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Relationship between Beliefs of Teachers about and Their Use of Explicit Instruction When Fostering Students' Scientific Inquiry Competencies

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Abstract: An efficient approach to fostering students' scientific inquiry (SI) competencies (e.g., planning investigations) is to combine student engagement in inquiry activities with explicit instruction that addresses corresponding concepts (e.g., the control-of-variables strategy). Despite its effectiveness, explicit instruction on SI-related concepts seems to be rarely employed in science classrooms. As a vital component of professional competence, teachers' beliefs are a potential cause for the rare use of explicit instruction. The aim of this study is to investigate the relationship between teachers' beliefs about the usefulness of explicit instruction as well as their own abilities and teacher performance. In a mixed method approach, the beliefs of $N = 16$ teachers were captured with a questionnaire, while their teaching practice was approximated through a combination of a lesson planning task and a semi-structured interview. Analyses of response patterns, a qualitative content analysis of the planned lessons, and correlation analyses were used to investigate the relationship between beliefs and performance. The findings suggest that beliefs about the usefulness of explicit instruction for fostering SI competencies may be a necessary but not a sufficient condition for its implementation. Furthermore, the results suggest the importance of assessing and investigating teachers' beliefs on a goal-specific level.

Keywords: teachers' beliefs; teacher performance; teaching practice; professional competence; explicit instruction; lesson planning; scientific inquiry competencies

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1. Introduction

Fostering students' competencies for engaging in and reflecting on scientific inquiry (SI) is acknowledged as a central goal of science education in many international standards and policy documents (e.g., [1–4]). SI competencies comprise, for instance, knowledge and abilities necessary to formulate scientific questions and hypotheses, plan and carry out scientific investigations, and analyze and interpret data. An effective approach to fostering SI competencies is to combine student engagement in inquiry activities with instruction in which the conceptual knowledge (e.g., definitions, rules, and strategies) that underlies these activities is elaborated and explained (explicit instruction, e.g., [5–7]). However, evidence also suggests that teachers rarely use explicit instruction for SI competencies in their teaching practice [8–13]. The scarcity of explicit instruction observed in classroom practice may be partially caused by teachers' beliefs about the effectiveness of such instructional approaches as well as their beliefs about their teaching abilities and their scientific abilities related to SI. By investigating this assumption, this paper provides insights into the relationship between teachers' beliefs as an essential element of teachers' professional competence (e.g., [14–16]) and teacher performance.

1.1. Scientific Inquiry and Related Competencies

The term inquiry can have multiple meanings in science education (e.g., [17,18]). Following the terminology outlined by Crawford, we use the term *scientific inquiry* (SI) to refer to the "various ways in which scientists study the natural world" [17] (p. 516). SI is often modelled as an idealized process consisting of several phases, sometimes called as "inquiry cycle" [19] (p. 48). These phases typically comprise inquiry activities such as formulating questions, generating hypotheses, planning and conducting investigations, and analyzing and interpreting data (e.g., [19,20]). Models of SI competencies are often based on an idealized inquiry process as they describe the abilities to engage in and reflect on its phases (e.g., the ability to formulate a scientific question or to plan a scientific investigation; see discussion in [21]). To unfold SI abilities and, thus, act competent, students need procedural knowledge about the rules, strategies, and criteria (i.e., the concepts) underlying these abilities (e.g., [6,22,23]; see also concepts of evidence in [24]). For instance, to plan a meaningful scientific investigation, students need to know what dependent and independent variables are, what the control-of-variables strategy is (e.g., [25]), and how repeated measurements impact the reliability of the collected data. Based on these considerations, *scientific inquiry competencies* can be defined as the procedural knowledge, abilities, and attitudes necessary to engage in and reflect on SI [6,26–28]. It is often argued that, alongside SI competencies, students also require a basic understanding of why carefully designed scientific investigations are a vital element of science (e.g., [22,23,29]). Corresponding epistemic knowledge, abilities, and attitudes can be summarized under the umbrella term nature of science (NOS) competencies (e.g., [30]). Even though SI competencies and NOS competencies are closely related, it is important to note that they are different constructs that comprise different kinds of knowledge: SI competencies, knowing "how scientists produce data", and NOS competencies, "'knowing why' such procedures are necessary" [22] (pp. 190–191; see also [17,23]).

1.2. The Role of Explicit Instruction in Fostering Scientific Inquiry Competencies

It is often assumed that engaging students in inquiry activities first hand contributes to developing their SI competencies (e.g., [22,31]). Empirical evidence suggests that such engagement is particularly effective when it is combined with explicit instruction about the SI concepts underlying the SI competencies students are supposed to develop (e.g., [5–7]). *Explicit instruction on SI* refers to instructional approaches in which the SI concepts students are supposed to learn are stated and explained to them (e.g., [21,32]). Such explications can occur, for instance, in the form of the teacher writing down criteria for meaningful scientific questions on the blackboard or explaining to students verbally what the control-of-variables strategy is and how it can be used when planning an investigation (e.g., [6]). In addition to this core feature, explicit approaches may provide good and bad examples for the application of SI concepts (e.g., examples of controlled and confounding experiments) or tasks that require students to state, elaborate, or reflect on SI concepts (e.g., "Which of the given investigations can be used to answer the research question and *why*?"; e.g., [32]). Explicit instructional approaches can be distinguished from implicit instruction, in which the targeted SI concepts are not explicated but have to be discovered by the students themselves while doing inquiry (e.g., [21,32]). It is important to note that within the boundaries of this definition, explicit instruction can still take many forms, not all of which are equally effective. For instance, just telling students an SI concept once during instruction seems to have no benefits over not telling them the concept at all (e.g., [25]). Conversely, implicit approaches can also be effective under particular circumstances [33]. Nevertheless, empirical evidence, overall, strongly suggests that explicit instruction is more effective than implicit approaches for fostering students' SI competencies (e.g., [5–7]).

Given that explicit instruction on SI is an important element of instruction that seeks to foster students' SI competencies through engagement in inquiry activities, the question arises as to whether such instructional approaches are used in classroom practice. First of all, it is worth noting that classroom observations have repeatedly shown that student engagement in inquiry activities plays an important role in science lessons [9,13,20,34,35]. At the same time, the question of whether inquiry activities are typically accompanied by explicit instruction has so far rarely been systematically investigated. There are, however, some studies that provide initial indications. For instance, Abrahams and Millar [8] analyzed 25 science lessons in the United Kingdom. They observed that "there was almost no discussion in any of the lessons observed of specific points about scientific enquiry in general, or any examples of use by the teacher of students' data to draw out general points about the collection, analysis, and interpretation of empirical data" [8] (p. 1953). Similar observations have also been reported for German classrooms [9–13]. It is important to note that most of these indications come from studies that did not analyze the lessons with a specific focus on explicit instruction. Nevertheless, the reported observations indicate that explicit instruction on SI is rarely used in classroom practice.

In sum, there seems to be a gap between research and practice: while empirical evidence shows that explicit instruction is an effective means to foster students' SI competencies, features of explicit instruction seem to be rarely used in teachers' classroom practice. This gap is particularly interesting, as it can be assumed that explicitly stating and explaining concepts related to science content (SC; e.g., Newton's laws) is a typical element of instruction in science classrooms [11,12,34,36].

1.3. Beliefs as an Element of Teachers' Professional Competence

From a theoretical perspective, science teachers' beliefs about explicit instruction on SI are a potential reason for the rare use of this instructional approach in classroom practice. Alongside professional knowledge, beliefs are assumed to be a vital component of teachers' professional competence (e.g., [14–16]). They can be defined as understandings or assumptions about the world or one's own self that are felt to be true ([37]; see also overview in [38–40]). In distinction to professional knowledge, beliefs are personal truths that only require an individual justification and do not need to be verified or accepted by others (e.g., [37–39,41,42]). For the purpose of this paper, two types of beliefs may be distinguished: *object-related* ("world") and *self-related* ("self") beliefs (e.g., [42,43]). In the context of teaching and learning, object-related beliefs encompass, for instance, beliefs about the usefulness of specific teaching strategies (e.g., explicit instruction, inquiry-based teaching), while self-related beliefs refer to, for instance, beliefs about one's own ability to enact these strategies successfully in the classroom (often referred to as self-efficacy [44]).

