	Begründung (en)
1. Kakteen können Wasser speichern.	Kakteen sind innen schwammig und speichern Wasser wie ein Schwamm.	Wasserspeichern ist nützlich, weil es sehr selten regnet und lange trocken ist.
2. Kakteen leben in der Wüste	Wir haben Kakteen in der Wüste gesehen.	Kakteen haben sich mit ihrem Äußeren an die Bedingungen in der Wüste angepasst.
Drawing Conclusion		
Kakteen haben sich mit ihrer runden Form und ihren Stacheln statt Blattern an die Wüste angepasst. Um die langen Trockenzeit zu überstehen können sie Wasser speichern.		

Interpretation of the discourse data for post-field trip

In the post-field trip, student I21 showed some improvement in her regulative and transformative processes; there was one high-level evaluating of learning process; one high-level evaluating of evidence and one high-level drawing of conclusion. Instances showing integration of her ideas at the group level are illustrated in figure 24 (indicated with blue bow arrows). This is evident where she proposed a brainstorming approach (see table 110: line 1), initiated the review of the group's hypothesis (see table 111: line 4), voiced her apprehension about the right word usage (table 112: line 7) and probed to understand more about water loss reduction (see table 113: line 14).

At the group level, the individual students in the PIS script condition, showed good regulative processes which facilitated two high-level transformative processes (one high evaluating of evidence and one high-level drawing of a scientific conclusion) (see figure 24). There were six occurrences of high-level regulative processes (one high-level planning, one occurrence of high-level grounding and four occurrences of high-level testing) and one occurrence low-level regulative process in testing (see figure 24). For instance, student I19 probed further to establish shared meaning on the use of 'Innenleben' for a cactus (see table 112: line 7), this led to a negotiation of shared understanding to co-construct scientific explanation. Another instance was where student I20 challenged the misconception that photosynthesis took place in the night for the cactus (see table 113: line 14), which evidently led to a clarification of the wrong perception that photosynthesis took place in the night for the cactus plant. Moreover, the group showed good regulatory support for one another by taking time to deal with unresolved issues or uncertainties expressed. This is evident when student I21 voiced her difficulties with the constructing scientific explanation (see table 114: line 18). At the group level, they had one high- and one low-level evaluating of evidence, and one high- and one low-level drawing of conclusion as shown in figure 24. The quality of communication and collaborative interaction could account for the high-regulative processes which led to some high-level transformative processes.

Legend

Interactive — Not Interactive (constructive or active)
Constructive — Active

Integration of individual ideas into collaborative work

Regulative Processes				Transformative Processes	
PH	Planning High	TH	Testing High	EEH	Evaluating Evidence High
PL	Planning Low	TL	Testing Low	EEL	Evaluating Evidence Low
MH	Monitoring High	GH	Grounding High	DCH	Drawing Conclusions High
ML	Monitoring Low	GL	Grounding Low	DCL	Drawing Conclusions Low

	Lines		Regulative Processes	Transformative Processes
Individual	L 1		EH	EEH ; DCH
Small Group	L 1-2	L 1	PH	
	L 3-5	L 4	MH	
	L 6-11	L 7	TH	EEH ; DCH
	L 12-17	L 14	GH	
	L 18&19	L 18	TH	
	L 20-23		TL	EEL ; DCL
	L 24&25		TH	

Figure 24: ***Graphical coding analysis of the PIS discourse in the post-field trip***

Summary

Overall from pre-to-post field, at the individual level, student I21 exhibited some good regulative processes at some points, but in the transformative processes she was not able to deliver similar performance. She showed relatively good *conceptual* and *strategic knowledge* but was still lacking in *procedural and situational knowledge* which would have enabled her to effectively identify and analyse problems in changing learning settings (De Jong & Ferguson-Hessler, 1996). The change in learning context from indoor to outdoor inquiry might be challenging at the individual level without peer support and feedback.

However, the collaborative interaction in the small group provided her a consolidation platform to work on her under-developed ideas or uncertain inferences. At the small group level, the group discourse showed more instances of both high-level regulative processes and high-level transformative processes. This could be attributed to a situation of 'productive failure' (Kapur, 2012) where the individuals were able to bring to bear their unexplored ideas generated at the individual level. At the small group level, there were only two occurences of non-interactive activities. The group showed relatively good coordination and communication to maintain and sustain the collaborative space by posing good questions and verifications statements to establish common grounds.

7 Discussion

The aim of this thesis is to investigate the effects of two differently sequenced classroom scripts on the transformative and regulative processes in individual and collaborative inquiry learning. The PSI classroom script exemplified elements of the *cognitive apprenticeship* with the *gradual fading of teacher and peer support* from the plenary to the individual level. Conversely, the PIS classroom script leveraged the conditions for *productive failure* where *desirable difficulties* at the individual level could maximize learning for the individual and the group in subsequent similar tasks. In both script conditions, the distribution and sequencing of the activities also built on the ICAP conceptual framework on the interactive, constructive, active and passive activity type and the corresponding cognitive processes and engagement behaviours these different activity types could evoke. The results of the study showed that the two differently sequenced classroom scripts yielded different effects on the individual and the collaborative inquiry learning processes.

In this chapter, the results of the study will be discussed and explained based on the conceptual framework of the study and prior findings. This is followed by a summary of the results and the limitations of the study. Finally, the implications for future research and practice will be presented.

7.1 Plenary-Small Group-Individual (PSI) versus Plenary-Individual-Small Group (PIS) Classroom Script on the Individuals' Transformative and Regulative Processes in Inquiry Learning

First, the effects of the PSI classroom script will be discussed followed by the PIS classroom script as per research questions on individual inquiry learning. Likewise, transformative processes will first be presented, followed by regulative processes.

7.1.1 Effects of the PSI vs. PIS Classroom Script on the Individuals' Transformative Processes, as well as High- and Low-Level Transformative Processes

The PSI classroom script: Students in the PSI script condition showed better engagement in the transformative processes, as well as high-level transformative processes. Although there was only statistical significance for generating evidence, high-level generating of evidence and high-level orienting, descriptive data showed that the PSI classroom script facilitated more occurrences of evaluating evidence, drawing conclusions and high-level evaluating of evidence with medium to strong effects. The gradual *fading of the scaffolds* in the PSI is one likely explanation for the overall trend of the results. Modeling at the plenary level and the presence of peer support at the small group level could have increased the individuals' capacity for learning and transfer. In particular, the collective externalization and differentiation of the different processes during the small group collaborative inquiry might have further reinforced the internalization and appropriation of these transformative processes during the individual undertaking of inquiry task three.

Next, it is noteworthy that the PSI script seemed to have rendered an effect on three significant transformative processes: the generating of evidences, the evaluating of evidences and the drawing of conclusions. These three transformative processes occurred during the field trip and post-field trip. Importantly, they are core cognitive processes for scientific reasoning and construction of scientific explanation. This could be attributed to the affordances of collaborative reasoning and argumentation in the scientific discourse (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Osborne, Enduran, & Simon, 2004). The plenary modeling and the small group interaction could have afforded the individuals greater agency to enact these transformative processes. It resonates with the findings of a study which showed that students who worked collaboratively were more reflective about the learning material than those who worked individually (Chi & Wylie, 2014). Moreover, the interactive activity at the small group level provided the platform for 'collaborative explanation activities' (Okada & Simon, 1997).

The gradual *fading of the scaffolds* in the PSI classroom script seemed to be of particular significance for outdoor inquiry learning. In an outdoor learning setting, students' interpretation of and interaction with the physical affordances is keenly shaped by teacher's modeling of the learning process and interaction with one another while employing other semiotic resources in the sense-making process (Kerawalla et al., 2012).

Here, the teacher provided both a scaffold and a structure, within which students' improvisations could occur. The provision of modeling at the plenary level by the teacher was an important step in scaffolding. It relates to findings from Chinn and Hung's (2007) study where students who received modeling of scientific reasoning outperformed those who did not. The collective articulation and the elaboration of their think-processes fostered the constitutive cognitive processes in scientific reasoning and argumentation.

In sum, for the individual engagement in transformative processes, the *gradual fading-out of the scaffolding* (Pea, 2004) in the PSI script has been beneficial because students were able to gradually internalize the components of the quite complex set of inquiry skills while learning partners created a zone of proximal development (see Fischer et al., 2013).

The PIS classroom script: The PIS script only facilitates generating of hypothesis and reduces the frequency of low-level drawing of conclusions showing medium to strong effect size but no statistical significance. The PIS script transition simulated a 'productive failure' learning condition with the aim to foster better acquisition and appropriation of the inquiry processes. In this script condition, the individuals proceeded to undertake inquiry task two after the modeling of inquiry task one at the plenary level. The plenary session set the stage for the learning context and provided a model of inquiry. However, the *generation and exploration phase* (Kapur, 2012) at the individual level could possibly have engaged them in particular type of cognitive processes such as *storing*, *integrating*, *infering* (Chi & Wylie, 2014). The active and constructive activities at the individual level have enabled them to activate prior knowledge, assimilate new knowledge into the activated schema and generate some new ideas for compare and contrast (Chi, 2009). However, it seemed apparent that without further scaffold and support, they were unable to appropriate these diverse ideas for deeper understanding and construction of new knowledge. Related studies on *productive failure* indicated that students might experience initial 'failure' during delayed feedback and delayed structure, but generated more diverse and innovative ideas and possibilities in problem-solving (Mathan & Koedinger, 2003; Kapur, 2008). 'Failure' here refers to a deviation from the standard solution presented at the consolidation phase (Kapur & Rummel, 2012). Hence, it should not be taken to mean that there was no learning taking place for the individuals in the PIS script condition (Kapur, 2014). These individuals were experiencing initial 'failure' which could form the conditions for 'productive failure' in the consolidation phase when they received peer scaffold and support during the interaction at the small group level to *co-infer* (Chi & Wylie, 2014) the new knowledge and perspectives they had generated during the active and constructive activities. The modeling at the plenary session might have familiarized them with the articulation of the transformative processes in inquiry learning. The individuals might only be equipped with situational knowledge e.g., task characteristics and strategic knowledge of sequence and steps but still gaining a foothold in applying conceptual and procedural knowledge to analyze problems and to administer relevant solutions (De Jong & Ferguson-Hessler,1996).

Knowledge inference processes such as formulating hypotheses, gathering data, evaluating data and constructing scientific explanations in inquiry learning are considered highly challenging and requires both higher cognitive and metacognitive demands (De Jong & Van Joolingen, 1998; Manlove et al., 2006; Van Joolingen, 2000). Therefore, it is not surprising that the individuals in the PIS script conditon should encounter more challenges emerging from the plenary session to take on inquiry task two individually.

7.1.2 Effects of the PSI vs. PIS Classroom Script on the Individuals' Regulative Processes, as well as High- and Low-Level Regulative Processes

The PSI classroom script: The PSI script that facilitated the individual engagement in the transformative processes did not seem to render similar effects for the regulative processes. The PSI script only facilitated more occurrences of evaluating, reduced the occurrences of low-level orienting and low-level monitoring showing medium to strong effects but with no statistical significance. The findings are intriguing for it seems to contradict theoretical convictions that the regulative processes manage the transformative processes in inquiry learning (Njoo & De Jong, 1993). There are theoretical explanations and empirical studies to understand this phenomenon. Here, it might be helpful to think about personal competencies, the type of regulative activities, the specific requirements of the learning context, the potentials and the constraints of the learning environment (De Jong et al., 2005). Their study found that when learning was regulated within an individual context, regulative activities that closely related to the individual's performance (e.g., knowledge construction) were coordinated by regulative processes such as testing, monitoring and evaluating. In this aspect, the PSI script did facilitate more occurrences of evaluating and reduced frequency of low-level monitoring. As for the expected occurrences of planning and testing in the regulative processes, study on regulation within the individual context showed that more successful students undertook fewer directing activities that involve planning and testing elements (De Jong et al., 2005). Therefore, how individuals appropriate self-regulation strategies is contingent on the demands and the challenges of the transformative processes, as well as his or her personal competencies.

