Instructional Quality Features in Biology Instruction and Their Orchestration in the Form of a Lesson Planning Model

Dissertation der Fakultät für Biologie

der Ludwig-Maximilians-Universität München

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München, 2019

Diese Dissertation wurde angefertigt

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im Bereich von Didaktik der Biologie

an der Ludwig-Maximilians-Universität München

Die vorliegende Arbeit verwendet Daten aus Forschungsprojekten, welche durch die Deutsche Forschungsgemeinschaft (DFG, Förderkennzeichen: FG 511; DFG, Förderkennzeichen: NE 1196/6-1) und das Bundesministerium für Bildung und Forschung (BMBF, Förderkennzeichen: 01JH0904) gefördert wurden. Die Arbeit wurde am Lehrstuhl Didaktik der Biologie der Ludwig-Maximilians-Universität München durchgeführt.

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Datum der Abgabe: 08.01.2019

Datum der mündlichen Prüfung: 15.04.2019

Abstract

Research on effective instructional quality features is a well-established empirical research field. Instructional quality features are commonly classified into sight structures and deep structures. Further, instructional quality features are separated into general and subject-specific features which means that some features like classroom management are valid for all subjects, whereas others like conducting experiments are more specific for single or few subjects. One widespread and feasible research method to analyze the occurrence and possible effects of instructional quality features on student outcome variables, e.g. achievement, is the usage of quantitative video studies. In previous studies, several instructional quality features for biology instruction as well as for other subjects, e.g. for mathematics or physics, were identified and analyzed using video data. However, an overview of quantitative video studies and their analyses as well as an overview of conspicuous instructional quality features are missing. Further, it is necessary to evaluate instructional quality features for each subject separately to make precise statements about the occurrence and the effectiveness of these features on student outcome variables. For biology instruction, several analyses of instructional quality features are missing to this day. Finally, a mere aggregation of knowledge about instructional quality features does not improve instruction. Thus, a meaningful, expedient orchestration of effective instructional quality features in biology instruction is desirable.

Consequently, this dissertation has the following three aims: (1) the creation of an overview of video-based research on instructional quality and conspicuous instructional quality features, (2) the conduction of further or replicating video analyses of instructional quality features in biology instruction, and (3) the meaningful orchestration of effective instructional quality features in the form of a lesson planning model for biology instruction.

These aims were addressed using data and videos from three externally funded projects: (a) *Teaching and Learning of Science* (nwu Essen), (b) *Competence-orientation and Task Culture in Nature and Science Instruction* (LerNT), and (c) *Professional Knowledge of Teachers in Science* (ProwiN). These three projects are quantitative video studies, in which different questionnaires and tests were used supplementarily. In the project *nwu Essen*, 47 biology teachers from several secondary schools (Gymnasium) in North-Rhine Westphalia were videotaped on the topic of *blood and circulatory system* in grade nine. In the framework of *LerNT*, 28 biology teachers from secondary schools (Gymnasium) in Bavaria were videotaped

on the topic of *botany* in grade six. In the project *ProwiN*, 43 biology teachers from secondary schools (Gymnasium) in Bavaria were videotaped on the topic of *neurobiology* in grade nine.

An overview of video-based research on instructional quality and conspicuous instructional quality features outlines that the three basic dimensions of instructional quality (*classroom management*, *supportive climate* and *cognitive activation*) were often analyzed in studies on mathematics and science instruction, and that an increased amount of characteristics of the three basic dimensions occur in high-achieving classes compared to low-achieving classes. Additionally, the further or replicating analyses show that *classroom management* and *supportive climate* are prerequisites for conducting cognitively activating instruction. Further, the deeper video analyses make clear that the framework of *Scientific Reasoning and Argumentation* (SRA) and a reduced usage of technical terms are effective methodical tools to foster students' learning in biology instruction. The results from this dissertation and from previous studies on instructional quality in biology instruction were finally considered to design a lesson planning model which can be used to foster students' conceptual knowledge in biology instruction.