In addition to the distinction between object- and self-related beliefs, teachers' beliefs may be systemized based on their level of specificity (e.g., [38,45,46]). Ziepprecht and others [46] propose that science teachers may hold beliefs on a *general level* (e.g., "all good teaching needs to activate students"), on a *subject-specific level* (e.g., "good science teaching needs to . . . "), and on a *goal-specific level* (e.g., "good science teaching to SI needs to . . . "). Empirical findings suggest that beliefs vary between different specificity levels [47] and even between different goals of science education [48–50]. For instance, science teachers believe that they are more able to foster SC competencies than SI competencies [48,49] or that explicit instruction is more important for fostering SC competencies than for SI competencies [49]. It thus seems important to examine teachers' beliefs at the goal-specific level as well.

1.4. The (Potential) Relationship between Teachers' Beliefs and Performance

From a theoretical perspective, beliefs are often assumed to impact teachers' thoughts and actions in multiple ways (e.g., [38–40]). For instance, beliefs may act as filters in the perception and interpretation of a situation or as guides for decision-making and the action itself (e.g., [38,40,51]). This assumption is also reflected in the refined consensus model of pedagogical content knowledge, which positions beliefs as the filters between knowledge and teaching practice, which includes planning, carrying out, and reflecting instruction [52,53]. Similar assumptions regarding the relationship between teachers' beliefs and their instructional practice are described in the teacher-competence-as-continuum model [15,16]. In this model, beliefs are described as personal dispositions, “which underlie [. . .] teachers’ situation-specific cognitive skills such as teachers’ perception, interpretation, and decision-making, which in turn give rise to observed teacher performance” [15] (p. 785; see Figure 1). It is important to note that this notion of teacher performance is not limited to actual classroom practice, but comprises other additional observable behavior related to teaching (e.g., the planning of and the reflection on instruction) [52]. Furthermore, while the planning of or reflection on instruction is sometimes used as a means to draw conclusions regarding latent variables such as teachers’ dispositions (e.g., regarding pedagogical knowledge in [54]), these activities may also be understood as stand-alone aspects of competence [55,56].

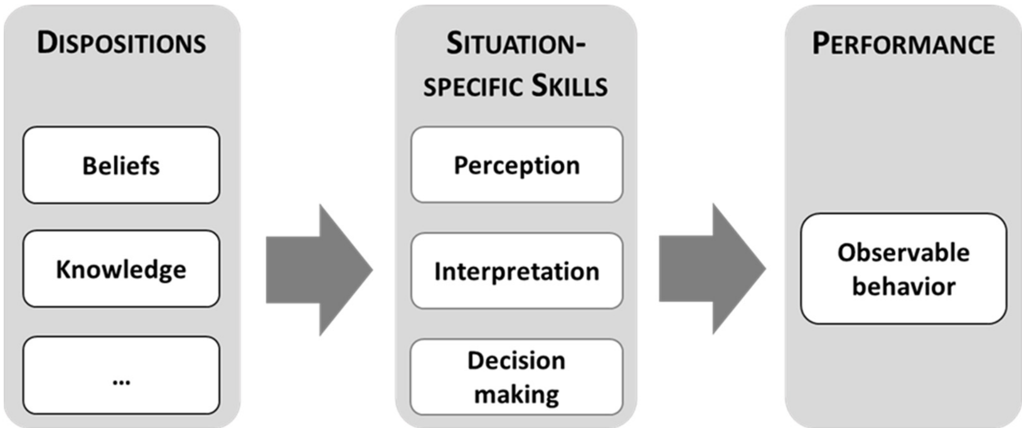

Figure 1. Teacher-competence-as-continuum model (based on [15]).

The empirical investigation of the relationship between beliefs of science teachers and their performance so far mainly addressed beliefs on a general (e.g., [57]) or a subject-specific level (e.g., [58–61]). Even though teachers’ beliefs are typically not assessed on a goal-specific level, there are some exceptions. For instance, Enzingmüller and Prechtl [62] investigated the relationship between teachers’ beliefs and performance in the context of teaching the construction of graphs, which can be assumed to be a part of SI competencies. They found that teachers’ goal-specific beliefs about the usefulness of explicit instruction and their beliefs about their teaching abilities are related to teachers’ use of graphs in classroom practice. Similar findings were reported by Lederman and colleagues, who investigated the relationship between beliefs and performance in the context of teaching the NOS: their studies suggest that teachers’ goal-specific beliefs about teaching and learning of NOS, about their scientific abilities related to NOS, and about their abilities to teach NOS impact their use of explicit instruction on NOS [63–67].

In summary, theoretical considerations and empirical findings support the assumption that teachers’ object-related beliefs about teaching and learning of SI and their self-related beliefs regarding their ability to teach and perform SI impact their implementation of explicit instruction on SI in their science teaching. Nevertheless, this assumption needs to be examined more thoroughly for multiple reasons: first, while it has to be assumed that beliefs vary between specificity levels [47], teachers’ beliefs are rarely investigated at the goal-specific level. Second, while the few studies that address the goal-specific level support the assumed relationship between beliefs and performance, they almost exclusively focus on the learning goal NOS. Even though SI and NOS competencies are closely related (e.g., [30]), it is unclear to what extent the findings on NOS are transferable to SI. On the one hand, object- and self-related beliefs may vary between different learning goals [48–50]. On the other hand, teachers typically believe that fostering SI competencies is more important than fostering NOS competencies [49,63,65], which indicates that there are potentially further differences between these goals. The aim of the study presented in this paper is to assess teachers’ goal-specific beliefs related to SI and to examine the extent to which these beliefs are related to teachers' implementation of explicit instruction on SI. The research question is: what is the relationship between science teachers' object- and self-related beliefs about fostering students' SI competencies through explicit instruction and their implementation of explicit instruction on SI?

Insights into the relationship between science teachers' goal-specific beliefs and their implementation of explicit instruction on SI may contribute to our understanding of the role of teachers' goal-specific beliefs as dispositions and how they impact teacher performance. Furthermore, such insights can potentially inform teacher training and professional development.

2. Materials and Methods

2.1. Setting and Sample

The study presented in this paper used a mixed-method approach. The data were collected in two consecutive studies in 2020. In the first study, an online questionnaire was used to assess teachers' goal-specific beliefs about the teaching and learning of SI and their respective abilities. This study was part of a larger project that aimed to investigate various goal-specific beliefs related to SI from teachers in different career stages and with varying science subjects (see [49]). Therefore, the sample of this study comprised N = 171 pre- and in-service teachers that teach at least one science subject in Germany (i.e., biology, chemistry, or physics). In the second study, a sub-sample of N = 16 in-service teachers of the questionnaire sample were asked to plan a science lesson that primarily aims at fostering SI competencies (planning task) and took part in an interview. The interview was conducted one week after the teachers received the planning task. In the interview, the participants were asked to present and elaborate on their lesson plans as well as to describe their reasoning and decision-making during the planning process. This second study was conducted approximately five months after the first study to minimize the impact of the questions asked in the questionnaire on teachers' responses in the interview. The teachers participating in the second study were selected based on two criteria: First, the teachers needed to have agreed in the questionnaire to participate in further studies. Second, we restricted the sub-sample to in-service teachers because of their higher routine in planning lessons compared to pre-service teachers. The sixteen teachers who met these criteria and were willing to participate in the second study received an incentive of 50 EUR as compensation for their invested time. The analysis presented in this paper uses the data from the N = 16 teachers who represent the sub-sample that participated in the first and the second study (see Table 1).

Table 1. Overview of basic characteristics of the sub-sample analyzed in this study.