Another possible explanation for the conflicting results between the regulative and transformative processes is the relation between metacognition and intellectual ability. Possessing good metacognitive knowledge and skills may compensate students' cognitive limitations but it should not be equated with intellectual ability, moreover, metacognitive abilities are task and domain specific (Veenman, Van Hout-Wolters, & Afflerbach, 2006). Hence, it does not necessarily imply that high-level regulative processes should always yield high-level transformative activities or vice versa. Further, Järvelä and Järvenoja's (2011) notion of a *socially constructed self-regulation* posit that the individual regulation of motivation is *socially constructed*, that is, constantly shaped and reshaped in collaborative undertaking of an activity. Students in the PSI script condition were in a collaborative learning situation during the small group inquiry task two before undertaking inquiry task three individually. Their self-regulation in the inquiry process is likely to have evolved through the reciprocal interactions between the individuals and the social-context (Meyer & Turner, 2002). This could possibly explain the occurrence of regulative activities such as evaluating and fewer occurrences of low-level monitoring. The individuals could have 'replicated' the necessary regulative activities that had implications on their performance in transformative processes such as generating evidence, evaluating evidence and drawing conclusions.

The PIS classroom script: The PIS script led to higher frequency of high-level orienting with statistical significance and facilitated more occurrences of orienting, planning, high-level planning, high-level testing, fewer occurrences of low-level evaluating with medium to strong effect sizes but no statistical significance. The results of the individuals' engagement in regulative processes showed a stark contrast to their engagement in the transformative processes. As aforementioned, a possible explanation for this phenomenon is the relation between metacognitive, cognitive abilities and intellectual capacity. (Veenman et al., 2006). Good regulative processes may compensate cognitive limitations, but not necessarily facilitate excellent transformative processes. The plenary activity could have modeled the regulation of cognition (Brown & Palinscar, 1989) for the individuals to emulate. The active and constructive activity at the individual level could have reinforced these acquired regulation skills and strategies. They might have possessed the metacognitive awareness in declarative knowledge (De Jong & Ferguson-Hessler, 1996) which explained the statistical significance for high-level orienting. However, metacognitive awareness also involves procedural and conditional knowledge in allocating resources and appropriating strategies to changing situational demands (Pintrich, 2002; Schraw, 1998). The regulation of one's cognition is closely associated with one's knowledge of cognition. A higher degree in procedural and conditional knowledge could have enhanced the individuals' regulative processes. The individuals could be making some good progress in these two types of knowledge as indicated in the results showing high-level planning and high-level testing with medium to strong effects.

7.2 Effects of the PSI vs. PIS Classroom Script on the Small Groups' Transformative and Regulative Processes in Collaborative Inquiry Learning

First, the effects of the PSI classroom script will be discussed, followed by the PIS classroom script as per sequencing of the research questions on small group collaborative inquiry learning. Similarly, transformative processes will first be presented, followed by regulative processes. Thereafter, the effects of the two script sequences on the three social levels of regulation (self, co- & shared regulation) will be discussed and explained.

7.2.1 Effects of the PSI vs. PIS Classroom Script on the Small Groups' Transformative Processes, as well as High- and Low-Level Transformative Processes

The PSI classroom script: In the small group collaborative inquiry, the PSI script facilitated the generating of hypothesis, high-level asking questions, reduced the frequency of low-level asking questions, low-level generating of evidence and low-level drawing of conclusions. There was no statistical significance though there was medium to strong effects for these transformative processes. For the rest of the transformative processes, the PSI script did not deliver any noticeable effect. The results gave rise to two main queries for discussion: one, why did the PSI script facilitate only a few of the transformative processes and two, why did the PSI script reduce the occurrences of some low-level transformative processes and facilitated only one high-level transformative process, i.e., asking of questions. The script transition, the quality of the collaboration and the learning context might be able to explain this phenomenon.

Premised on the theory of the cognitive apprenticeship, the modeling at the plenary session could have enabled the small groups to externalize and appropriate most of the transformative processes which also explained the fewer occurrences of some of the low-level transformative processes. The script transition from the plenary level to small group did to some measure provide a structure for the small group to emulate the transformative processes for inquiry task two. However, the occurrences of high-level transformative processes are contingent on the quality of the collaboration and the interaction at the small group level. Studies on communication and interaction during the collaborative phase showed that good macro-level coordination and micro-level communication characterize good collaboration (Rummel & Spada, 2005). Levine and Resnick (1993) contend that collaboration is a *coordinated cognitive activity* which relies on *intersubjectivity* to create shared understanding, shared meaning and a shared common perception of task goals and strategies. Coordinated cognitive interactons with one another in the group determine the quality of the collaborative learning processes and the emerging cognitive products. Akin to Teasley and Roschelle's (1993) notion of a *joint problem space*, the communication and exchanges are key to constructing and maintaining the collaborative space. Hence, apart from possible issues of coordination at the small group level, the lack of occurrences of high-level transformative processes could be related to quality of collaborative interaction. The students in the PSI script transition moved from the plenary to small group activity, i.e., interactivity. In the light of the ICAP framework (Chi, 2009), interactivity fosters the externalisation and exploration of diverse ideas which is instrumental for emergent new perspectives and new knowledge. However, the successful integration of individual ideas and contributions into the collective unit is contingent on 'anticipated interactions' (Levine & Resnick, 1993). Put simply, individual expectations and readiness to engage in interactive activity may require scaffolding: whether one recieves, shares or exchanges information and how one expects the others to engage in the interaction process. The students in the PSI script may not possess this readiness and may have different interaction goals. The active and constructive activities may have provided this platform for the individuals, however, the students in the PSI script proceeded to small group immediately after the plenary session. Therefore, they could have encountered two main problems in such a script transition: one, they had not had the individual time to generate knowledge and to make inferences and two, relating to the first problem, they could not integrate their own perspectives into the collaborative space without sufficient individual reflection.

Finally, the learning context could possibly explain why the PSI script seemed to have reduced low-level generating of evidence and low-level drawing of conclusions. The two closely related transformative processes in scientific reasoning occurred during the field trip and after the field trip. As aforementioned, teacher modeling at the plenary and collaborative interaction in small groups is a pivotal scaffold for interaction with the physical affordances in the real world learning setting (Kerawalla et al., 2012). The PSI script could have provided these two essential platforms to enhance these transformative processes in outdoor inquiry learning at the small group level. This explained the fewer occurrences of low-level evidence generation in the field trip and drawing of conclusions in the post-field trip.

The PIS classroom script: Reiterating the theoretical arguments for *productive failure*, students may experience challenges in the *generation and exploration* phase, but this eventually facilitated the contrast and the organization of the ideas in the 'consolidation' phase (Kapur & Bielaczyc, 2012; Kapur & Rummel, 2012). In the PIS script transition, the individual level could be likened to *generation and exploration* phase for inquiry task two and the small group collaborative inquiry formed the *consolidation* phase where the individuals as a collective unit now, undertook inquiry task three.

Results of the study showed that the PIS script led to significantly more occurrences of generating evidence. Although there was no statistical significance, the PIS script facilitated more occurrences of drawing conclusions, high-level orienting and high-level generating of evidence and reduced the occurrences of low-level orienting with medium to strong effect size. Relating to the earlier discussion on the poorer performance of the individuals in the PIS script condition as compared to the PSI classroom script, these same individuals as a collective unit seemed to have showed better engagement in the transformative, as well as high-level transformative processes at the small group level. Withholding support may instead provide the necessary platform for students to persevere in active sense-making and problem-solving activities (Kapur & Rummel, 2009). The *consolidation* phase at the small group level seemed to have successfully integrated the individuals' contributions and built on these diverse ideas to coconstruct new perspectives. The *productive failure* design invokes learning processes that fostered prior knowledge activation and differentiation (Kapur, 2012). However, it is needful here to mention that the PIS script transition began with a plenary level where students were able first to observe the inquiry model before embarking on the second inquiry task at the individual level and the third inquiry task collaboratively at the small group level. The plenary level provided the baseline learning context and condition for productive failure that would not be overwhelmingly challenging for the individuals and the small groups. It would be a case of 'unproductive failure' if there was absolutely no instructional guidance. Inquiry learning is a complex process where minimal guidance would not suffice to engender learning (Kirschner et al., 2006). The plenary session also created the relational context for subsequent coordination and interaction at the small group level.

Next, by designing individual level before the small group collaborative inquiry, the individuals were able to engage in active and constructive activities which activated prior knowledge and integrated new ideas with existing ones to compare and contrast. Active and constructive activities evoke important cognitive processes such as *gap-filling* processes and *generating* processes respectively (Chi, 2009). Hence, there are strong theoretical arguments to believe that the active and constructive activities could have eased the integration of individuals' contributions during the collaborative inquiry learning in the PIS script transition. Collaborative process itself entails corresponding individual processes. As Stahl (2005) puts it, "the individuals learned as a result of the group learning, and that the group could only learn by ensuring that the individuals learned" (p. 82). The individual group members would have to construct their own interpretation of the meaning in the shared meaning-making process. On the same token, it is likely that the active and constructive activities in the individual phase have enhanced the quality of interaction and communication in the collaborative space. In joint work phase, fruitful discussion of the individual views and perspectives are paramount for the pooling together of unshared information (Rummel & Spada, 2005).This is also a likely explanation for the high-level generating of evidence and higher occurrences of drawing of conclusions.

7.2.2 Effects of the PSI vs. PIS Classroom Script on the Small Groups' Regulative Processes, as well as High- and Low-Level Regulative Processes

The PSI classroom script: The PSI script facilitated more occurrences of orienting, planning, instructing and monitoring, high-level orienting and high-level evaluating with medium to strong effect size but no statistical significance. The results suggest that the PSI script rendered an effect on two levels: one, the occurrences of most of the regulative processes necessary to facilitate the transformative processes in inquiry learning as hypothesized, second and interestingly, the PSI wrought two high-level regulative processes; orienting and evaluating. For the first level, the results were not surprising as it mirrored one of the expected effects of scaffolding which consequentially led to the differentiation and the externalization of activities (Collins et al., 1989). The PSI script transition enabled the small groups to collectively articulate and appropriate the regulative processes. The plenary level provided an inquiry model for the small groups and thereby, scaffolded the students' sense-making process and collaborative reflection (Hmelo-Silver, Duncan & Chinn, 2007). Orienting, planning, instructing and monitoring are fundamental regulative processes to coordinate the planning of the task and to get things started.

Next, small groups in the PSI script condition show better engagement in two regulative processes: high-level orienting and high-level evaluating. Regulation within the collaborative context and specific learning setting may see priority on specific regulative processes over the others (De Jong et al., 2005). The PSI script conditions could have increased the unique affordances of the individuals with the presence of fellow group members as a source of scaffold (Barron, 2003) where both the start and the end of task would require more transitional support. Emerging from the plenary session, students proceeded to work in small groups in the PSI script transition. This could have imposed a greater demand for regulative processes to facilitate immediate coordination of the collaborative space, which explains the occurrences of the high-level orienting. The small group engagement in the regulative processes certainly shaped many of the transformative processes. Whilst the PSI script facilitated high-level orienting, high-level evaluating and the mandatory regulative processes of orienting, planning, instructing and monitoring which reduced the occurrences of low-level transformative processes (asking question, generating hypothesis and drawing conclusions), the PSI script did not facilitate any high level transformative processes apart from the asking of questions. There could be undeniably some form of coordination and communication problem which explained the reduction of low-level transformative processes. Notwithstanding, there are legitimate reasons to suggest that the lack of high-level transformative processes could be attributed to the quality of interaction, i.e., the quality of the grounding process to maintain a joint problem space, and importantly, high-level grounding to foster the co-construction of higher-order knowledge. The order of the activity type, that is, interactive, constructive and active might have a determinant role in the overall trend of results. The discussion of the case study will further elucidate the current findings on the regulative processes of the small groups in the PSI script condtion.

The PIS classroom script: The PIS script facilitated more occurrences of high-level grounding, high-level testing and reduced the occurrences of low-level orienting, low-level planning, low-level instructing, low-level monitoring and low-level testing showing medium to strong effect sizes for these regulative processes. The results of the study showed that the transition from the individual to the small group level invoked some regulative processes more than other regulative processes, as well as the high-and low-level of these regulative processes.