Zusammenfassung

Die Untersuchung effektiver Unterrichtsqualitätsmerkmale ist ein etabliertes empirisches Forschungsfeld. Unterrichtsqualitätsmerkmale werden üblicherweise in Sicht- und Tiefenstrukturen unterteilt. Des Weiteren werden Unterrichtsqualitätsmerkmale in allgemeine und fachspezifische Unterrichtsqualitätsmerkmale unterschieden, was bedeutet, dass einige Merkmale, wie beispielsweise Klassenführung, über Fächergrenzen hinaus gelten, und andere, wie beispielsweise der Einsatz von Experimenten im Unterricht, spezifisch für einzelne oder einige wenige Fächer bestimmt sind. Eine weit verbreitete und gut durchführbare Forschungsmethode zur Analyse des Vorkommens und der Effekte von Unterrichtsqualitätsmerkmalen auf Schülervariablen, z. B. auf Schülerleistung, ist die Durchführung quantitativer Videostudien. In bereits durchgeführten Studien wurden Unterrichtsqualitätsmerkmale für den Biologieunterricht und andere Fächer, z. B. Mathematik oder Physik, identifiziert und anhand von Videodaten analysiert. Dennoch fehlt bisher ein Überblick über quantitative Videostudien und deren Analysen sowie über auffallende Unterrichtsqualitätsmerkmale. Darüber hinaus müssen Unterrichtsqualitätsmerkmale für jedes Fach einzeln analysiert werden, um präzise Aussagen über das Vorkommen und die Wirksamkeit dieser Merkmale auf Schülervariablen treffen zu können. Für den Biologieunterricht fehlen bisher bestimmte Analysen zu Unterrichtsqualitätsmerkmalen. Außerdem ist zu berücksichtigen, dass eine bloße Ansammlung von Wissen über Unterrichtsqualitätsmerkmale den Unterricht per se nicht verbessert. Eine sinnvolle, zweckmäßige Orchestrierung effektiver Unterrichtsqualitätsmerkmale im Biologieunterricht ist somit erstrebenswert.

Die vorliegende Dissertation verfolgt deshalb folgende drei Ziele: (1) die Erstellung eines Überblicks über videobasierte Forschung zu Unterrichtsqualität und zu auffallenden Unterrichtsqualitätsmerkmalen, (2) die Durchführung weiterer bzw. replizierender Videoanalysen von Unterrichtsqualitätsmerkmalen im Biologieunterricht, und (3) eine Orchestrierung effektiver Unterrichtsqualitätsmerkmale in Form eines Unterrichtsplanungsmodells für den Biologieunterricht.

Diese gesetzten Ziele wurden basierend auf Videodaten aus drei drittmittelfinanzierten Projekten bearbeitet: (a) *Naturwissenschaftlicher Unterricht* (nwu Essen), (b) *Kompetenzorientierung und Aufgabenkultur im Natur-und-Technik-Unterricht* (LerNT) sowie (c) *Professionswissenschaften in den Naturwissenschaften* (ProwiN). Bei diesen drei Projekten handelt es sich um quantitative Videostudien, bei denen neben Videoaufnahmen

verschiedene Fragebögen und Tests verwendet wurden. Im Rahmen des Projekts *nwu Essen* wurden 47 Biologielehrkräfte aus Gymnasien in Nordrhein-Westfalen zum Thema *Blut und Kreislaufsystem* in der neunten Klasse videographiert. Im Zuge des Projekts *LerNT* wurden 28 Biologielehrkräfte aus Gymnasien in Bayern zum Thema *Botanik* in der sechsten Klasse videographiert. Im Rahmen des Projekts *ProwiN* wurden 43 Biologielehrkräfte aus Gymnasien in Bayern zum Thema *Neurobiologie* in der neunten Klasse videographiert.

Ein Überblick über die videobasierte Forschung zur Unterrichtsqualität und über auffallende Unterrichtsqualitätsmerkmale macht deutlich, dass die drei Basisdimensionen der Unterrichtsqualität (*Klassenführung*, *konstruktive Unterstützung* und *kognitive Aktivierung*) oftmals in Studien aus dem mathematisch-naturwissenschaftlichen Unterricht analysiert wurden und dass sich Merkmale dieser drei Basisdimensionen vermehrt in leistungsstärkeren Klassen als in leistungsschwächeren Klassen zeigen. Durch die weiteren bzw. replizierenden Videoanalysen wird ersichtlich, dass *Klassenführung* und *konstruktive Unterstützung* Voraussetzungen für die Durchführung von kognitiv aktivierendem Unterricht sind. Darüber hinaus verdeutlichen die Videoanalysen, dass die Anwendung des Rahmenmodells zum *Scientific Reasoning and Argumentation* (SRA) und eine reduzierte Nutzung von Fachbegriffen wirksame methodische Werkzeuge sind, um das Lernen der Schülerinnen und Schüler zu fördern. Die gewonnenen Ergebnisse dieser Dissertation und vorangegangener Studien zur Unterrichtsqualität im Biologieunterricht wurden berücksichtigt, um schließlich ein Unterrichtsplanungsmodell zu entwerfen, anhand dessen das Konzeptwissen der Schülerinnen und Schüler im Biologieunterricht gefördert werden kann.