Sex	Science Subject(s)	Teaching Experience
Female: 5	Physics: 12	≤10 years: 6
Male: 11	Physics and Chemistry: 2	11 to 20 years: 5
	Biology: 2	21 to 30 years: 2
		>30 years: 3

2.2. Instruments

The study presented in this paper uses multiple data sources: a questionnaire, a planning task, and an interview. In the following sections, these three instruments are described in more detail.

2.2.1. Questionnaire

The first study used an online questionnaire, as questionnaires are an established method in belief research [68,69] that allow for collecting data from large samples. The questionnaire was developed in the context of the larger project that aimed to assess not only teachers' beliefs about explicit instruction but various goal-specific beliefs about the teaching and learning of SI competencies (e.g., the usefulness of different teaching strategies for fostering SI competencies). For the purpose of this study, three scales of the original instrument were used (Table 2; for a detailed description of the entire instrument, see [49]). The scales were selected based on their presumed relevance for teachers' implementation of explicit instruction. They addressed teachers' beliefs about the usefulness of *explicit instruction* for the teaching and learning of SI competencies, their beliefs about their *teaching abilities* regarding SI competencies, and their beliefs about their SI-related *scientific abilities*. The scale *explicit instruction* comprised four Likert-type items that addressed *object-related beliefs* about the usefulness of features of explicit instruction, such as explications and explanations of SI concepts, for teaching and learning of SI competencies (see example in Table 2). Each item used a 6-point Likert scale: (1) not useful, (2) rather not useful, (3) rather useful, (4) useful, (5) very useful, and (6) essential. The scales *teaching abilities* and *scientific abilities* comprised twelve, respectively four, Likert-type items that addressed *self-related beliefs* about teaching, respectively performing, SI. Both scales used the same 6-point Likert scale: (1) strongly disagree, (2) disagree, (3) rather disagree, (4) rather agree, (5) agree, and (6) strongly agree. The items in both scales were based on existing instruments [70–74], but had to be reformulated to address the goal-specific level. Furthermore, the existing items were supplemented by self-developed items to capture a broader range of teaching and scientific abilities related to SI. In addition to these three scales, a fourth scale of the original instrument contained one additional item that we assume to be particularly relevant for the context of this study. This item asked teachers to directly compare the use of explicit instruction for fostering SI and SC competencies ("Fostering SI competencies requires equally extensive developing and summarizing phases as fostering SC competencies") and was thus included in the data analyses. This additional item used the same 6-point Likert scale as the items on self-related beliefs.

Table 2. Overview of the three scales on teachers' beliefs used in the questionnaire.

Scale	Description	Item Example
Explicit Instruction	Beliefs about the extent to which it is useful that the students are provided SI concepts.	For good teaching of inquiry, it is (1) not useful/(2) rather not useful/ . . . /(5) very useful/(6) essential that SI concepts are verbalized.
Teaching Abilities	Beliefs about one's own abilities to successfully perform specific teaching tasks to SI.	I am able to explain inquiry at an appropriate level for students.
Scientific Abilities	Beliefs about one's own abilities to successfully perform specific scientific tasks to SI.	I am able to explain inquiry correctly.

Note. SI = scientific inquiry.

2.2.2. Planning Task and Interview

The second study used a combination of a planning task and a subsequent interview to investigate teacher performance related to fostering students' SI competencies and their implementation of explicit instruction on SI. We focused on the planning of a lesson for multiple reasons. First, planning is a relevant aspect of teacher performance [52]. Second, we assume that teacher performance in planning a lesson provides a meaningful approximation to their classroom practice; if explicit instruction on SI is not implemented in the lesson plan, then it is unlikely that explicit instruction is an essential element of the actual lesson. Furthermore, using a planning task as an approximation of classroom practice allowed us to control potentially relevant contextual factors [45], and thus increase the comparability of teacher performance. To that end, the planning task included specific guidelines. First, the teachers had to document their lesson plan in written form (2 to 3 pages, including information on time, teacher and student activity, teaching strategies, material, and media) and were asked to invest about 60 min in its completion. Second, teachers were prompted to plan a science lesson primarily aimed at fostering a specific SI competency, namely the competency to plan a scientific investigation. In line with typical models of SI competencies, planning of investigations refers to developing a scientific investigation's design and determining the necessary materials and equipment to conduct the investigation (e.g., [19,75]). Third, the teachers were told that the planned lesson should be 90 min long and embedded in a series of lessons that address the overarching theme "human perception with all senses". This theme was chosen because it requires little prior SC knowledge and offers connections to biology, chemistry, and physics (i.e., the subject typically taught by German science teachers). Fourth, the planning task provided teachers information about the fictional class the lessons should be planned for (e.g., 24 students in grade 6 with little prior experience regarding SI) as well as the available equipment (e.g., well-equipped rooms, no constraints regarding available materials and equipment). Apart from these guidelines, the teachers were free to decide what their lessons should look like (e.g., which teaching strategies, materials, and media they would use) to create enough openness for them to plan a lesson that reflects their teaching style.

The interview was conducted one week after the teachers received the planning task. All interviews were conducted by the primary author and lasted on average 43 (*SD* = 15) minutes. The interview was designed as a semi-structured interview, as this format allows comparability between teachers while also creating enough openness to address individual differences in the planned lessons. The interview comprised six predefined questions to elicit teachers' considerations and reasoning regarding the planned lessons. These questions prompted teachers to elaborate on their lesson plans (e.g., "Please describe your planned lesson in detail") as well as to provide additional information about the planned lessons that is presumably not written down (e.g., "In your point of view, which part of your lesson contributes most to fostering students' competency to plan scientific investigations?"). In addition to these predefined questions, the teachers were typically asked two to three individual questions regarding specific parts of their planned lesson that may contain features of explicit instruction. These questions were developed based on the written lesson plans the participants sent to the interviewer prior to the interview. To clarify whether a specific part of the lesson contains a feature of explicit instruction, the teachers were asked, for instance, to describe a specific part of their lesson in more detail or to give an example of what a specific element of their lesson looks like.

2.3. Data Analysis

The data analysis was conducted in two steps: First, the data from the first study (questionnaire) and the second study (planning task combined with an interview) were analyzed separately to assess teachers' beliefs respectively their performance regarding the implementation of explicit instruction on SI. Second, the results from both studies were linked to investigate the relationship between beliefs and performance.

2.3.1. Analysis of Teachers' Beliefs

To analyze teachers' beliefs, the raw Likert scores collected with the questionnaire were used to estimate a unidimensional Rasch Model (Andrich Rating-Scale Model; [76]) for each of the three scales (explicit instruction, teaching abilities, scientific abilities). The estimation was conducted in Winsteps (Version 4.4.4; [76]). Even though we were only interested in the beliefs of the $N = 16$ teachers that also participated in the second study, we used the data from all 171 participants of the first study for model estimation, as the larger sample size allowed for a more precise estimation of the model parameters. Furthermore, this approach allowed us to investigate the extent to which the selected 16 teachers are representative of the larger main sample in terms of their beliefs. After the initial estimation of the model parameters, the measurement quality was assessed for each scale individually (see overview in Table 3). The analysis of the item fit statistics (Outfit MNSQ) showed that almost all items were productive (0.5 < Outfit MNSQ < 1.5) and none of the items were degrading for measurement (Outfit MNSQ > 2.0; [76]). The model person reliabilities of the scales (comparable to Cronbach's Alpha; [76]) suggest satisfactory (>0.70) to good (>0.80) internal consistency of the scales [77]. Furthermore, an analysis of the model item reliability indicated that most items could be precisely located on the latent variable represented by the corresponding scale (item reliability > 0.90; [76]). In sum, the Rasch analyses indicate a satisfactory to good item and scale functioning for all three scales. The Rasch person measures of the *N* = 16 participants of the interview were then used to investigate their beliefs by analyzing the distribution of the person measures. In addition to the Rasch-based analyses, the distribution of the Likert raw scores for individual items was also analyzed to gain additional insights into teachers' beliefs.

Table 3. Overview of psychometric characteristics for each scale.