Grounding forms a core regulative process where shared meaning and common grounds is established through group discourse. Stahl (2005) contend that the "status of this shared meaning must be continually achieved in the group interaction"; frequently the shared status of 'breaks down' and repair is necessary" (p. 345). *Grounding* coordinates the content and the process in collaborative undertaking (Clark & Brennan, 1991; Koschmann & LeBaron, 2003). Studies on collaborative learning showed that students spent most of the time on grounding to ensure that learning partners understood what had transpired. In other words, they were very busy confirming that their partners understood what had been said in collaborative work (Beers, Boshuizen, Kirschner, & Gijselaers, 2004) to procure common grounds. The high-level transformative processes for the small groups in the PIS script could be attributed to the higher occurrences of high-level grounding, as well as high-level testing. The posing of verification questions during grounding is an important regulative activity in the inquiry process (De Jong et al., 2005). Collaborative inquiry demands collective reflection; a reflective inquiry process (White et al., 1999). High-level grounding is contingent on critical reflection and deep thinking. Asking critical questions, posing of good verification questions and clarification statements are vehicles to achieve high-level grounding. Next, testing in the regulative processes usually occur during the execution and towards the end of task where students check the sufficiency and the accuracy of information, pose questions and preempt possible problems (De Jong et al., 2005). Asking question at the micro-level communication is of central importance to foster the effective exchange of diverse ideas and opinions (Rummel & Spada, 2005). The active and constructive activities preceding the small group interactive activity was likely to have evoked the occurrences of high-level grounding and high-level testing processes. This also explained the reduction of a number of low-level regulative processes such as low-level orienting, low-level planning, low-level instructing, low-level monitoring and low-level testing. Reiterating Kaptelinin and Cole's (1997) conception of *pre-intersubjectivity activity* to coordinate individual and collective activites, the PIS script conditon enabled the individuals to assimiliate into the collective activity. The active and constructive activities at the individual level could be likened to a pre-intersubjectivity activity which facilitated quality interaction and communication at the small group level.

7.2.3 Effects of the PSI vs. PIS classroom script on the Three Social Levels of Regulation in Collaborative Inquiry Learning

The PSI classroom script: In the light of the above discussion on the small group's engagement in the type of regulative and transformative processes, the effects of the PSI script transition on the three levels of social regulation is expected. In particular, results showed that there was significant effect of the PSI script on co-regulation and medium to strong effect size for self- and shared- regulation. Coregulation is instrumental to arrive at shared representation (Saab, 2012). Co-regulation brings about 'emergent interaction' and activity within the ZPD zone (McCaslin & Hickey, 2001). Co-regulation accentuates the elements of interdependency to develop strategies and plans to achieve shared goals (Jarvela & Hadwin, 2013). The PSI script essentially facilitated more occurences of regulation at the social three levels in the collaborative space: the plenary and the small group level provided the scaffolds for the transitory support in co-regulation to arrive at shared regulation of task. However, more regulative activities at the three social levels do not necessarily imply better quality of coordination and communication. One main explanation for the more occurrences of all three levels of regulation could be attributed to the sequencing of activity types. Emerging from the plenary level and undertaking immediate small group work require team regulation (Saab, 2012) to coordinate and to organise the task at hand.

The PIS classroom script: Although the PIS script did not render an effect on any of the three social levels of regulation during the collaborative inquiry, it still facilitated some of the high-level regulative processes and reduced the frequency of low-level regulative processes. Whilst is true that for any successful collaboration to take place, these three levels of regulation co-evolve (Järvelä & Hadwin, 2013). However, equally significant is the quality of the regulation at these three social levels. The results of this present study and other empirical studies suggested that there are more mechanisms underlying effective collaborative interaction (Barron, 2003; Rummel & Spada, 2005). Further, the activity type and the sequencing of activity types across the social planes inherently shaped the occurrences of co- and shared regulatory activities. Students in the PIS script condition engaged in active and constructive activities which afford them individual time for regulative and reflective activities, which in turn brought about better planning and coordination at the group level. These findings align with Rummel and Spada's (2005) results on individual time before joint work which facilitated better coordination and communication. More regulative activities do not equate better regulation.

7.3 Effects of the PSI vs. PIS classroom script on the Individual Domain-Specific knowledge, as well as Individual and Small Group Inquiry Skills

The effects of both script conditions will be discussed with domain-specific knowledge, individual inquiry skills and small group inquiry skills respectively.

Domain-specific knowledge: Results showed that there were significant learning gains in domain-specific knowledge but neither the PSI nor the PIS script render an effect on this significant increase in knowledge gains. The result was not surprising as a number of studies showed that simulation learning environments facilitated domain knowledge and conceptual knowledge gains. Studies on the effects of simulations showed that learners improved significantly in *definitional knowledge* and *intuitive knowledge* when learning with the simulation environments (Swaak & De Jong, 1996). Other empirical studies on the use of simulation environments also indicated that the advantage of simulation on acquisition of central concepts (e.g., Lewis, Stern, & Linn, 1993; Linn & Songer, 1991). During the pre-field trip, students learnt about photosynthesis and cellular respiration through a series of simulations on the WISE online learning environment. The pre-post domain knowledge test consisting of 13 items testing factual and conceptual knowledge on photosynthesis and cell-respiration. Students' marked improvement in domain knowledge gains could be attributed to the nine simulations in the WISE learning environment. Hence, it should not be surprising that none of the two script conditons could account for the significant knowledge gains in domain-specific knowledge.

Individual inquiry skills: Similarly, results showed that there was marked increase in the individual acquisition of inquiry skills but neither of the two script conditions delivered an effect. There are two main explanations for this. First, it had to do with the nature and content of the test. Owing to curriculum constraints, the pre-post inquiry tests could only design to test students' transformative processes in orienting, generating hypothesis, identifying variables and designing an experiment. These transformative processes are categorised as the hypothesis space (Klahr & Dunbar, 1988). Transformative processes such as generating evidence, evaluating of evidence and drawing of conclusions could not be tested as students did not carry out a full scale inquiry and investigation. As shown in the results of the individual inquiry process in 7.1.1, there was no script effect except for these three transformative processes of the experiment space which are core processes in the scientific reasoning process. Hence, it could be possible to predict that the PSI script might have also rendered an effect on these three transformative processes had they been tested in the pre-post inquiry test.

Second, the simulation learning environment and the guided inquiry process could also explain the lack of script effect. Guided inquiry with or without leveraging technological affordances has been empirically proven to foster the scientific inquiry process (De Jong, 2006). The Scaffolded Knowledge Integration Environment framework (KIE) (Linn, 1995) guided the design of the inquiry tasks on plant adaptation, as well as structured the inquiry process, i.e., the transformative processes from orienting to drawing conclusions. Relating to the above discussion on the transformative processes in the hypothesis and experiment space, the PSI script seemed to have only affected the transformative processes in the experiment space. Apart from the presence of cognitive scaffolds (i.e., KIE embedded in the curriculum design), the transformative processes for scientific reasoning could pose higher cognitive demands which required the gradual fading of modeling at the plenary and the peer support in collaborative explanation activities. This could possibly explain the lack of script effect on the pre-post inquiry tests where the transformative processes of evidence generation, evidence evaluation and drawing of scientific conclusions which occurred in the field trip and post-field trip could not tested owing to time and curriculum constraints. Further, the learning context and setting were different for the pre-post inquiry tests and the full-scale inquiry learning process as the latter consisted of in and out of the classroom activities.

Small group inquiry skills: There was neither script effect nor substantial increase in inquiry skills for small groups in both script conditions. One main reason lies in the motivational factor. The pre-post inquiry test was first done individually before the individuals undertook the same inquiry test as a collective unit. This could possibly have affected the motivational level. Further, as aforementioned, the inquiry test was not designed to test transformative processes in an actual outdoor learning setting. The students were not expected to carry out the inquiry or experiment plan. That could have caused a further decrease in their motivation. Motivational issue and time factor could explain the lack of script effects.

7.4 Discussion of the Effects of the Differently Sequenced Classroom Scripts (PSI vs. PIS) on the Processes and Discourse Structures in Case Studies

The case studies aim to exemplify the quantitative results. The analysis of the individual and the group discourse, as well as the respective written work in the two differently sequenced classroom scripts provides a needful platform to identify the transformative and regulative discourse structures. Essentially, it affords an insight into how the two different script transitions shaped both the individual and small group inquiry learning processes. The case studies have added value to the study by identifying and illustrating these critical aspects in the two script conditions. Quantitative analyses may conceal why and how the two script sequences affected the transformative and regulative processes of the individual and the small group collaborative inquiry discourse. Case studies disclose to what extent the specific process phenomena align with the theoretical assumptions. In this section, the discourse structures of the PSI classroom script will first be discussed, followed by the PIS classroom script.

The PSI classroom script: The first case study examines one small group (group 2) and one of the members (student S07) in the PSI script condition from pre-field trip to post-field trip. In the PSI classroom script sequence, the students first worked in small groups before working individually. Overall, the small group discourse showed attempts at collaborative interaction to create a joint problem space. The group was relatively engaged in orienting, planning, instructing and grounding processes to arrive at shared task perception, goals and strategies. As reflected in the quantitative analyses, the small groups in the PSI script condition did show engagement in the same range of regulative processes, but not many high-level regulative processes. Moreover, the small group discourse showed considerable occurrences of non-interactive moments, where one member of the group was merely articulating his/her contribution and assuming a consensus from the other members. In the pre-field trip, this amounted to a total of six such instances where an intended interactive activity was reduced to constructive during the enactment. Another noticeable feature of the small group discourse was the high occurrences of low-level regulative processes (total of 14 occurrences), in particular, in *grounding*. There were seven instances of low-level grounding where verification questions posed, were either dismissed or superficially responded. Low-level grounding also occurred where good ideas and contributions were not adequately dealt with or given a token treatment. The lack of *socio-cognitive conflicts* (Bearison et al., 1986; Mugny & Doise, 1978; Tudge & Rogoff, 1999) could explain the low-level transformative processes during the small group collaborative inquiry in the pre-field trip. Conflict is the source for cognitive growth and conceptual change (Levine & Resnick, 1993). Conflict consensus building is the underlying mechanism in the social co-construction of knowledge (Weinberger & Fischer, 2006). At the individual level, student S07 seemed to still have benefited from the interaction. He was able to incorporate and apply some of the unexplored ideas into his own inquiry process, which was manifested in his written work. This was also demonstrated in his individual reflection where he showed awareness of his own strength and weakness in both progress and performance.

At the field trip, the small group discourse showed better engagement in regulative processes. The number of low-level regulative processes was visibly reduced to only six such instances and there were only two instances of non-interactive activities. The occurrences of one high-level grounding and one high-level testing apparently contributed to the two high-level generating of evidences. The group discourse showed better quality of interaction with more posing of good verification questions to establish common grounds, to consolidate evidences and to co-construct scientific explanations. During the individual inquiry task, the effects of *fading of the scaffolds* is strongly evident in student S07's individual reflection. He demonstrated confidence in monitoring and testing his inquiry plan. He was keenly aware of the need to substantiate these claims with evidences and he had three high-level generating of evidence and one low-level generating of evidences.

In the post-field trip, the quality of interaction and communication in small group discourse mirrored very much the discourse trend of the pre-field trip. There were no occurrences of high-level regulative processes and four occurrences of non-interactive moments. Ideas and contributions were not sufficiently dealt with. There was also an inclination for one or two members of the group to dominate the discourse moves in an attempt for quick coordination and consolidation of ideas. Notwithstanding the lack of quality in interaction, student S07 was again able to leverage some of the ideas surfaced at the group level and incorporate applicable elements in his own written work where he had two high-level evaluation of evidence and one high-level drawing of conclusion. His individual reflection indicated that he was appreciative of the small group inquiry work for he found it challenging to work individually and the think-through process was more effortful.

Overall, the PSI classroom script evidently benefited the individual more than the small group. The *fading of the scaffold* has enhanced the inquiry process; the automation and the appropriation of the transformative processes, in particular, for the individual. What could have countered the effects of the scaffolding for the small group, would be the order of activity type. It is apparent from the number of instances where intended interactive activities at the small group level were reduced to constructive. This inevitably led to low-level grounding processes and lack of deep discourse.

The PIS classroom script: The second case study investigates one individual student (I21) and one small group (group 6) in the PIS classroom script condition. Students in this script transition first work individually before working in small groups. Similarly, the individual and group discourse with their respective written work was analysed from pre-to-post-field trip.

Individual reflection in the pre-field trip showed that student I21 was keenly aware of the task requirements and able to engage in high-level orienting and high-level planing activities. She knew how to mobilize her prior knowledge and activate the appropriate strategies for her inquiry task. However, her individual reflection also hinted of the diversity of her interesting ideas that she wanted to explore but she was uncertain about how to develop these ideas. This was also indicated in her written work where she had six low-level transformative processes and only two high-level transformative processes. At the small group level, she was able to explore some of her unpolished ideas and integrate them into the collective contributions. The group discourse showed six occurrences of high-level regulative processes and six occurrences of low-level regulative processes. There were two instances of non-interactive moments where members engaged in active and constructive activity type; externalizing one's idea and eliciting quick consensus. The high-level regulative processes such as orienting, planning and grounding demonstrated the emergence of deep discourse where the group collectively advanced one another's ideas to co-construct new perspectives and new queries. The two occurrences of high-level grounding to forge common grounds deepen the critical thinking and collaborative effective inquiry process where the group questioned the misconception that cactus performed photosynthesis in the night. The group delivered five high-level transformative processes and four low-level transformative processes.