Content

1. Introduction

For more than two decades now, great international attention has been given to teachers' instruction and its effects on student outcome variables like achievement or interest. In this context, so-called instructional quality features are increasingly taken into focus by educational researchers (Helmke, 2014). The question of which factors are relevant for "good" instruction has concerned teachers, psychologists, and sociologists alike for a long period of time (Bloom, 1976; Bromme, 1992; Brophy & Good, 1986; Carroll, 1963; Ditton, 2000; Kounin, 1970; O'Neill, 1988). In recent years, many instructional quality features have been identified, analyzed and categorized in theoretical summaries and meta-analyses (e.g. Hattie, 2009; Helmke, 2014; Seidel & Shavelson, 2007). The status quo in research on instructional quality is that the instructional quality is separated into sight structures and deep structures (Kunter & Trautwein, 2013; Kunter & Voss, 2013; Oser & Baeriswyl, 2001). Deep structures can be further categorized into (a) general instructional quality features, and (b) subject-specific instructional quality features (Seidel & Shavelson, 2007; Wüsten, 2010; Wüsten, Schmelzing, Sandmann, & Neuhaus, 2008; Wüsten, Schmelzing, Sandmann, & Neuhaus, 2010). To identify such instructional quality features, one frequently used, continually developed, and well-established evaluation tool is the usage of quantitative video studies (von Kotzebue et al., 2015). Inspired by the *TIMSS 1995 Video Study* (Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999) and *TIMSS 1999 Video Study* (Hiebert et al., 2003; Roth et al., 2006), several video studies with different foci according to their analyses have been conducted in mathematics and science subjects, e.g. in biology. Video studies provide the possibility to perform descriptive and deeper analyses based on real instruction, and thus allow to draw conclusions about the effects of instructional quality features on student outcome variables. Further, well-examined video-based results could be used to design empirically based lesson models for practitioners, teacher educators, and educational researchers (e.g. Nawani, von Kotzebue, Spangler, & Neuhaus, 2018). However, three important research gaps in research on instructional quality have been identified. First, an overview of video-based research on instructional quality and conspicuous instructional quality features is lacking. Second, further or replicating video-based analyses of instructional quality features and their effects on student outcomes in biology instruction are necessary. Third, an orchestration of effective instructional quality features in biology instruction is of great importance.

These three research gaps which were systemically derived from literature research are examined and addressed in this dissertation. In the following, an overview of the structure of this dissertation is presented. It includes the theoretical framework, the derivation of the three research gaps, the aims of this dissertation with the corresponding publications or manuscripts, and points for discussion (see Fig. 1). The introduction section (see Section 1.) illustrates instructional quality with the according classification (see Section 1.1.). Further, the separation of instructional quality into sight structures and deep structures (see Section 1.1.1.), the division into general and subject-specific features within this field (see Section 1.1.2.), and the basic dimensions of instructional quality (see Section 1.1.3.) are explained in detail. Subsequently, the field of video-based research on instructional quality is considered in general (see Section 1.2.). After clarifying these theoretical aspects, three important research gaps within the field of instructional quality are derived from literature (see Section 1.3.). First, it is clarified that an overview of video-based research on instructional quality and conspicuous instructional quality features is missing, and possibilities of how to derive such overviews are explained (see Section 1.3.1.). Second, it is outlined which further or replicating analyses of instructional quality features in biology instruction are needed (see Section 1.3.2.). There is a specific need to analyze the basic dimensions of instructional quality and their interplay (see Section 1.3.2.1.), the fostering of students' scientific inquiry skills (see Section 1.3.2.2.), and the use of technical terms in biology instruction and its effects on student outcome variables (see Section 1.3.2.3). Finally, the necessity for the orchestration of effective instructional quality features in biology instruction is outlined (see Section 1.3.3.). All three research gaps are then reviewed in detail in the last section of the introduction (see Section 1.3.4.). After the introduction section, the three aims of this dissertation are clarified (see Section 2.) before the corresponding publications or manuscripts are presented in the results section (see Section 3.). Afterwards, the results (see Section 4.1.) and limitations of this dissertation (see Section 4.2.) are discussed, before future research possibilities (see Section 4.3.) and implications (see Section 4.4.) are outlined.