Scale	Item Outfit MNSQ	Item Reliability	Person Reliability
Explicit Instruction	0.82–1.11	0.92	0.67
Teaching Abilities	0.57–1.61	0.95	0.91
Scientific Abilities	0.80–1.08	0.93	0.85

2.3.2. Analysis of Teacher Performance

To capture teacher performance regarding the implementation of explicit instruction on SI in the planned lessons, a qualitative content analysis of the written lesson plans and the teachers' verbal elaborations during the interview was conducted (see [11]). The lesson plans and the verbal elaborations were used in a complementary manner. If a teacher stated in either the lesson plan or the interview that she or he intended to use features of explicit instruction, this feature was coded regardless of whether it was also visible in the other data source.

The qualitative content analysis of the planned lessons (i.e., the teachers' written lesson plans and their elaborations in the interview) was based on the procedure described in Mayring [78] and consisted of two consecutive steps. In the first step, the planned lessons were analyzed regarding the existence of features of explicit instruction on SI. In the second step, the overall alignment of the planned lessons with an explicit instructional approach was captured.

Step 1—Features of explicit instruction: To capture the existence of features of explicit instruction on SI, two categories were derived from existing definitions of explicit instruction (see Section 1.2) and from approaches that capture such features in classroom practice [12]. The first category captured whether the planned lessons included *explications of SI concepts*. The second category captured whether the planned lessons included *tasks that asked students to state, elaborate, or reflect on SI concepts* (see detailed category descriptions in Table 4). Both of these categories used a dichotomic rating (feature existent vs. feature non-existent) and were rated for the lesson as a whole.

An initial data screening revealed multiple instances in which teachers explicitly addressed SI competencies other than planning investigations (i.e., the competency prescribed as the primary goal of the lesson) in their planned lessons. Therefore, we have decided to code not only features of explicit instruction on planning investigations but also features of explicit instruction regarding four additional SI competencies: developing questions, developing hypotheses, conducting investigations, and analyzing data (Table 5). The selection of these competencies was based on typical models of SI competencies (e.g., [19,20]). Even after including these four competencies in the analysis, some SI-related explications and tasks could not be assigned to a specific SI competency. These instances were collected in "other". The existence of the two features of explicit instruction on SI was rated for each of the five SI competencies and "other", resulting in a total of 12 coding decisions per lesson in step 1. However, it is important to note that the analysis only captured the existence of these features but not the quality of their implementation.

Table 4. Overview of categories used to rate the existence of features of explicit instruction in the planned lessons (see [11]).

Category and Corresponding Codes	Examples for X = Planning Investigations
Explications: Concepts regarding competency X are stated, explained, or written down. (0) non-existent (1) existent	(1) The teacher writes down a rule for identifying dependent, independent, and control variables on the blackboard.
Tasks: Students are provided tasks to state, explain, elaborate, or reflect on concepts regarding competency X. (0) non-existent (1) existent	(1) The teacher asks the students: What rules should be kept in mind when planning scientific investigations? (1) Students get the task: Which of the given investigations can be used to answer the research question and *why*?

Note. X = developing questions, developing hypotheses, planning investigations, conducting investigations, analyzing data, or other inquiry competencies.

Table 5. Overview of the inquiry competencies for which the two features of explicit instruction were coded.

Inquiry Competency	Description Students Are Able to …
Developing Questions	… formulate scientific questions.
Developing Hypotheses	… formulate predictions about the scientific relationships to be investigated.
Planning Investigations (Primary Goal)	… develop a design for a scientific investigation that matches the research questions/hypotheses and to determine the equipment and materials necessary to conduct the investigation.
Conducting Investigations	… perform scientific investigations and collect data.
Analyzing Data	… process and visualize the collected data as well as to formulate interpretations based on the collected data.
Other	Other scientific inquiry competencies that are clearly related to SI but could not be assigned to the other five distinguished competencies (e.g., documenting scientific investigations)

Step 2—Overall alignment with an explicit instructional approach: When analyzing the use of explicit instruction on SI in the planned lessons, it has to be considered that the lesson as a whole is more than the sum of its parts. For instance, a lesson might include both explications and tasks on SI concepts and, therefore, seems to be in line with an explicit instructional approach. If, however, a more in-depth analysis reveals that the explications are isolated instances spread across the lesson and that explicated SI concepts are not the same concepts necessary to solve the tasks, one would probably come to a different conclusion. To address this issue, the analysis also addressed the overall alignment of the planned lesson with an explicit instructional approach. To that end, the overall emphasis on SI concepts in the planned lessons and the relative emphasis on SI concepts compared to concepts related to SC were rated (see detailed category descriptions in Table 6).

To assess the reliability of the two-step coding procedure, approximately 10% of the data (2 of the 16 planned lessons) were coded independently by two different raters. The estimation of the intercoder reliability revealed a very good agreement between the coding of the two raters ($\kappa = 0.76$, calculated based on Brennan and Prediger [79]). To further increase the validity of our interpretations of the coding, the primary rater of the planned lessons consulted with the secondary rater on difficult rating decisions throughout the entire coding process.

Table 6. Overview of categories used to rate the overall alignment of the planned lessons with an explicit instructional approach (see [11]).

Category and Corresponding Codes	Examples
Overall explicit emphasis on SI concepts (0) *no emphasis* (no explications of or tasks regarding SI concepts) (1) *small emphasis* (few isolated explications of and/or tasks regarding SI concepts) (2) *high emphasis* (more isolated/few clearly connected explications of and tasks regarding SI concepts)	(1) The teacher briefly reminds students during the data analysis that observations include only the perceptions made with one's senses and have to be distinguished from interpretations. (2) Students work out criteria of scientific questions by comparing different examples. These criteria are written down on the blackboard. Thereafter, students are asked to use these criteria to formulate scientific questions.
Overall explicit emphasis on SI concepts compared to SC concepts (0) *predominantly orientated on SC concepts* (1) *not clearly orientated on SI or SC concepts* (2) *predominantly orientated on SI concepts*	(0) While analyzing the data, the teacher reminds their students briefly of the difference between observation and interpretation. The rest of the lesson is focused entirely on the investigated phenomena and addresses only concepts related to SC. (1) Concepts related to SC are addressed primarily in the first half of the lessons, concepts related to SI primarily in the second half. (2) The planned lesson starts with a short repetition of SC concepts taught in the previous lessons. In the remainder of the lesson, students are engaged in different inquiry activities and receive multiple tasks and explications that specifically address concepts related to SI.

Note. SI = scientific inquiry, SC = science content.

2.3.3. Analysis of the Relationship between Teachers' Beliefs and Performance

The first step in investigating the relationship between teachers' goal-specific beliefs and performance consisted of analyzing the correlation between the teachers' responses to the questionnaire and the results of the rating of their planned lessons. Correlations were calculated for the three scales (Rasch person measure) and the responses to a specific selection of items within the scale (Likert raw scores) using IBM SPSS Statistics (Version 27). For instance, we calculated the correlation between teachers' performance and teachers' beliefs about the usefulness of explicit instruction for fostering SI competencies (Rasch person measure for the scale "explicit instruction"), as well as between their performance and their response to individual items of this scale (e.g., Likert raw scores regarding the item on the usefulness of verbalizing SI concepts; see Table 2). The selection of the items was based on the proximity between the content of the item and the categories used in the rating. For instance, the item on the usefulness of verbalizing SI concepts from the scale explicit instruction was selected, as the rating of the lessons contains an almost identical category (existence of explications). In contrast, the item on the usefulness of writing down SI concepts on the blackboard was not selected, as there is no directly related category in the rating of the planned lessons. All correlations (person measures and individual item responses) were calculated using (biserial) Kendall's tau (τ), as this is a suitable estimate of the correlation even in small datasets [72,80]. In the second step, cross-tabulations were used to examine the relationship between beliefs and performance more closely for items and rating categories that exhibited a potentially relevant correlation.