In the field trip, student I21's individual reflection showed one high-level testing and one low-level monitoring. She displayed uncertainty about the monitoring of her progress in the inquiry process; what to take note of and how to proceed. She generated four evidences, three of which were not relevant as they were interesting but too general. Moving to the collaborative inquiry at the small group level, she was able to leverage on the ideas of the group to refocus some of her own earlier ideas. The group discourse showed relatively good coordination and communication. There were no instances of non-interactive activities. The group had five occurrences of high-level regulative processes and three instances of low-level regulative processes. The high-grounding and high-level statements led to the emergence of four high-level generating of evidences. They were able to validate the knowledge claims with evidences and scientific explanation. This could be attributed to the collaborative communication at negotiation and consensus with one another (Reiser et al., 2001) which encapsulates the essence of collaborative reflective inquiry.

In the post-field trip, student I21 showed good evaluation of her inquiry learning process in her individual reflection. She displayed more confidence in her review of her entire execution process. She had one high-level evaluating of evidence and one high-level drawing of conclusion. At the small group level, group discourse showed there was only one occasion of low-level regulative process but no instances of non-interactive activity. Moreover, the group discourse showed that there was good regulatory support for one another by taking time to reflect on queries and dealing with unresolved issues. This was evident in the high-level grounding and testing of claims to evaluate and to affirm evidences for the eventual construction of the final scientific conclusions. The group had one high-level evaluating of evidence and drawing of conclusion, as well as one low-level evaluating of evidence and drawing conclusion.

Overall, at the individual level, student I21 exhibited some good regulative processes but these did not mirror her engagement in the transformative processes. However, the collaborative interaction at the small group level enhanced her performance and the group's performance as a collective unit. The group discourse also revealed that the other individuals in the group were keen to bring to bear their raw ideas or uncertain inferences made at the individual level. The active and constructive activity at the individual level could have provided the platform for generation and exploration of ideas, and the small group collaborative inquiry became a consolidation phase.

In conclusion, the two differently sequenced classroom scripts impacted the discourse moves and structures in different ways for the individual and the small group collaborative inquiry learning. It became increasingly clear how and why the two different script transitions have yielded differing effects on the individuals' and small group's engagement in the inquiry processes. Discourse moves and structures showed that the PSI script transition did render the necessary scaffolds, in particular, for the individuals and to some measure, for the small group. The gradual fading of the scaffolds had certainly enhanced individual engagement in the transformative processes, as well as high-level transformative processes. However, at the small group level in the PSI script transition, what could have inhibited the occurrences of more high-level transformative and high-level regulative processes was that the platform for active and constructive activities only occurred after the interactive activity. This was apparent in the number of non-interactive, but active and constructive activities during group discourse, which also explained some of the low-level regulative processes. Conversely, the small groups in the PIS script condition experienced better coordination and interaction. The group discourse exhibits the diverse ideas and perspectives the individuals were able to contribute at the collective level. The active and constructive activities at the individual phase could have afforded them the space for generation and exploration. It might have created challenges at the individual level in transformative processes, but yielded positive outcomes at the group level. It gave rise to more socio-cognitive conflicts which was instrumental for collaborative reasoning and argumentation in scientific discourse (Driver et al., 2000; Duschl & Osborne, 2002; Osborne et al., 2004). *Productive failure* in the PIS script condition did not yield equally positive results for the individuals for the short term performance. Instead, the individuals showed better performance at the small group level where the collaborative inquiry and reflective learning harness the collective cognitive activity.

7.5 Summary of the Results

The results of the study present a relatively comprehensive account of the processes and outcomes of the individual and the collaborative inquiry learning in differently sequenced classroom scripts. The two different script transitions in the PSI and PIS classroom script had wrought different effects on the transformative and regulative processes, as well as the quality of these two core processes for the individual and the small group inquiry learning. Classroom scripts prescribe the structure of activities (Kollar et al., 2011) with the aim to foster learning effectiveness. Studies on different sequencing and distribution of classroom scripts at various social levels of the classroom showed how the structure of activities at plenary, group and individual level could influence overall quality of learning, patterns of interactions and quality of collaboration (Hmelo-Silver, 2004; Kollar et al., 2011; Mäkitalo-Siegl et al., 2011). The following will sum up the results of the two different classroom script sequences on the individual and collaborative inquiry learning: the PSI and the PIS respectively.

The PSI classroom script transition seemed to have supported the individual's engagement in transformative processes during and after the field trip study. Generating of evidence, evaluating of evidence and drawing of conclusions are transformative processes which constitute the core cognitive processes in scientific reasoning and construction of explanation. The PSI script sequence exemplifies *cognitive apprenticeship* (Collins et al., 1989) and *gradual fading of the scaffolds* (Pea, 2004), which might have increased the individuals' affordances in outdoor learning. The scaffolding at the plenary and the small group provided the initial help the students would need for learning and transfer during the individual inquiry task when these scaffolds were gradually withdrawn. On similar grounds, for the small group engagement in transformative processes, the PSI script reduced the occurrences of low-level transformative processes in generating evidence and drawing conclusions. Learning in real world setting imposes higher cognitive demand where one has to engage in "*interpretation of and interaction with* the physical environment" to create meaning and construct knowledge (Kerawalla et al., 2012, emphasis added) and in science education, "the process of learning is informed by sense of place" (Lim & Barton, 2006). This could possibly explain why the PSI script affected the transformative processes that occurred during and after the field trip for both the individual and the small group, whilst most of the other transformative processes saw no script effect. Another intriguing phenomenon is the effect of PSI script on individual and group regulative processes. Case study of the group discourse indicated several instances of non-interactive activities and low-level grounding and low-level testing processes, which explained the lack of occurrences of high-level transformative processes such as generating and evaluating evidence to construct sound scientific conclusions. The quality of interaction and coordination seemed to have inadvertently shaped the individuals' regulation too.

The PIS classroom script transition seemed to have facilitated the small groups' transformative processes, but not so for the individuals. The transition from plenary to individual could have equipped the individuals with the necessary know-how to activate and appropriate the transformative and regulative processes in inquiry learning. However, the immediate undertaking of inquiry task two individually following the plenary session though allowed them a *generation and exploration* platform, but the students working individually were not able to advance these raw ideas further to make valid scientific connections and interpretations without further support. On the same token, it was the individual phase that afforded them the preparation platform for the collaborative inquiry learning at the small group level. They were able to bring to bear their prior knowledge, as well as new knowledge to rework through them collectively. Case study showed that there was better coordination and collaborative interaction at the small group level which enabled the integration of the individuals' contribution and the advancement of these ideas to deepen knowledge for the small groups in the PIS classroom. High-level regulation in grounding and testing also visibly increased the quality of socio-cognitive conflicts, which in turn, explained the high-level transformative processes in orienting and generating of evidence, as well as more occurrences of the drawing of conclusions. The PIS script seemed to have facilitated better regulation for both the individuals and the group, though it did not facilitate the individual engagement in the transformative processes. Reiterating the *essence of productive failure,* it seeks to maximise learning in the long run but does not promise immediate performance (Kapur, 2012). Students do learn from their own failed attempts (Kapur, 2014) but 'failure' does not amount to 'no learning'. There was learning and transfer in subsequent similar inquiry task for the individuals at the small group level as shown in the descriptive quantitative results and the case study. There is certainly cognitive value in every activity type but the sequencing of these activity types play a crucial role to bring about the desired learning outcomes. In a similar vein, Chi and Wylie's (2014) study showed that students perform increasingly better as they progressed from passive to active to constructive and to interactive mode of engagement. In brief, the PIS script transition mirrored such a movement of cognitive engagement which could possibly explain why the small groups in the PIS script condition fared better compared to the small groups in the PSI classroom script. Designing the individual phase before small group, the active and constructive activities were instrumental for better regulatory skills and strategies during the collaborative interaction, which was reflected in the group's engagement in transformative processes.

7.6 Limitations of the Study

There are several limitations of the study that need to be addressed so that the results of the study and the implications for future research and educational practice may be viewed in perspective. The main limitation of this study is the small sample size and the cohort of students. Other limitations are: (1) the ecological validity, (2) the analysis of the processes, and (3) the orchestration of inquiry learning with two differently sequenced classroom scripts.

This research study was conducted with 61 students from two international schools, grade six to nine. First, the small sample size has constrained the use of greater variety of statistical procedures, moreover affected the significance level and the statistical power. As evident in the quantitative analyses, there were a number of medium to large effect sizes for most of the dependent variables in the two script conditions but without statistical significance. Increasing the sample size would provide a more robust representation of the results and its interpretation. Second, the cohort of students from two international schools might not be a good representation of the general population of students at large who attend public schools. Different school climate and culture, curriculum design and instructional approaches have bearings on the processes of effective schooling. Apart from students' background variables, school variables could account for variance in students' performance (Teddlie & Reynolds, 2000). Third, notwithstanding that the majority of the students were from grade nine and the small number of grade six and seven students were equally motivated and engaged from pre-to-post field trip, the grade level difference remain an issue of contention.

The study has been conducted in an ecologically valid setting. The methods, materials and setting of the study could appropriate the real world. It has engaged students in *doing science* (Barab & Hay, 2001) in in and out of classroom learning settings with the aim to promote authenticity in scientific inquiry (De Jong, 2006; De Jong & Van Joolingen, 1998; Lim & Barton, 2006; Zimmerman & Bell, 2008). Creating authentic science experiences aligns with theories of situated learning (Lave 1993; Lave & Wenger, 1991), situated cognition and apprenticeship learning (Brown et al., 1989; Collins et al., 1989) and a constructivist approach (Palincsar, 1998) where learners are active agents in constructing knowledge. The drawback of this highly ecological setting is the inherent limitations in a real world learning environment where individuals' interpretation of and interaction with the rich physical affordances is highly dynamic and subjective too (Lim & Barton, 2006; Kerawalla et al., 2012). This could possibly imply that students may require more time individually, as well as as a collective unit to explore and to interact with the rich physical affordances. New queries could ensue during the interaction with the real world environment and students may alter their course of inquiry. Therefore, it is unclear to what measure less complex and debatable problems in other learning settings could initiate scientific discourse and facilitate authentic inquiry in similar ways. This implies that the results of the study needs affirmation by investigating a variety of learning settings and materials, for instance, pursuing scientific inquiry in laboratory experiments.

Another possible limitation is the analysis processes. From a sociocultural perspective on *engagement in science learning*, a combination of critical discourse analysis (CDA) and social network analysis (SNA) might be a more effective means to measure individual and collective engagement in specific science learning situation as it also captures the relation between the two units (Ryu & Lombardi, 2015). This might afford a richer understanding of how the two differently sequenced classroom scripts could affect the individual and collaborative engagement in transformative and regulative processes. On the same note, for in and out of classroom inquiry learning, video-based interaction analysis which facilitates a micro-level analysis of human interaction (Jordan & Henderson, 1995) could expand and enrich our understanding of how learners employ and assemble the material and social resources available in indoor and outdoor learning context in the sense-making process. The set of analytic foci in interaction analysis such as turn-taking interaction, participation structure, artefacts and documents, trouble and repair, might provide useful insights into individual and collective engagement in science inquiry learning. Relating to the analysis approach, one other limitation in this study was the use of individual reflection to assess the individuals' regulative processes. Self-report measures may contain biasness as it hinges on one's own perception of one's capability and capacity for task. Think aloud protocols might be a more objective instrument for measuring individual learning regulation to determine the adequacy of regulation and its relation to performance within individual learning context (De Jong et al., 2005). Although the case study of the group discourse did to some measure enabled an insight into the individuals' regulation processes, one could still argue that the analysis results remained inferential.

Another limitation was the design of the pre-post tests. First, owing to time constraints in the school curriculum and resource issue, the design of the pre-post inquiry tests could not accommodate other core transformative processes such as generating evidences, evaluative evidences and drawing conclusions, which are important cognitive processes in scientific reasoning and argumentation. It was also therefore difficult to compare and contrast the findings of the learning outcomes with the results of the learning process where both script conditions seemed to have yielded more impact on the transformative processes during and after the field trip. Second, motivational issue also affected the small group learning outcomes for the post inquiry test as it was the same test they undertook individually before doing it as a collective unit.