3. Results

3.1. Teachers' Goal-Specific Beliefs

The distribution of the Rasch person measures for the scale explicit instruction showed that the $N = 16$ teachers in the analyzed sub-sample typically believed explicit instruction was useful but not essential for fostering SI competencies (Figure 2). It is particularly worth noting that none of the teachers considered explicit instruction to not be helpful for fostering students' SI competencies (person measure < 2). The analysis of the individual items of the scale further showed that the agreement was particularly high for the items regarding verbalizing and explaining SI concepts, as only one teacher chose a response that indicated disagreement (response category 2 "rather not helpful") for these items (Figure 3). In line with this result, the analysis of the additional item showed that only three teachers strongly disagree (response category 1 or 2) with the statement that fostering SI competencies requires equally extensive developing and summarizing phases as fostering SC competencies (Figure 3).

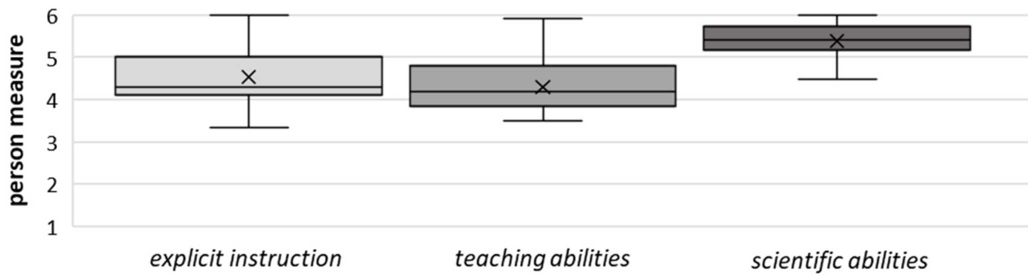

Figure 2. Distribution of the observed Rasch person measures of the $N = 16$ teachers in the analyzed sub-sample regarding the three scales. *Note.* The Rasch person measures originally reported in logits were rescaled to match the Likert scale range (1 to 6) to make the figure more tangible.

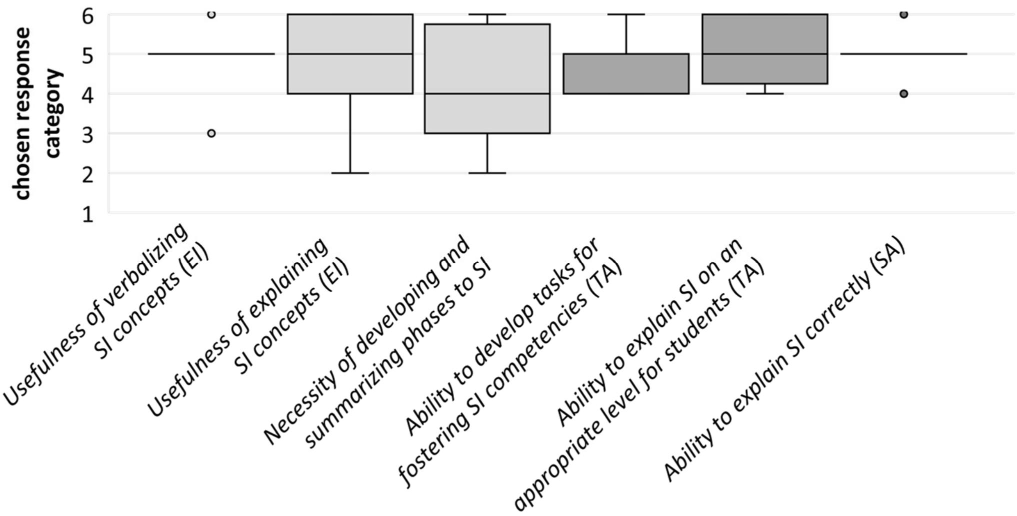

Figure 3. Distribution of the observed responses of the $N = 16$ teachers in the analyzed sub-sample regarding the selected subset of items that match the rating categories for the planned lessons. *Note.* EI/TA/SA: Items from the scales explicit instruction/teaching abilities/scientific abilities.

The distribution of the Rasch person measures observed for the scales teaching abilities and scientific abilities suggested that the teachers believed that they are able to teach SI to students and to perform SI themselves (Figure 2). Similar to the scale explicit instruction, there were no teachers at the lower end of the scale (person measure < 3). The analysis of the individual items selected from these scales showed a matching and homogeneous picture. All teachers scored all three self-related beliefs in the highest three response categories (Figure 3).

Overall, almost all teachers in our sub-sample believed that explicit instruction was useful for fostering SI competencies. In addition, all teachers believed that they were able to teach and perform SI. It is worth noting that we observed overall very high person measures (respectively scores for each item) and rather low variance in the sub-sample. To investigate whether the beliefs of the $N = 16$ teachers from the sub-sample differ from the beliefs of the $N = 155$ teachers in the rest of the larger main sample, Mann–Whitney-U-tests were conducted both on the scale and the item level. The results show no significant differences between the two samples (Table 7). However, the rest of the main sample showed a slightly larger range of Rasch person measures and Likert raw scores than the sub-sample (Table 7).

Table 7. Results of the Mann–Whitney-*U*-tests as comparisons between the analyzed sub-sample (N = 16) and the rest of the main sample (N = 155).

Scale/Item	Rest of the Main Sample		Sub-Sample		*U*	*z*	*p*	*r*
	Mdn	*R*	*Mdn*	*R*				
Explicit instruction	4.35	2.80	4.30	2.65	1274.0	0.225	0.822	0.02
Verbalizing SI concepts	5	3	5	3	1174.5	0.650	0.516	0.05
Explaining SI concepts	5	3	5	4	1058.0	0.095	0.924	0.01
Developing and summarizing phases to SI	5	4	5	4	870.0	−1.626	0.104	−0.13
Teaching abilities	4.13	3.06	4.18	2.41	1302.5	0.468	0.640	0.04
Developing tasks for fostering SI competencies	5	4	5	2	1126.5	−0.036	0.971	0.00
Explaining SI on an appropriate level for students	5	3	5	2	562.0	−0.582	0.561	−0.06
Scientific abilities	5.12	3.72	5.42	1.53	1432.0	1.171	0.242	0.09
Explaining SI correctly	5	4	5	2	1033.5	−0.639	0.523	−0.05

3.2. Implementation of Explicit Instruction in the Planned Lessons

The analysis of the written lesson plans and the corresponding interview data showed that half of the 16 planned lessons included explications of SI concepts ("any SI competency" in Figure 4). However, only in two lessons did these explications refer to the planning of investigations, which was prescribed as the primary goal of the lesson. Tasks that ask students to state, elaborate, or reflect on SI concepts were observed in seven planned lessons and in six of these seven lessons they addressed the planning of investigations. Both the explications and the tasks related to the competency "planning investigations" mainly addressed the control-of-variables strategy. Explications of and tasks on SI concepts that did not address the planning of investigations typically addressed the documentation of investigations (e.g., concepts regarding structure and components of protocols) or the steps of an inquiry process. In line with our coding procedure, both aspects (documentation and steps of the inquiry process) were categorized as "other"; their occurrence in the planned lessons is reflected in the corresponding bar in Figure 4. Interestingly, all six planned lessons that contained explications or tasks related to the planning of investigations also contained explications or tasks related to other SI competencies. Furthermore, three lessons included explications or tasks on SI concepts, but none specifically on planning investigations.

Overall, 6 of the 16 planned lessons showed a high alignment with an explicit instructional approach for fostering SI competencies, while seven lessons showed no emphasis on SI concepts at all. In addition, a comparison of the emphasis on SI concepts with the emphasis on SC concepts in the lesson revealed a predominant emphasis on SI in only five lessons, a predominant emphasis on SC in eight lessons, and an equal emphasis on SC and SI in the remaining three lessons. In sum, a typical lesson planned by the teachers in our sample showed no or little explicit emphasis on SI concepts. In addition, SC concepts typically played a predominant role in the lessons, even though the prescribed primary goal was to foster students' competency in planning scientific investigations.