The trajectory of this research and the core inquiry of this study was to pursue how orchestrating inquiry learning with differently sequenced classroom scripts could foster both individual and collaborative inquiry learning, i.e., what would be the best classroom script sequence. No control condition was administered, nor was there more varied script sequences employed to attest that the PIS script sequence was more beneficial for collaborative inquiry learning and the PSI script sequence fostered individual inquiry learning. Hence, it is difficult to draw conclusive statements from the current results of this study.

7.7 Implications for Future Research and Practice

The results of this study suggest that there are three possible platforms for further research on individual and collaborative inquiry learning: (1) individual time in collaborative inquiry (2) collaborative inquiry learning as reflective inquiry, (3) indoor and outdoor inquiry learning.

First, future research on harnessing collaborative inquiry learning may need to consider assisting and equipping the individuals to assimiliate into the collaborative inquiry space. This calls for more than collaboration scripts to scaffold effective communication and interaction. Findings from the PIS classroom script suggest that allotting individual time has bearings on the collective inquiry learning process. Inquiry learning is a highly self-directed learning process; a very specific form of constructivistic learning (De Jong & Van Joolingen, 1998). Inquiry learning, therefore, requires learners to be both *active and reflective participants* (Garrison, 2003). Learners need individual space to reflect, interpret and construct meaning. In the PIS script sequence, the individual phase before the small group collaborative provided such a platform for transition into collaborative work. The active and constructive activities at the individual level invoke cognitive processes such as *gap-filling* and *generative* processes (Chi, 2009). 'Generative' processes enable learners to reflect on conditions of a procedure and provide explanations. Self-explanation and asking questions during the individual level is instrumental in establishing common grounds through posing verification questions during the *mutually generative processes* in interactive activity. It mirrors the notion of a *pre-intersubjectivity* activity at the individual level which primarily aims to help the learners coordinate two different views: the individual and the collective view (Kaptelinin & Cole, 1997). The individuals in the PIS script condition were apparently more engaged in high-level grounding of their diverse ideas as a collective unit. Likewise, the studies on collaborative learning from Rummel and Spada (2005), as well as Barron's (2003) studies attribute the differing collaborative learning outcomes to the quality of collaborative interactions. Baron's study showed that the efforts of the individuals involved and their understanding of the activity and the available materials are crucial determinants of a productive collaboration. Allowing individual time "to think before talk" enabled reflection (Veerman, Andriessen, & Kanselaar, 2000). Hence, more research is needed on the kind of cognitive and metacognitive processes that could help the individuals function at the group level and become effective collaborators (Hmelo-Silver, 2004).

Second, it might be helpful to focus research more on fostering metacogntive and sociocognitive processes in collaborative inquiry. An essential component of collaborative inquiry is reflection learning (White et al., 1999) where reflection is pivotal for "learning to engage in inquiry and for developing the metacognitive expertise" (p. 10). This postulation underscores Njoo and Dejong's (1993) contention that the regulative processes manage the transformative processes in inquiry learning. Results of the PSI classroom script showed that students were relatively engaged in most of the regulative processes (e.g., orienting, planning, instructing, monitoring) during the small group inquiry learning, whereas the students in the PIS script showed more engagement in grounding and testing, as well as high-level grounding and testing processes. *Grounding* and *testing* are two core constitutive processes in reflective inquiry and in forging common grounds to converge at shared meanings. The display of more grounding and testing activities in the PIS script condition could be attributed again to the design of the individual work before the small group work. In the words of Garrison (2003), "reflective inquiry represents both constructive (internal) and collaborative (external) aspects of cognition, the perspective here is from the inside out. That is, the emphasis is on the generation of knowledge and less so on the control of learning activities" (p. 51). This could possibly explain the hidden efficacy of the PIS script for collaborative inquiry learning. It may not promise immediate performance for the individuals, but it has equipped and empowered the individuals for the collaborative reflective inquiry where the individuals were able to integrate their unexplored ideas and advance them as a collective unit. In the PIS script, the *generation and exploration* phase prior to the *consolidation* phase (Kapur & Bielaczyc, 2012) affords the individuals that much needed space for individual reflection before consolidating and organizing multiple ideas and views at the small group level.

Third, future research may need to examine how individuals and groups of individuals interact with the physical environment in outdoor inquiry learning. Interaction with the real world environment has given learning, new shades of meaning and intent. Learning is a situated activity and the "agent, activity and the world are mutually constitutive" (Lave & Wenger, 1991). Here, learning is reciprocal, reflexive and communal. Specific scaffolds and supports might be needed to help students interpret and interact with physical learning setting endowed with rich physical affordances (Kerawalla et al., 2012). Next, 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. Essentially, how students leverage the sense of place in outdoor science learning is both dynamic and subjective (Lim & Barton, 2006). There is paucity of research investigating outdoor science learning, in particular, how individuals' and groups' regulative processes and transformative processes might differ in indoor and outdoor science inquiry. In outdoor learning, Pachler (2009) accentuates that the focus should be on 'contexts, context generation and context crossing' and defines learning as 'semiotic work and meaning making' where new cultural practices could emerge through which "learners strengthen their resources in meaning making while interacting with the world" (p. 5). This interaction with the physical affordances of a real world environment may differ not only from individual to individual, but also from individual to group in outdoor learning setting. The integration of the individual into the collaborative learning space in an outdoor learning setting may require more research attention.

In sum, it might be useful to think about how orchestrating inquiry learning could expand to include context crossing, i.e., from classroom to outdoor learning and back to the classroom. Also, future research on classroom scripts could consider supporting both individual and collaborative inquiry in outdoor science learning.

7.8 Conclusion

Empirical studies have indicated that embedding collaboration in the inquiry learning process promises better engagement and learning effectiveness in science education. At the same time, research also showed that the collaboration is a complex process, beset with multiple constraints and challenges which require instructional supports. In the last four decades, instructional support has assumed various forms ranging from software scaffolds to collaboration scripts with prompts to help learners collaborate better. Levine and Resnick (1993) spoke of 'anticipated interactions' which account for the successful integration of individual ideas and contributions into the collective unit. The collaborative process involves corresponding individual processes (Stahl, 2005) and the group can only learn when the individuals learn (Stahl, 2006). Hence, this study aims to examine 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 both the individual and group learning.

This study investigates the effects of two differently sequenced classroom scripts on the transformative and regulative processes in individual and small group collaborative inquiry. Essentially, it aims to examine how the orchestration of the inquiry learning activities at different social levels could shape the individual and collaborative inquiry learning processes and learning outcomes. The PSI script embodies theory of *scaffolding* and *fading* (Collins et al., 1989; Pea, 2004), whereas, the PIS script exemplifies idea of *productive failure* (Kapur, 2006). These two differently sequenced classroom scripts also encapsulate conceptual elements in ICAP conceptual framework that different activity types invoke different cognitive processes. Not all hypotheses could be verified and the small sample size was a restrain to the interpretation of the findings. Overall, the results showed that the two different script transitions in the PSI and PIS classroom scripts produced differential effects on the transformative and regulative processes, as well as the quality of these two processes for the individual and the small group inquiry learning. In a nutshell, for individual inquiry learning, sufficient scaffolding is pivotal to ensure learning effectiveness. Perkins (1993) contends that small group work is a cognitive scaffold itself. In particular for outdoor learning, a combination of teacher modeling and collaborative interaction is a pivotal to help students' *'interpretation of and interaction'* with the physical affordances (Kerawalla et al., 2012). And for collaborative inquiry learning, the quality of collaborative interactions (Barron, 2003) determines performance of the group: the more successful groups experience better quality of communication. Establishing common grounds is likened to sustaining a shared status of 'breaks down and repairs' (Stahl, 2005) which must be continually achieved through the posing of verification questions and statements (De Jong et al., 2005). To this end, the sequencing and distribution of active, constructive and interactive activities could also play a crucial role to evoke the desired modes of engagement.

In sum, this study provides an insight into the orchestrating of inquiry learning using classroom scripts to embed collaboration in the inquiry learning process. Importantly, it shows how the sequencing and distribution of individual and collaborative activites could shape interaction, coordination and collaboration. The PSI classroom script seems to have benefited the individual inquiry learning while the PIS classroom script has brought about better performance in collaborative inquiry learning. Perhaps a plenary-individual-small group-individual (PISI) classroom script might benefit both the individual inquiry learning and the collaborative inquiry, where the individuals are given the platform to re-work through one's think processes after emerging from the individual and small group activites. Future studies may also need to investigate how individuals and groups of individuals learn in outdoor science inquiry and the implications for classroom orchestration.

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Tables

Figures

Appendix

A. Worksheets for Students in the PSI Classroom Script

Note:
1. The content of the worksheets for the PIS classroom script is exactly the same as for PSI, hence, only the worksheets for the PSI classroom script is featured. The only difference is the change in German dependent possessive pronouns for Du und Ihr depending on the script sequence of individual and small group activities.
2. Owing to space constraints in the appendix, the boxes provided for students' response is reduced to two to three.

Das Energie-Rätsel (PSI)

AUDIO / ACTIVITY CODE [ ]

Willkommen!

Diese Unterrichtseinheit dreht sich um eine große Frage:

Wie produzieren Pflanzen unter unterschiedlichen Lebensbedingungen Nahrung?

Um diese Frage beantworten zu können, werdet Ihr Euch drei rätselhafte Phänomene genauer ansehen:

- Rätsel 1: **Pflanzen in der Dunkelheit**
- Rätsel 2: **Pflanzen im tropischen Regenwald**
- Rätsel 3: **Kakteen in trockenen Umgebungen**

Dabei sollt Ihr lernen…

- **…wie Pflanzen sich ernähren (Fotosynthese)**
- **…wie Pflanzen die Nahrung nutzen (Zellatmung)**

Denkt wie ein Forscher!

Um die drei Rätsel zu lösen, sollt Ihr versuchen, wie Forscher vorzugehen. Forscher handeln wie Detektive, wenn sie versuchen, Fragen über die Welt zu beantworten.

Was genau machen erfolgreiche Forscher? Sie:

- **Stellen Fragen und entwickeln Hypothesen:** Fragt Euch, (a) was Ihr wisst, (b) was Ihr nicht wisst und überlegt Euch (c) Fragen, auf die Ihr Antworten haben wollt.

- **entwickeln einen Plan zur Datensammlung:** Überlegt Euch genau, wie Ihr vorgeht, um Eure Hypothese zu überprüfen. Ein guter Plan hilft Euch dabei, Euch auf relevante Beobachtungen zu konzentrieren und unwichtige Beobachtungen außer Acht zu lassen.

- **sammeln, analysieren und interpretieren Daten:** Das Beobachten und das Sammeln von Daten ist die Grundlage für die Untersuchung Eurer Hypothesen.

- **verwenden die Daten, um zu wissenschaftlichen Antworten auf Ihre Fragen zu kommen:** Achtet darauf, dass Eure Erklärungen auf Euren Daten und Beobachtungen basieren und Eure Schlussfolgerungen nachvollziehbar sind.

Drei rätselhafte Phänomene…

Ihr habt gelernt, dass Pflanzen drei wesentliche Elemente benötigen, um Nahrung zu produzieren und zu wachsen: Sonnenlicht, Wasser und Luft.

Ihr sollt nun versuchen, eine **wissenschaftliche Erklärung für drei rätselhafte Phänomene** zu entwickeln. Um diese Rätsel lösen zu können, müsst Ihr ähnlich wie ein Forscher vorgehen.

Die große Frage für die drei Rätsel ist:

Wie produzieren Pflanzen in unterschiedlichen Lebensbedingungen Nahrung?

- Rätsel 1: **Pflanzen in der Dunkelheit**
- Rätsel 2: **Pflanzen im tropischen Regenwald**
- Rätsel 3: **Kakteen in trockenen Umgebungen**

✓ Jedes Rätsel kann **mit den Belegen und Ideen erklärt werden,** die in dieser Lerneinheit enthalten sind.

✓ **Für jedes Rätsel** werdet Ihr einige **Hinweise bekommen.**

Das Energie-Rätsel. Los geht's!