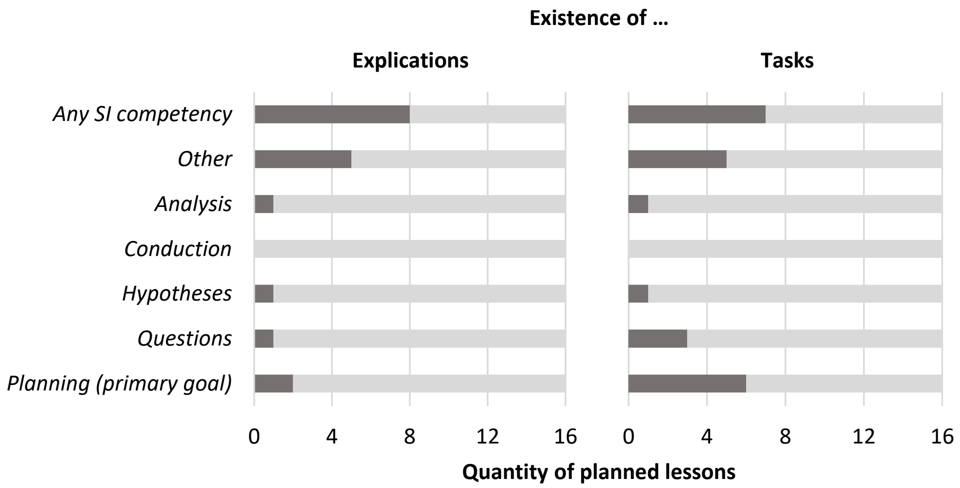

Figure 4. Existence of explications and tasks in the 16 planned lessons. *Note.* SI = scientific inquiry.

3.3. Relationship between Teachers' Beliefs and Implementation of Explicit Instruction

The relationship between teachers' beliefs and their implementation of explicit instruction on SI was analyzed for planning investigations and for all SI competencies combined. We decided to perform both analyses because the observed implementations of explicit instructions were not limited to the planning of investigations, even though this competency was prescribed as the primary goal of the lesson. Interestingly, the correlations between beliefs and implementation for planning investigations were typically similar or slightly lower than those for all SI competencies combined (Tables 8 and 9).

Table 8. Correlations between the person measures regarding the scales used in the questionnaire and the results of the rating of the planned lessons.

Beliefs about the . . .		Existence of Explications		Existence of Tasks		Emphasis on SI Concepts	Emphasis on SI Compared to SC
		Planning	*SI*	*Planning*	*SI*		
usefulness of explicit instruction on SI	τ	0.18 †	0.13 †	0.05 †	0.23 †	0.18	0.30
	p	0.423	0.560	0.827	0.310	0.400	0.161
ability to teach SI	τ	−0.02 †	0.06 †	−0.23 †	−0.09 †	0.00	0.09
	p	0.937	0.792	0.302	0.671	>0.999	0.655
ability to perform SI	τ	−0.02 †	0.14 †	−0.06 †	0.11 †	0.15	0.07
	p	0.936	0.523	0.784	0.630	0.487	0.763

Note. † Biserial Kendall's tau.

On the scale level, the correlations between teachers' object-related beliefs about the usefulness of explicit instruction for fostering SI competencies and their implementation of explicit instruction on SI in the planned lesson were typically small ($\tau < 0.30$) and not statistically significant on the level of $p < 0.05$ (Table 8). The only exception was the medium (but non-significant) correlation between these beliefs and the rating category that addressed the teachers' relative emphasis on SI compared to SC concepts in the planned lessons. In addition to the analysis of the scale level, we also investigated correlations between selected items and the rating of the planned lessons. This detailed analysis of the correlations for items that represented two key features of explicit instruction (verbalizing and explaining SI concepts) revealed medium ($0.30 \leq \tau < 0.50$) to large ($\tau \geq 0.50$) correlations between object-related beliefs and the implementation of explicit instruction on SI (Table 9). These correlations were mostly not significant. Interestingly, the correlations between the responses to the single item regarding the necessity of developing and summarizing phases for fostering SI competencies and the rating of the planned lessons were slightly larger

(Table 9). In most cases, the correlations with the responses to this item were medium to large and statistically significant. For instance, a stronger belief about the necessity of developing and summarizing phases to SI was often accompanied by the existence of tasks for the planning or any SI competency, as well as an overall explicit emphasis on SI (compared to SC) concepts in the planned lesson.

Table 9. Correlations between the responses to selected items in the questionnaire and the results of the rating of the planned lessons.

Beliefs about the . . .		Existence of Explications		Existence of Tasks		Emphasis on SI Concepts	Emphasis on SI Compared to SC
		Planning	*SI*	*Planning*	*SI*		
usefulness of verbalizing SI concepts	τ	0.29 †	0.32 †	0.13 †	0.34 †	0.36	0.38
	p	0.263	0.212	0.621	0.188	0.138	0.120
usefulness of explaining SI concepts	τ	0.26 †	0.38 †	0.27 †	0.43 †	0.44	**0.55**
	p	0.287	0.116	0.268	0.080	0.056	**0.018**
necessity of developing and summarizing phases to SI	τ	0.31 †	0.27 †	**0.64** †	**0.56** †	**0.45**	**0.46**
	p	0.189	0.254	**0.007**	**0.019**	**0.048**	**0.040**
ability to develop tasks for fostering SI competencies	τ	−0.13 †	0.06 †	−0.27 †	−0.20 †	−0.08	0.07
	p	0.600	0.817	0.282	0.414	0.745	0.784
ability to explain SI on an appropriate level for students	τ	−0.02 †	0.08 †	−0.23 †	−0.07 †	0.01	0.15
	p	0.932	0.736	0.352	0.777	0.958	0.524
ability to explain SI correctly	τ	0.00 †	0.00 †	−0.21 †	0.00 †	0.00	0.00
	p	>0.999	>0.999	0.421	>0.999	>0.999	>0.999

Note. † Biserial Kendall's tau.

Similar to the object-related beliefs, the self-related beliefs exhibited on the scale level small and non-significant correlations to the implementation of explicit instruction on SI in the planned lesson (Table 8). In contrast to the object-related beliefs, a detailed analysis of the correlations for individual, selected items further revealed only small and non-significant correlations, even for items that were closely linked to features of explicit instruction such as the ability to explain SI or the ability to develop tasks for fostering SI competencies (Table 9).

Given the small sample size and the lack of variance in beliefs, it is not surprising that—even though medium to large correlations were observed between object-related beliefs and the implementation of explicit instruction—about three-quarters of the correlations regarding object-related beliefs were not statistically significant. Because of the comparatively large correlations regarding object-related beliefs, the relationship between these beliefs and performance was examined in more detail. Therefore, an in-depth analysis was conducted to identify patterns in the combinations of corresponding responses in the questionnaire and the ratings of the planned lessons. For this analysis, the responses to the selected six-point Likert-type items regarding explicit instruction were grouped into disagreement (response categories 1 and 2), low agreement (response categories 3 and 4), and high agreement (response categories 5 and 6). These groups were then used to create cross tables that show the existing combinations of item responses and implementation of explicit instruction in the planned lessons (Figure 5). This analysis revealed that there was no combination of "disagreement" and higher ratings regarding the implementation of explicit instruction on planning or any SI competency in the planned lessons. All teachers in our sample, who implement explicit instruction for at least one SI competency, believed that explicit instruction is at least somewhat useful for fostering SI competencies. Likewise, none of the teachers in our sample who rejected the usefulness of explicit instruction for fostering SI competencies implemented explicit instruction on any SI competency. Similar results were observed concerning the implementation of explicit instruction on planning investigations. However, not all teachers, who believed that explicit instruction is useful for fostering SI competencies, transferred these beliefs into consistent performance. Taking into account explicit instruction on any SI competency, about half of the teachers described a planned lesson that seemed consistent with their beliefs. This proportion declined when only explicit instruction on planning investigations was considered. For instance, 13 teachers agreed with the usefulness of the verbalization of SI concepts to foster SI competencies and 8 of these 13 teachers consistently described at least one explication to any SI competency in their planned lesson. However, only 2 of these 13 teachers described an explication regarding the competency planning investigations.