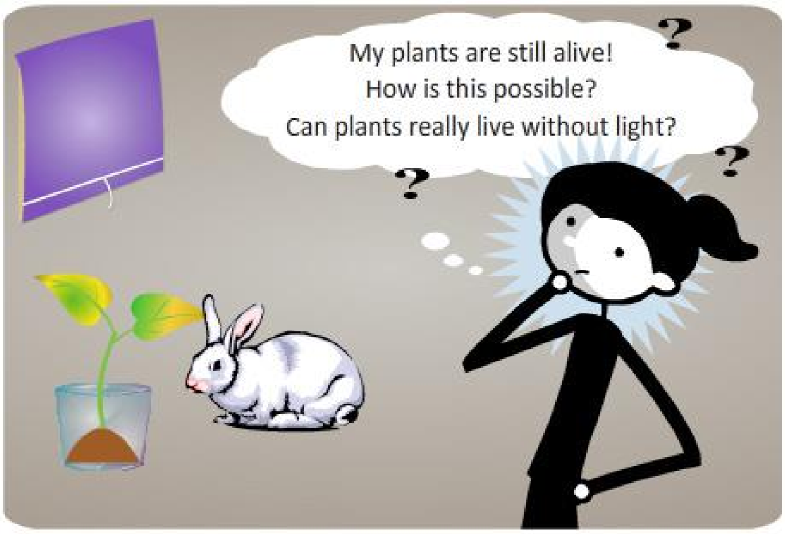
Rätsel 1: Pflanzen in der Dunkelheit

Maria will wissen, wie ihre Pflanzen in der Dunkelheit einige Tage überleben konnten.

Wie ist das möglich?

Können Pflanzen wirklich ohne Licht leben?

Wie produzieren Pflanzen im Dunkeln Nahrung?



Rätsel 1: Eure Hypothese

Warum hat Marias Pflanze in der Dunkelheit überlebt?

Um eine Hypothese aufzustellen, müsst Ihr Euch über die folgenden Fragen Gedanken machen:

Was wissen wir bereits über Pflanzenteile und darüber, was Pflanzen brauchen, um Nahrung herzustellen?

Wozu haben wir noch Fragen?

Was wollen wir herausfinden?

Was wir bereits wissen ...	**Wir haben Fragen zu ...**	**Was wir herausfinden wollen…**

Eine Hypothese ist eine Idee oder eine Vermutung darüber, wie bestimmte Dinge funktionieren.

Eine Hypothese kann mit Hilfe von Beobachtungen oder Experimenten überprüft werden.

Schreibt Eure Hypothese, warum Marias Pflanze ohne Licht für ein paar Tage überlebt hat, in den Kasten.

Rätsel 1: Euer Untersuchungsplan

Um Eure Hypothese überprüfen zu können, müsst Ihr Daten sammeln, die euch helfen, zu erklären, warum Marias Pflanze im Dunkeln überlebt hat. Diese Daten können von unterschiedlicher Art sein.

Wählt mindestens drei *Datentypen aus, von denen Ihr denkt, dass sie als Belege für Eure Hypothese verwendet werden können.

** Datentypen:*
Beobachtungen z. B. Menge von Sonnenlicht
Messungen z. B. Raumtemperatur
Foto
Zeichnungen
Kurzer Videoclip

Welche Arten von Daten werdet Ihr sammeln?	**Wie werdet Ihr Eure Daten sammeln?**	**Was können die Daten zur Aufklärung des Rätsels beitragen?**

Rätsel 2: Pflanzen im tropischen Regenwald

Konkurrenten um Sonnenlicht!

Drei wichtige Informationen, die Ihr über Pflanzen in tropischen Regenwäldern wissen solltet:

- Sie sind in der Lage unter sehr heißen und feuchten Bedingungen zu überleben. Die monatlichen Durchschnittstemperaturen sind das ganze Jahr über höher als 18°C und die Regenmenge liegt bei mindestens 168 cm pro Jahr und kann 1000 cm überschreiten (in Mitteleuropa: 40 – 80 cm pro Jahr).
- Sie konkurrieren miteinander um Nahrung und Sonnenlicht. Das erklärt, warum einige Pflanzen, die in Regenwäldern wachsen, wirklich groß sind und andere Pflanzen auf ihren Zweigen leben.
- Viele Blätter im tropischen Regenwald haben eine Abtropfspitze, die es ermöglicht, dass Regenwasser schnell abläuft.

Das Rätsel der Pflanzen des tropischen Regenwaldes

Ihr habt gelernt, dass Pflanzen drei Elemente benötigen, um ihre eigene Nahrung herzustellen: Sonnenlicht, Wasser und Luft.

Eure Aufgabe ist, zu untersuchen, wie Pflanzen im tropischen Regenwald ihre eigene Nahrung produzieren:

- Wie erhalten sie die richtige Menge an Sonnenlicht und Wasser?
- Wo und wie bekommen sie Nährstoffe?
- Wo und wann findet Fotosynthese statt?

Hier sind einige Pflanzenarten aus den tropischen Regenwäldern, die ihr im Botanischen Garten München Nymphenburg finden werdet. Für Eure Forschung sollt Ihr Euch eine davon aussuchen.

Kletterpflanzen

- verwenden andere Bäume und Pflanzen, um an ihnen nach oben zu klettern
- verwenden das Meiste ihrer Wachstumsenergie, um nach oben zu wachsen
- haben breite Gefäße, um große Wasservolumen zu fassen

Grandleaf Seagrape (Eve's Umbrella)

- kann 24 Meter Höhe erreichen
- hat sehr große Blätter
- bevorzugt Schatten

Bambuspflanze

- am schnellsten wachsende Pflanze der Erde
- holziger Bambus ist resistent gegen Kälte und Frost
- Stängel sind hohl

Orchideen

- entnehmen Nährstoffe aus der Luft oder aus fallendem Regen
- haben besondere Strukturen, um Wasser zu speichern
- Wurzeln nehmen Wasser und Nährstoffe schnell auf

Geweihfarn

- hat zwei Arten von Blättern
- hat sternförmige Haare, um Feuchtigkeit zu speichern
- seine Wurzeln wachsen sowohl aus dem Stamm als auch aus den Ästen

Rätsel 2: Unsere Hypothese

Wie können Regenwaldpflanzen unter derart warmen und feuchten Lebensbedingungen überleben?

Um eine Hypothese aufzustellen, müsst Ihr Euch über die folgenden Fragen Gedanken machen:

Was wissen wir bereits über Pflanzenteile und darüber, was Pflanzen brauchen, um Nahrung herzustellen?

Wozu haben wir noch Fragen?

Was wollen wir herausfinden?

Was wir bereits wissen ...	Wir haben Fragen zu ...	Was wir herausfinden wollen …

Eine Hypothese ist eine Idee oder eine Vermutung dazu, wie Dinge funktionieren.

Eine Hypothese kann durch Beobachtungen oder Experimente überprüft werden.

Schreibt Eure Hypothese, wie die tropische Regenwaldpflanze (die Ihr Euch ausgesucht habt) Nahrung produziert, in den Kasten.

Rätsel 2: Unser Untersuchungsplan 😎

Um erklären zu können, wie Eure Regenwaldpflanze Nahrung produziert, müsst Ihr Daten sammeln.

Wählt mindestens drei *Datentypen von denen Ihr denkt, dass sie als Belege für Eure Hypothese verwendet werden können.

* *Datentypen:*
Beobachtungen z. B. Menge von Sonnenlicht
Messungen z. B. Raumtemperatur
Foto
Zeichnungen
Kurzer Videoclip

Welche Arten von Daten werdet Ihr sammeln?	Wie werdet Ihr Eure Daten sammeln?	Was können die Daten zur Aufklärung des Rätsels beitragen?

Rätsel 3: Pflanzen in trockenen Umgebungen

Kakteen in verschiedenen Formen und Größen

Drei wichtige Informationen, die Du **über Kakteen** (Plural für Kaktus) wissen solltest:

- Die meisten Kakteen leben in extrem trockener Umgebung und sind in der Lage, Wasser zu speichern.
- Die häufigsten Kakteen sind Stammsukkulenten. Diese haben dicke grüne Stängel.
- Kakteen machen Fotosynthese in der Nacht, um den Wasserverlust zu verringern.

Das Rätsel der Kakteen

Du hast gelernt, dass Pflanzen drei Elemente benötigen, um ihre eigene Nahrung herzustellen: Sonnenlicht, Wasser und Luft.

Deine Aufgabe ist, zu untersuchen, wie Kakteen in extrem trockenen Gegenden ihre Nahrung herstellen:

- Wo speichern sie Wasser?
- Wie bekommen sie die richtige Menge an Sonnenlicht?
- Wo und wann findet Fotosynthese in "blattlosen" Pflanzen wie Kakteen statt?

Hier sind einige Kakteen, die Du im Botanischen Garten München-Nymphenburg finden wirst. Für Deine Forschung sollst Du Dir einen davon aussuchen.

		
Kugelkaktus ▪ tolerant gegenüber Trockenheit ▪ gerundeter Körper in vollständigem Kontakt zum Boden ▪ dicker äußerer Schaft reduziert Wasserverlust	**Weißhaarige Kaktus** ▪ sehr wetterbeständig ▪ die Haare dienen als Verdunstungsschutz und um Tau oder Nebel aufzufangen. ▪ braucht wenig Wasser	**Stacheliger Bär - Kaktus** ▪ Nähe zum Boden ▪ Stacheln und Borsten als Abwehrmechanismus gegen Tiere ▪ verbreitet sich schnell ▪ flache & faserige Wurzeln

Rätsel 3: Meine Hypothese

Um eine Hypothese darüber aufzustellen, wie Kakteen überleben können, musst Du Dir zu den folgenden Fragen Gedanken machen:

Was weiß ich bereits über Pflanzenteile und darüber, was Pflanzen brauchen, um Nahrung herzustellen?

Wozu habe ich noch Fragen?

Was möchte ich herausfinden?

Was ich bereits weiß ...	**Ich habe Fragen zu ...**	**Was ich herausfinden möchte…**

Eine Hypothese ist eine Idee oder eine Vermutung darüber, wie bestimmte Dinge funktionieren.

Eine Hypothese kann mit Hilfe von Beobachtungen oder Experimenten überprüft werden.

Schreibe Deine Hypothese, wie ein Kaktus Nahrung produziert, in den Kasten.

Rätsel 3: Mein Untersuchungsplan

Um erklären zu können, wie Dein Kaktus Nahrung in extrem trockener Umgebung produziert, musst Du Daten sammeln.

Wähle mindestens drei *Datentypen aus, von denen Du denkst, dass sie als Belege für Deine Hypothese verwendet werden können.

** Datentypen:*
Beobachtungen z. B. Menge von Sonnenlicht
Messungen z. B. Raumtemperatur
Foto
Zeichnungen
Kurzer Videoclip

Welche Arten von Daten wirst Du sammeln?	**Wie wirst Du Deine Daten sammeln?**	**Was können die Daten zur Aufklärung des Rätsels beitragen?**

Aktivität 4: Forscher auf Mission!

Los Geht's!!!

Jetzt kannst Du mit Deinen Forschungen beginnen!

Denke daran:

- Sammle Ideen und Belege, um Deine Hypothese zu testen.
- Entwickle eine überzeugende Erklärung für Deine Hypothese. Am Ende der Einheit sollst Du eine Erklärung für das zweite und das dritte Rätsel haben und in der Klasse vorstellen.

Rätsel 1: Unsere Ideen und Belege

Entwickelt jetzt mindestens fünf Ideen zum Rätsel „Pflanzen in der Dunkelheit“ und schreibt sie in die Tabelle.

Hier sind einige Fragen, die Euch dabei helfen sollen:

- Was bedeutet "Leben im Dunkeln" für Euch?
- Welche Beobachtungen habt Ihr in Bezug zu Pflanzen gemacht, die für ein paar Tage in der Dunkelheit leben?
- Warum können Pflanzen einige Tage ohne Sonnenlicht überleben?
- Welche Ideen oder Erklärungen zu der Frage, warum Pflanzen in der Dunkelheit überleben können, habt Ihr während Euren Forschungen entwickelt, und welche Ideen oder Erklärungen habt Ihr von Freunden, Familienmitgliedern, Lehrern oder Experten gehört?

Nummer	Unsere Ideen und Belege	Quelle	√, ‘X’, ‘?’

Rätsel 1: Ideen und Belege ordnen

Schaut Euch die Ideen und Belege noch mal an, die Ihr in die Tabelle geschrieben habt:

- Welche davon sind hilfreich für die Entwicklung einer Erklärung, warum Marias Pflanzen in der Dunkelheit überlebt haben?
- Welche Ideen und Belege sind nicht hilfreich?
- Bei welchen Ideen und Belegen seid Ihr unsicher, ob sie Eure Hypothese unterstützen?

Ordnet Eure Ideen und Belege in der Tabelle: Verwendet ein **Häkchen '√' für relevante** Ideen, ein **Kreuz 'X' für irrelevante** Ideen und **ein Fragezeichen '?'** für Ideen und Belege, bei denen Ihr Euch unsicher seid!

Rätsel 2: Unsere Ideen und Belege

Entwickelt jetzt mindestens fünf Ideen zum Rätsel „Pflanzen im tropischen Regenwald" und schreibt sie in die Tabelle.

Hier sind einige Fragen, die Euch dabei helfen sollen:

- Welche Beobachtungen habt Ihr bei der von euch ausgesuchten Regenwaldpflanze gemacht?
- Hat Eure Pflanze irgendwelche Besonderheiten, was ihre Bestandteile (z.B. Stamm, Blätter, Wurzeln) angeht und was sind deren Funktionen?
- Was meint Ihr, wie tropische Regenwaldpflanzen genug Sonnenlicht und die richtige Menge an Wasser bekommen, um Nahrung zu produzieren?
- Welche Ideen oder Erklärungen zu der Frage, wie Pflanzen im tropischen Regenwald überleben können, habt Ihr während Euren Forschungen entwickelt, und welche Ideen oder Erklärungen habt Ihr von Freunden, Familienmitgliedern, Lehrern oder Experten gehört?

Nummer	Unsere Ideen und Belege	Quelle	√, 'X', '?'

Rätsel 2: Ideen und Belege ordnen

Schaut Euch die Ideen und Belege noch mal an, die Ihr in die Tabelle geschrieben habt:

- Welche davon sind hilfreich für die Entwicklung einer Erklärung, warum Eure Pflanze genug Sonnenlicht und die richtige Menge an Wasser bekommt, um Nahrung zu produzieren?
- Welche Ideen und Belege sind nicht hilfreich?
- Bei welchen Ideen und Belegen seid Ihr unsicher, ob sie Eure Hypothese unterstützen.

Ordnet Eure Ideen und Belege in der Tabelle: Verwendet ein **Häkchen '√' für relevante** Ideen, ein **Kreuz 'X' für irrelevante** Ideen und **ein Fragezeichen '?'** für Ideen und Belege, bei denen Ihr Euch unsicher seid!

Rätsel 3: Meine Ideen und Belege

Entwickle jetzt mindestens fünf Ideen zum Rätsel „Kakteen in trockenen Umgebungen“ und schreibe sie in die Tabelle.

Hier sind einige Fragen, die Dir dabei helfen sollen:

- Welche Beobachtungen hast Du bei dem von Dir ausgesuchten Kaktus gemacht?
- Hat der Kaktus irgendwelche Besonderheiten, was seine Bestandteile (z.B. Stamm, Blätter, Wurzeln) angeht und was sind deren Funktionen?
- Was meinst Du, wie der Kaktus genug Sonnenlicht und die richtige Menge an Wasser bekommt, um Nahrung zu produzieren?
- Welche Ideen oder Erklärungen zu der Frage, wie Kakteen in extrem trockenen Umgebungen überleben können, hast Du während Deinen Forschungen entwickelt, und welche Ideen oder Erklärungen hast Du von Freunden, Familienmitgliedern, Lehrern oder Experten gehört?

Nummer	Meine Ideen und Belege	Quelle	√, ‘X’, ‘?’

Rätsel 3: Ideen und Belege ordnen

Schaue Dir die Ideen und Belege noch mal an, die Du in die Tabelle geschrieben hast:

- Welche davon sind hilfreich für die Entwicklung einer Erklärung, wie der von Dir untersuchte Kaktus genug Sonnenlicht und die richtige Menge an Wasser bekommt, um Nahrung zu produzieren?
- Welche Ideen und Belege sind nicht hilfreich?
- Bei welchen Ideen und Belegen bist Du Dir unsicher, ob sie Deine Hypothese unterstützen.

Ordne Deine Ideen und Belege in der Tabelle: Verwende ein **Häkchen '√' für relevante** Ideen, ein **Kreuz 'X' für irrelevante** Ideen und **ein Fragezeichen '?'** für Ideen und Belege, bei denen Du Dir unsicher bist!

Aktivität 5: Des Rätsels Lösung

Rätsel 1: Pflanzen in der Dunkelheit: Was ist Eure Lösung?

Rätsel 1: Was ist Eure wissenschaftliche Erklärung für das Rätsel „Pflanzen in der Dunkelheit“?

Es ist Zeit, das Rätsel zu lösen, wie Marias Pflanze in der Dunkelheit für ein paar Tage überleben konnte. Nutzt die Tabelle, um Eure Behauptung(en), Beleg(e) und Begründung(en) zu notieren.

Behauptung(en)	Beleg(e)	Begründung(en)
z. B. Ein Tiefdruckgebiet bringt meistens schlechtes Wetter.	z.B. Letzte Woche lag ein Tiefdruckgebiet über Deutschland, und es hat bei uns viel geregnet.“	z. B. In Tiefdruckgebieten steigt die warme Luft nach oben und kühlt dabei ab – irgendwann erreicht sie eine Höhe, in der die Luft kondensiert, sich Wolken bilden und dann abregnen.“

Verwendet Eure Behauptung(en), Beleg(e) und Begründung(en) aus der Tabelle, um eine wissenschaftliche Erklärung zu konstruieren, warum Marias Pflanze in der Dunkelheit für ein paar Tage überlebt hat. Fügt diese in den Kasten unten ein.

Rätsel 2: Pflanzen im tropischen Regenwald: Was ist Eure Lösung?

Rätsel 2: Was ist Eure wissenschaftliche Erklärung für das Rätsel „Pflanzen im tropischen Regenwald“?

Es ist Zeit, das Rätsel zu lösen, wie die tropische Regenwaldpflanze, die Ihr Euch ausgesucht habt, in heißen, feuchten und nassen Lebensbedingungen Nahrung produziert. Nutzt die Tabelle, um Eure Behauptung(en), Beleg(e) und Begründung(en) zu notieren.

Behauptung(en)	Beleg(e)	Begründung(en)
z. B. Ein Tiefdruckgebiet bringt meistens schlechtes Wetter.	z. B. Letzte Woche lag ein Tiefdruckgebiet über Deutschland, und es hat bei uns viel geregnet.“	z. B. In Tiefdruckgebieten steigt die warme Luft nach oben und kühlt dabei ab – irgendwann erreicht sie eine Höhe, in der die Luft kondensiert, sich Wolken bilden und dann abregnen.“

Verwendet Eure Behauptung(en), Beleg(e) und Begründung(en) aus der Tabelle, um eine wissenschaftliche Erklärung zu konstruieren, wie Pflanzen im tropischen Regenwald genügend Sonnenlicht und die richtige Menge an Wasser bekommen, die sie zum Überleben benötigen. Fügt diese in den Kasten unten ein.

Rätsel 3: Kakteen in trockenen Umgebungen: Was ist Deine Lösung?

Rätsel 3: Was ist Deine wissenschaftliche Erklärung für das Rätsel „Kakteen in trockenen Umgebungen“?

Es ist Zeit, das Rätsel zu lösen, wie der Kaktus, den Du ausgewählt hast, in trockenen Umgebungen die richtige Menge an Sonnenlicht und genügend Wasser bekommt, um Nahrung zu produzieren. Nutze die Tabelle, um Deine Behauptung(en), Beleg(e) und Begründung(en) zu notieren.

Behauptung(en)	**Beleg(e)**	**Begründung(en)**
z. B. Ein Tiefdruckgebiet bringt meistens schlechtes Wetter.	z. B. Letzte Woche lag ein Tiefdruckgebiet über Deutschland, und es hat bei uns viel geregnet.“	z. B. In Tiefdruckgebieten steigt die warme Luft nach oben und kühlt dabei ab – irgendwann erreicht sie eine Höhe, in der die Luft kondensiert, sich Wolken bilden und dann abregnen.“

Verwende Deine Behauptung(en), Beleg(e) und Begründung(en) aus der Tabelle, um eine wissenschaftliche Erklärung zu konstruieren, warum Dein Kaktus in trockener Umgebung überleben kann. Füge diese in den Kasten unten ein.

Super! Du hast das Energie-Rätsel erfolgreich abgeschlossen! 

B. Pre- and Post Domain-Specific Knowledge Test on Photosynthesis and Cell Respiration

AUDIO / ACTIVITY CODE:

Im Folgenden würden wir gerne herausfinden, wie viel Du bereits zu den Themen dieser Unterrichtseinheit weißt. Bitte beantworte die folgenden Fragen über Pflanzen und Energie. Kein Problem, wenn Du die Antworten zu einigen Fragen nicht kennst. Versuche einfach, Dein Bestes zu geben und die Fragen nach bestem Wissen zu beantworten.

1. Woher bekommen Pflanzen Energie? Stelle eine wissenschaftliche Vermutung auf und beschreibe sie so genau wie möglich.

2. Welche Art von Energie steckt in der Sonnenstrahlung?
   - o Wärmeenergie
   - o Chemische Energie
   - o Lichtenergie
   - o Infrarot-Strahlung

3. Welche Art von Energie bekommt die Pflanze von der Sonne?
   - o Wärmeenergie
   - o Chemische Energie
   - o Lichtenergie
   - o Infrarot-Strahlung

4.1 Was passiert, wenn Sonnenenergie auf die Pflanzen trifft?
   - o Die Energie wird umgewandelt.
   - o Die Energie wird gespeichert.
   - o Die Energie wird übertragen.
   - o Die Energie verschwindet.

4.2 Bitte begründe deine Antwort:

5.1 Welche Elemente benötigen Pflanzen, um die Nahrung herzustellen, die sie zum Überleben brauchen?

5.2 Welche Rolle spielt Kohlendioxid bei der Fotosynthese und der Zellatmung?

5.3 Welche Rolle spielt Sauerstoff bei der Fotosynthese und der Zellatmung?

6. Bitte setze im Folgenden die fehlenden Begriffe ein.

Bei der Fotosynthese wird die ________ in ________ Energie umgewandelt und in ________-Molekülen gespeichert.

7.1 Welche beiden Stoffe nehmen Pflanzen für die Fotosynthese auf?

- o Sauerstoff
- o Kohlendioxid
- o Glukose
- o Wasser
- o Lichtenergie

7.2 Welche beiden Stoffe geben Pflanzen im Prozess der Fotosynthese ab?

- o Sauerstoff
- o Kohlendioxid
- o Glukose
- o Wasser
- o Lichtenergie

7.3 Welche beiden Stoffe nehmen Pflanzen für die Zellatmung auf:

- o Sauerstoff
- o Kohlendioxid
- o Glukose
- o Wasser
- o Lichtenergie

7.4 Welche beiden Stoffe geben Pflanzen im Prozess der Zellatmung ab:

- o Sauerstoff
- o Kohlendioxid
- o Glukose
- o Wasser
- o Lichtenergie

C. Pre-Test Inquiry Task (Individual and Group)

AUDIO / ACTIVITY CODE:

8. Das Wasser-Rätsel
8.1 Wasser und Pflanzenwachstum

Wie viel Wasser ist genug für meine Pflanzen?

Du wusstest bestimmt, dass die Wassermenge, die Pflanzen erhalten, ihr Wachstum beeinflusst.

Drei wichtige Informationen über **Pflanzenwachstum und Wasser**:

Die Wassermenge, die für das Wachstum einer Pflanzen notwendig ist, ist abhängig von:

- der Erde, auf der die Pflanze wächst,
- der Größe des Topfes und
- der Art und dem Alter der Pflanze.

Stelle Dir vor, Du sollst untersuchen, wie sich unterschiedliche Mengen von Wasser auf das Wachstum einer Bohnenpflanze auswirken. Um diese Frage beantworten zu können, musst du einen Untersuchungsplan entwickeln.

Forschungsfrage: Wie viel Wasser ist am besten für das Wachstum von Bohnenpflanzen?

Bitte beschreibe in dem Textfeld **SO GENAU WIE MÖGLICH**, wie Du vorgehen würdest, um diese Forschungsfrage zu untersuchen.

GROUP CODE:

(Alle Mitglieder in der Gruppe)

8.2 Unser Untersuchungsplan

1. Bitte gehe nun mit Deinen anderen Gruppenmitgliedern zusammen und diskutiert Eure Vorschläge bezüglich der Frage, wie man die Forschungsfrage „Wie viel Wasser ist am besten für das Wachstum von Bohnenpflanzen?“ untersuchen könnte.

2. Haltet im Kasten unten Euren gemeinsamen Untersuchungsplan SO GENAU WIE MÖGLICH fest.

D. Post-Test Inquiry Task (Individual and Group)

AUDIO/ ACTIVITY CODE:

8. Das Licht-Rätsel
Zum Abschluss erhältst du noch ein weiteres Rätsel. Für dieses Rätsel sollst du dir zuerst alleine einen Untersuchungsplan überlegen. Danach sollst du wieder zurück in deine Kleingruppe gehen, wo ihr eure verschiedenen Untersuchungspläne diskutieren und euch auf einen Plan einigen sollt.