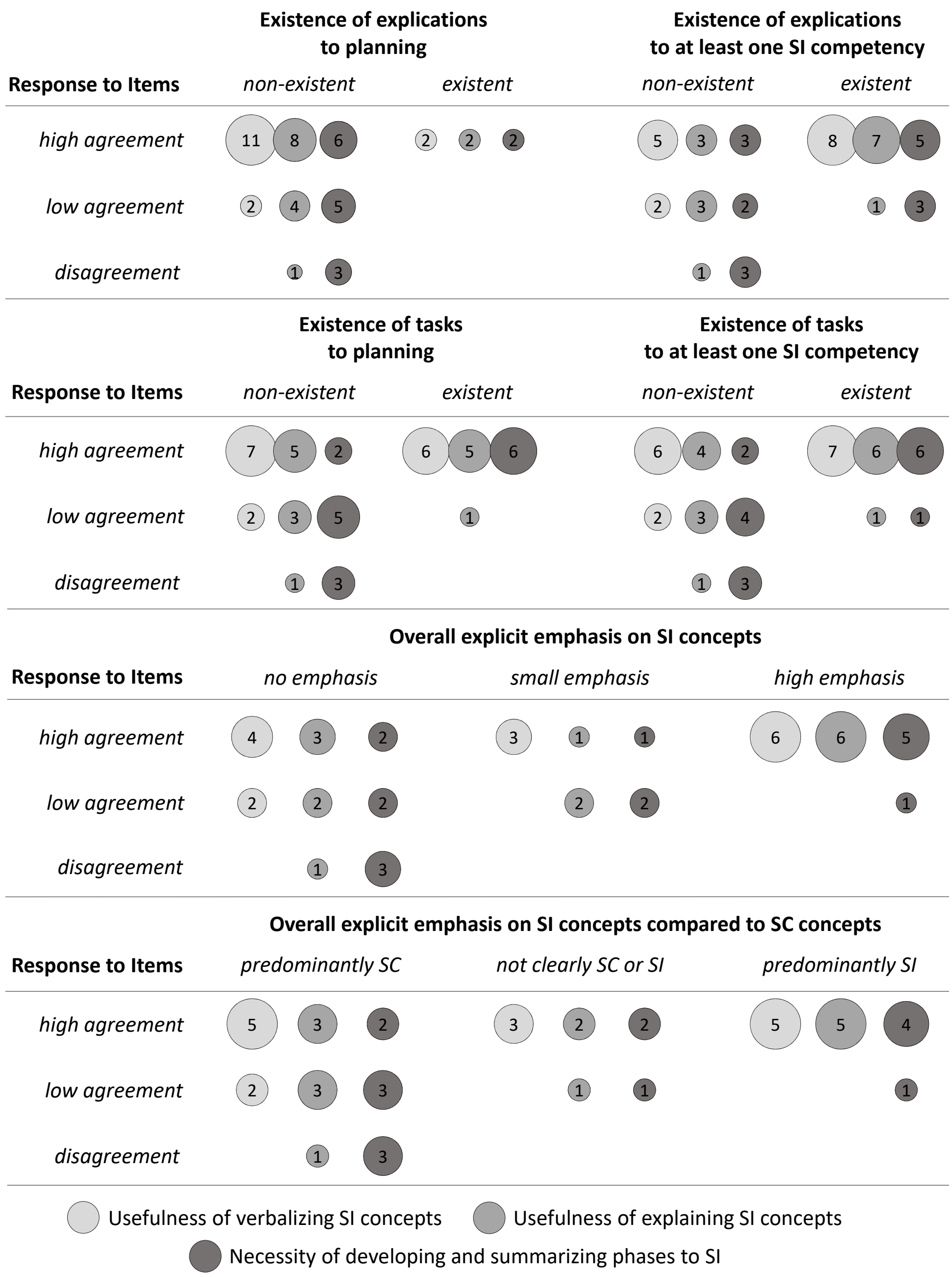

Figure 5. Observed combinations of responses in the questionnaire about the usefulness of explicit instruction and the results of the rating of its implementation in the planned lessons. *Note.* Disagreement = response category 1 or 2 of corresponding Likert scale, low agreement = response category 3 or 4 of corresponding Likert scale, high agreement = response category 5 or 6 of corresponding Likert scale. SI = scientific inquiry, SC = science content. Not all items were answered by all teachers. Therefore, the sum of responses slightly varies between the analyzed combinations.

4. Discussion

Fostering students' SI competencies is an important goal of science education (e.g., [1–4]). To foster SI competencies, engaging students in inquiry activities combined with explicitly addressing SI concepts is an effective approach (e.g., [5–7]). However, such explicit instruction on SI seems to be rarely used in classroom practice [8–13]. Based on the assumption that beliefs are a vital element of teachers' professional competence (e.g., [14–16]) and impact their thoughts and actions in the classroom (e.g., [38–40]), this study investigated the relationship between teachers' beliefs and performance regarding explicit instruction on SI. The first step to that end was to separately analyze teachers' object- and self-related beliefs regarding explicit instruction for fostering SI competencies and their ways of implementing explicit instruction on SI. Thereafter, the data from these analyses were used to investigate the relationship between beliefs and performance. Before interpreting the results, it is important to note that the teachers analyzed in this study may represent a positive selection because participation in the interview and the lesson planning were voluntary and required a considerable investment of time and effort. Furthermore, the sample analyzed in this study consisted almost exclusively of physics teachers. However, a comparison with a larger sample of teachers from all science subjects showed no considerable differences regarding object-related beliefs about the usefulness of explicit instruction for fostering SI competencies as well as regarding self-related beliefs about their own SI-related teaching and scientific abilities.

4.1. Teachers' Beliefs Related to Explicit Instruction for Fostering Scientific Inquiry Competencies

In line with previous studies, the results of this study suggest that teachers typically believe that explicit instruction is useful but not essential for fostering SI competencies [62], and that they are able to teach and perform SI [48]. Furthermore, there is only a relatively small variance in these beliefs between the teachers, suggesting that the beliefs of the sixteen teachers in the analyzed sub-sample are rather homogeneous in this regard. In contrast to their abilities related to SI, teachers often seem to struggle with their ability to teach NOS and their understanding of NOS concepts [63,65]. Given that SI and NOS are different but closely related constructs (e.g., [30]), this contrast between self-related beliefs regarding SI and NOS underlines the relevance of assessing teachers' beliefs on a goal-specific level [48–50].

4.2. Teachers' Implementation of Explicit Instruction in Lesson Plans

Explicit instruction on SI directly related to the prescribed primary goal of the lessons—fostering students' competency to plan scientific investigations—was rarely observed in the planned lessons. This finding is, on the one hand, caused by the fact that some lessons did not contain any features of explicit instruction on SI. On the other hand, some lessons contained features of explicit instruction on SI, which exclusively addressed other SI competencies. In particular, we frequently observed explications and tasks that addressed not the planning of investigations but the typical steps of an entire inquiry cycle. The teachers often introduced these steps as a means to design or document a whole scientific investigation. In sum, these results may suggest that teachers struggle with the term "planning investigations" and the question of what knowledge and abilities this competency does and does not comprise. While we considered the planning of an investigation as a specific step of an inquiry process (choosing dependent and independent variables, number of repetitions, etc.), some teachers may have understood planning as organizing the different steps of an (idealized) inquiry cycle (development of questions, formulation of hypotheses, conducting the investigation, etc.). However, even if the analysis is not restricted to just explications and tasks on planning investigations but includes explications and tasks on concepts related to other SI competencies, features of explicit instruction on SI were only observed in approximately half of the planned lessons. Furthermore, only about one-third of the planned lessons had a clear emphasis on SI concepts. In sum, this study suggests that explicit instruction on SI is rarely considered when planning science lessons, even if the goal of these lessons is to foster SI competencies primarily. Since the planning of a lesson may also be used as an approximation of actual classroom practice, the study also provides additional empirical support for the assumption that explicit instruction on SI is only rarely used in science classrooms [8–13]. It is important to note that this approximation comes with limitations, as the lesson plan can only provide a condensed and incomplete account of everything that is supposed to happen in the classroom, let alone what is actually happening. However, given that the teachers in our study only had to plan a lesson and, thus, did not face the typical timely and organizational constraints associated with actual classroom practice, we assume that our findings represent an over- rather than an underestimation of the amount of explicit instruction on SI used in classroom practice.

4.3. The Relationship between Beliefs and Performance

Two methodological approaches were combined to investigate the relationship between teachers' beliefs and their performance: correlation analyses and an analysis of patterns observed in the cross tables. While correlation analyses are an established method and, in principle, well suited to addressing our research question, we faced multiple challenges using this method: First, the sample size available for this study is relatively small ($N = 16$). Second, the variance in teachers' beliefs is already relatively small within this sample (all observed person measures > 3 on a scale from 1 to 6; Figure 2). In light of these restrictions, a threshold of $p < 0.05$ seems too restrictive to detect potentially relevant correlations in the data (cf. [81]), since even medium effects will typically not reach statistical significance under these circumstances. Therefore, we decided to evaluate the potential relevance of an observed correlation based on a combination of its size and a less restrictive *p*-threshold ($p < 0.30$). In addition, the correlation analyses were followed-up with an analysis of the patterns of beliefs and performance. In addition to these methodological constraints, it is worth noting that a considerable number of teachers in our sample implemented features of explicit instruction that addressed SI concepts which were not related to the competency planning investigations (e.g., formulating questions, documenting investigations). As we have argued above, the high proportion of explicit instruction on other SI competencies might be caused by the teachers having a broader understanding of the term planning investigations than we intended and used in our analyses (i.e., planning as a specific step versus planning as the organization of multiple steps). To address this issue, the following discussion of the relation between teachers' goal-specific beliefs and their performance is based not only on explicit instruction on planning investigations but on any SI competency within the scope of this study. It is, however, worth noting that both the correlations between teachers' beliefs and their performance and the proportion of teachers who planned a lesson that seems to be consistent with their beliefs are lower when just explicit instruction on planning investigations is taken into account.

4.3.1. The Relationship between Object-Related Beliefs and Performance

The correlations between object-related beliefs and performance were typical of a medium to large size and exhibited *p*-values lower than 0.30. The analysis of the cross tables further revealed that teachers, who believed explicit instruction to be not useful for fostering SI competencies, consistently did not use explicit instruction in their planned lesson. Vice versa, approximately half of the teachers, who strongly believed in the usefulness of explicit instruction on SI, implemented corresponding features and clearly emphasized SI concepts in their planned lessons. However, there was also a noticeable number of teachers who believed explicit instruction on SI to be very useful but did *not* implement corresponding features in their planned lessons. In this regard, this study's findings are similar to those of studies conducted in the context of NOS, where beliefs about the usefulness of explicit instruction were found to make the implementation of explicit instruction more likely [63,65–67]. This similarity may suggest that even though NOS and SI are different constructs, the relationship between beliefs about explicit instruction and performance regarding its implementation seem to be similar for the two.

Factors that may impact whether beliefs about the usefulness of explicit instruction on SI are transformed into respective performance are manifold. They comprise, for instance, professional knowledge about typical characteristics of explicit instruction on SI, strategies and concrete examples of its implementation, and the SI concepts that require explication ([67]; see also [15,16]). Without such knowledge, even teachers who believe explicit instruction to be useful for fostering SI competencies may fail to plan and conduct lessons in line with this approach. In addition, without such knowledge, teachers may think that they are implementing explicit instruction for fostering SI competencies, but in the view of experts, they do not (cf. [63,64,82]). Conversely, such knowledge may not be transformed into corresponding actions without beliefs about the usefulness of explicit instruction. This notion is reflected in the refined consensus model of pedagogical content knowledge, which positions beliefs as the filters between knowledge and teacher performance [52,53]. Other factors that may impact teacher performance are situation-specific skills such as perception and decision-making [15,16]. Teachers may have professional knowledge about the explicit instruction on SI and believe that this approach is effective but decide to pursue other ways of fostering SI competencies in a given situation (e.g., implicit instruction, see [21]; historical cases, see [83]). Beliefs about the usefulness of explicit instruction for fostering SI competencies may determine whether the use of explicit instruction is considered in decision-making at all (e.g., [38,40,51]).

4.3.2. The Relationship between Self-Related Beliefs and Performance

In contrast to teachers' object-related beliefs, the correlations observed between self-related beliefs and performance were small and typically exhibited *p*-values higher than 0.30. Even though these correlations do not confirm the relationship between teachers' beliefs about their ability to perform and to teach SI and their implementation of explicit instruction [63,65,67], it is important to note that our findings also did not contradict this assumption. While findings of studies conducted in the context of NOS suggest that a lack of beliefs in one's own scientific and teaching abilities hinders the implementation of explicit instruction on NOS [63,65,67], the fact that such an inhibitory effect was not observed in our study could be explained by the fact that the teachers in our sample demonstrated very positive self-related beliefs overall (Figures 2 and 3). Therefore, an inhibitory effect of low self-related beliefs for the implementation of explicit instruction on SI should thus not be discarded based on the observations in our study.

5. Conclusions

Explicit instruction is a means of fostering SI competencies that, despite its effectiveness, is only rarely used in classroom practice [8–13]. In sum, empirical evidence supports the hypothesis that strong positive object-related beliefs and strong positive self-related beliefs are necessary but not sufficient conditions for the implementation of explicit instruction on SI [62,63,65,67]. This finding is also in line with the assumption that "teachers are more likely to act on their beliefs about [. . .] various aspects of instruction when they believe in their own capability to do so" [45] (p. 75). Teachers' beliefs are therefore a potential cause for the rare implementation of explicit instruction on SI in classroom practice. However, given that most teachers seem to have strong positive object- and self-related beliefs about explicit instruction on SI [48,62] and, therefore, fulfil the necessary conditions, it can be assumed that the scarcity of explicit instruction on SI is not primarily caused by their beliefs. Therefore, further studies are required that shed light on the mechanisms by which teachers' beliefs interact with other relevant dispositions (e.g., professional knowledge), as well as situation-specific skills (perception, interpretation, decision-making; [15,16]) and how they affect teacher performance. Given that we did not assess the teaching practice directly, but via planning a lesson for a fictitious school class, such studies should also investigate to what extent the hypothesized relationship between teachers' beliefs and their performance is valid in real-life classroom situations.

In addition to the specific insights into teachers' beliefs about and their implementation of explicit instruction for fostering SI competencies, this study contributes to our understanding of the relationship between beliefs and performance on a more general note. So far, studies investigating the relationship between science teachers' beliefs and their instructional practice provide an inconclusive picture. While some studies support the assumption that teachers' beliefs influence teaching practice (e.g., [61,84,85]), others report no clear relationship (e.g., [57,86,87]; see also overview in [51,88,89]). Fives and Buehl hypothesized that this inconclusive picture "may pertain to the level of specificity at which beliefs and practices are assessed" [38] (p. 482). This hypothesis has, so far, only rarely been tested, given that the relationship between teachers' beliefs and performance is mostly analyzed on a general (e.g., [57]) or a subject-specific level (e.g., [58–61]). Our study addressed this gap by capturing both beliefs and performance at the goal-specific level (i.e., regarding the fostering of SI competencies) and, in sum, seems to provide additional empirical support for the hypothesis of Fives and Buehl [38]. Nevertheless, it is important to note that even when beliefs are assessed on a goal-specific level, the relationship seems to be not straightforward (beliefs as a necessary but not a sufficient condition). Furthermore, understanding the role of the level of specificity requires studies in which the specificity level is systematically varied. In addition, further studies should include, for instance, a wider range of teachers (with different science subjects), learning goals, and aspects of teacher performance to increase the overall validity (and generalizability) of our conclusions. While the sample of our study, which consisted almost exclusive of physics teachers, seems to have similar beliefs to teachers of other science subjects, it remains to be investigated whether teachers with different science subjects are also similar regarding their performance and its relationship to beliefs.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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