8.1 Licht und Pflanzenwachstum

In welche Richtung sollen Pflanzen wachsen?

Drei wichtige Informationen über den Zusammenhang zwischen Pflanzenwachstum und Licht:

- Licht liefert die Energie zum Wachsen und dafür, dass Pflanzen Photosynthese betreiben können.
- Menge, Farbe und Richtung des Lichts beeinflussen das Pflanzenwachstum.
- Blätter nutzen nur drei Farben aus dem Spektrum des Sonnenlichts: rot, blau und gelb.

Im Licht-Rätsel soll untersucht werden, wie sich die verschiedenen Farben des Lichts auf das Wachstum einer Bohnenpflanze auswirken. Hierzu sollst du ein Experiment planen.

Forschungsfrage: Welche Lichtfarbe ist am besten für das Wachstum der Bohnepflanze?

Bitte beschreibe in dem Textfeld SO GENAU WIE MÖGLICH, wie Du vorgehen würdest, um diese Forschungsfrage zu untersuchen.

GROUP CODE:

(Alle Mitglieder in der Gruppe)

8.2 Unser Untersuchungsplan

Forschungsfrage: Welche Lichtfarbe ist am besten für das Wachstum von Bohnenpflanzen?

1. Bitte gehe nun wieder zurück in Deine Gruppe. Diskutiert dort Eure Vorschläge bezüglich der Frage, wie man die Forschungsfrage „Welche Lichtfarbe ist am besten für das Wachstum von Bohnenpflanzen?“ untersuchen könnte.

2. Haltet im Kasten unten Euren gemeinsamen Untersuchungsplan SO GENAU WIE MÖGLICH fest.

E. Scoring Rubric for Pre-Post Inquiry Tests (Individual and Group)

Scoring Elements	Does not reach a standard described by any of the descriptors given below.	Not Yet		Approaches Expectations		Meets Expectations
	0	1	1.5	2	2.5	3

Scoring Elements	Not Yet	Approaches Expectations	Meets Expectations
Aim of the Experiment and Development of Hypothesis	Attempts to define the purpose of the investigation but no mention of a testable testable hypothesis. OR An idea is proposed but it is not stated as a hypothesis that is testable and can guide investigation.	Defines the correct purpose of the investigation based on the problem and provides a hypothesis but this is not fully developed.	Defines the purpose of the investigation based on the problem and formulates a testable hypothesis and is directly to the subject of study.
Identifying Variables	Attempts to identify the variables but these are incomplete or not fully developed.	The student identifies 2 correct variables from any of the variables used in the experiment (Independent, Dependent, or Controlled)	The student identifies all correct variables used in the experiment (Independent, Dependent and Controlled)
Discussion of Methods /Procedure	A discussion of methods /procedure is provided but the proposed methods will not allow investigators to engage their question (i.e., no link between methods and hypothesis/ question).	A discussion of methods/ procedure is provided and the methods discussed are related to the proposed question. However, the discussion might not be entirely clear. In addition, various details necessary to investigating the hypothesis/ question may have been left out.	A detailed discussion of methods/ procedure is provided and the discussion is entirely clear. Most if not all details necessary to investigating the hypothesis/ question have been included.

F. Pre-test on Interest in Domain Knowledge, Learning with Media and Learning with Others

	1 stimme überhaupt nicht zu	**2** stimmt eher nicht	**3** teils – teils	**4** stimmt eher	**5** stimme vollständig zu
1. Ich lerne gerne mit anderen zusammen.	☐	☐	☐	☐	☐
2. Ich lerne gerne mit digitalen Medien (Computer, Internet).	☐	☐	☐	☐	☐
3. Ich interessiere mich für naturwissenschaftliche Fragen.	☐	☐	☐	☐	☐
4. Mich interessieren Diskussionen über wissenschaftliche Themen.	☐	☐	☐	☐	☐
5. Ich finde Biologie interessant.	☐	☐	☐	☐	☐
6. Ich interessiere mich für Fotosynthese.	☐	☐	☐	☐	☐
7. Ich interessiere mich dafür, wie Pflanzen an verschiedenen Standorten überleben.	☐	☐	☐	☐	☐
8. Es ist mir wichtig zu wissen, wie Pflanzen an verschiedenen Standorten Energie produzieren und speichern (z. B Wüstenpflanzen, Pflanzen im tropischen Regenwald).	☐	☐	☐	☐	☐
9. Es ist mir wichtig zu wissen, wie und warum Pflanzen die Luft reinigen können.	☐	☐	☐	☐	☐
10. Ich bin daran interessiert, etwas zur Wirkung von Wasserqualität und Wassermenge auf das Pflanzenwachstum zu lernen.	☐	☐	☐	☐	☐
11. Ich bin daran interessiert, etwas über die Wirkung der Menge von Sonnenlicht auf das Pflanzenwachstum zu lernen.	☐	☐	☐	☐	☐

	1 stimme überhaupt nicht zu	**2** stimmt eher nicht	**3** teils – teils	**4** stimmt eher	**5** stimme vollständig zu
12. Ich würde gerne mehr über den Treibhauseffekt erfahren und lernen, wie Sonnenenergie durch das Glas hindurchgeht und von Pflanzen, der Erde und andere Objekte im Gewächshaus absorbiert wird.	☐	☐	☐	☐	☐
13. Ich bin daran interessiert, die Auswirkungen des Klimawandels auf Pflanzen zu verstehen.	☐	☐	☐	☐	☐
14. Es macht mir Spaß, mit anderen über gesellschaftliche Fragen mit naturwissenschaftlichem Hintergrund (z. B. Klimawandel) zu diskutieren.	☐	☐	☐	☐	☐
15. Ich möchte meine Argumente und wissenschaftlichen Erklärungen zu wissenschaftliche Themen verbessern.	☐	☐	☐	☐	☐

G. Pre-test on Metacognitive Awareness

	1 stimme überhaupt nicht	2 stimmt eher nicht	3 teils – teils	4 stimmt eher	5 stimme vollständig zu
1. Um meine Ziele für jede Aufgabe am besten zu erreichen, organisiere ich meine Zeit.	☐	☐	☐	☐	☐
2. In Gruppenarbeiten gebe ich meistens das Tempo an.	☐	☐	☐	☐	☐
3. Während der Aufgabenbearbeitung frage ich mich selbst, ob mein Vorgehen gut ist.	☐	☐	☐	☐	☐
4. Wenn ich eine Aufgabe/ ein Problem bearbeite, überwache ich von Zeit zu Zeit meinen Fortschritt und überprüfe, ob ich meine Ziele erfüllen werde.	☐	☐	☐	☐	☐
5. Nachdem ich eine Aufgabe abgeschlossen habe, frage ich mich, ob ich meine Lernziele erreicht habe.	☐	☐	☐	☐	☐
6. Nach einer Aufgabe weiß ich, wie gut ich sie geschafft habe.	☐	☐	☐	☐	☐
7. Normalerweise setze ich mir spezifische Ziele, bevor ich eine neue Aufgabe beginne.	☐	☐	☐	☐	☐
8. Wenn ich eine Aufgabe/ein Problem bearbeite, frage ich mich, ob ich alle möglichen Optionen in Betracht gezogen habe, um die Aufgabe/das Problem zu lösen.	☐	☐	☐	☐	☐
9. Nachdem ich eine Aufgabe abgeschlossen habe, frage ich mich, ob es einen besseren Ansatz gegeben hätte, um sie zu lösen.	☐	☐	☐	☐	☐

	1 stimme überhaupt nicht	2 stimmt eher nicht	3 teils – teils	4 stimmt eher	5 stimme vollständig zu
10. Nachdem ich ein Problem gelöst habe, frage ich mich, ob ich alle Optionen in Betracht gezogen habe.	☐	☐	☐	☐	☐
11. Während des Lernens denke ich immer wieder über die Nützlichkeit der Strategien nach, die ich anwende.	☐	☐	☐	☐	☐
12. Bevor ich eine Aufgabe beginne, lese ich die Aufgabenstellung und Hinweise aufmerksam durch.	☐	☐	☐	☐	☐
13. Bevor ich mit einer Aufgabe beginne, stelle ich mir meist Fragen zum Lernstoff.	☐	☐	☐	☐	☐
14. Während der Bearbeitung einer Aufgabe denke ich normalerweise immer wieder über die Aufgabenstellung nach, um die wichtigsten Zusammenhänge zu verstehen.	☐	☐	☐	☐	☐
15. Nach einer Aufgabe fasse ich zusammen, was ich gelernt habe.	☐	☐	☐	☐	☐
16. Wenn ich mich mit Aufgaben oder Problemen beschäftige, überlege ich mir meistens mehrere Lösungen und wähle dann die beste aus.	☐	☐	☐	☐	☐

H. Pre-test on Epistemological Beliefs

	1 stimme überhaupt nicht	2 stimmt eher nicht	3 teils – teils	4 stimmt eher	5 stimme vollständig zu
1. Was in Biologiebüchern steht, muss man glauben.	☐	☐	☐	☐	☐
2. Die Ideen für biologische Experimente kommen daher, dass man neugierig ist und darüber nachdenkt, wie etwas funktioniert.	☐	☐	☐	☐	☐
3. Gute Theorien stützen sich auf die Ergebnisse aus vielen verschiedenen Experimenten.	☐	☐	☐	☐	☐
4. Was man in einem Biologielehrbuch liest, ist sicher wahr.	☐	☐	☐	☐	☐
5. In der Biologie ist beinahe alles bekannt; es gibt nicht mehr viel, was man noch herausfinden könnte.	☐	☐	☐	☐	☐
6. Durch neue Entdeckungen kann sich verändern, was Biologen für wahr halten.	☐	☐	☐	☐	☐
7. Manchmal ändern Biologen ihre Meinung darüber, was in ihrem Fach wahr ist.	☐	☐	☐	☐	☐
8. In der Biologie können sich neue Vorstellungen aus den eigenen Fragen und Experimenten entwickeln.	☐	☐	☐	☐	☐

	1 stimme überhaupt nicht	2 stimmt eher nicht	3 teils – teils	4 stimmt eher	5 stimme vollständig zu
9. Es ist wichtig, Experimente mehr als einmal durchzuführen, um Ergebnisse abzusichern.	☐	☐	☐	☐	☐
10. Es gibt nur die eine Lösung, wenn Biologen einmal das Ergebnis eines Experiments gefunden haben.	☐	☐	☐	☐	☐
11. Die wichtigste Aufgabe von Biologen ist die Suche nach einzig richtigen Lösungen.	☐	☐	☐	☐	☐
12. Es gibt manche Fragen in der Biologie, die auch Biologen nicht beantworten können.	☐	☐	☐	☐	☐
13. In der Biologie kann es mehrere Wege geben, um Vorstellungen zu überprüfen.	☐	☐	☐	☐	☐
14. Nur Biologen wissen genau, was in ihrem Fach wahr ist.	☐	☐	☐	☐	☐
15. Einige Vorstellungen in der Biologie sind heute anders als das, was Biologen früher dachten.	☐	☐	☐	☐	☐
16. Es ist wichtig, eine konkrete Vorstellung zu haben, bevor man mit einem Experiment beginnt.	☐	☐	☐	☐	☐
17. Was der Lehrer im Biologie-Unterricht sagt, ist wahr.	☐	☐	☐	☐	☐
18. Biologen stimmen immer darin überein, was in ihrem Fach wahr ist.	☐	☐	☐	☐	☐
19. Manchmal verändern sich die Vorstellungen in der Biologie.	☐	☐	☐	☐	☐

	1 stimme überhaupt nicht	2 stimmt eher nicht	3 teils – teils	4 stimmt eher	5 stimme vollständig zu
20. Gute Ideen in der Biologie können von jedem kommen, nicht nur von Biologen.	☐	☐	☐	☐	☐
21. Was Biologen herausfinden, muss man glauben.	☐	☐	☐	☐	☐
22. Alle Fragen in der Biologie haben genau eine Lösung.	☐	☐	☐	☐	☐
23. Die Vorstellungen in Biologiebüchern verändern sich manchmal.	☐	☐	☐	☐	☐
24. Ein Experiment ist ein guter Weg, um herauszufinden, ob etwas wahr ist.	☐	☐	☐	☐	☐
25. Ein wichtiger Teil der Biologie ist es, Experimente durchzuführen, um neue Ideen zu finden.	☐	☐	☐	☐	☐
26. Das Wissen in der Biologie ist für alle Zeit wahr.	☐	☐	☐	☐	☐