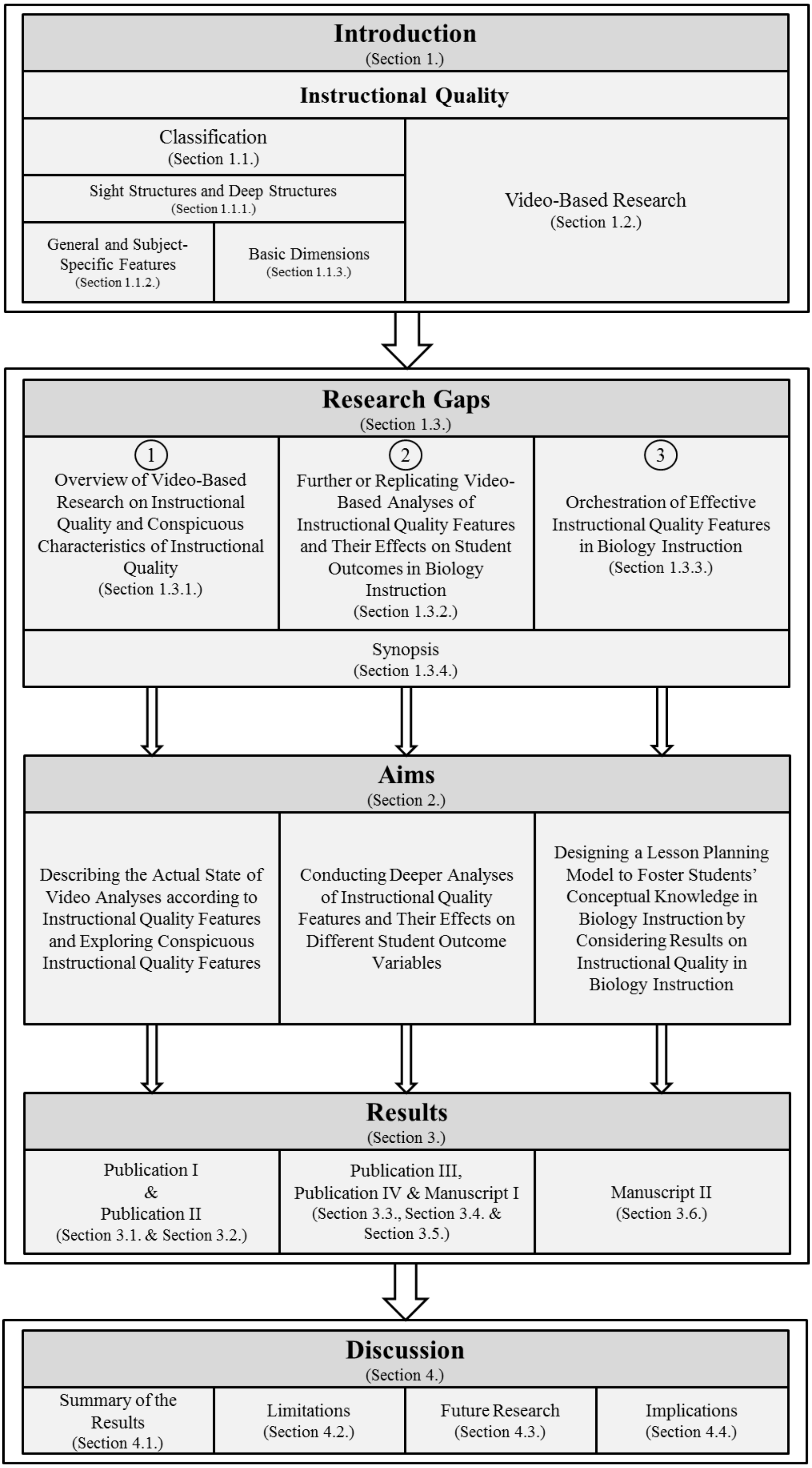

Fig. 1 Overview of the structure of this dissertation

1.1. Instructional Quality – Classification

The quality of instruction is widely accepted as playing a key role for students' learning (Kuijpers, Houtveen, & Wubbels, 2010; Wadouh, Liu, Sandmann, & Neuhaus, 2014). Therefore, many studies on teaching and teaching effectiveness have been conducted (Wadouh et al., 2014) in order to systematically discover relations of instructional quality features and student outcome variables, e.g. students' achievement (von Kotzebue et al., 2015). This research line is called process-(mediation-)product-paradigm (Brophy, 2000; Brunner et al., 2006; Neuhaus, 2007; von Kotzebue et al., 2015). Thereby, learning opportunities that a teacher offers constitute the process which can be used by students (= mediation), and the use of such learning opportunities could potentially lead to a higher learning outcome (= product) (Praetorius, Lenske, & Helmke, 2012; Steffensky & Neuhaus, 2018; von Kotzebue et al., 2015). Surely, instruction depends on several other factors, like contextual factors (e.g. family), individual requirements (e.g. intelligence), and teacher personality (e.g. professional knowledge). Helmke (2014) summarized these factors in a model called *supply-usage model* (see Fig. 2).

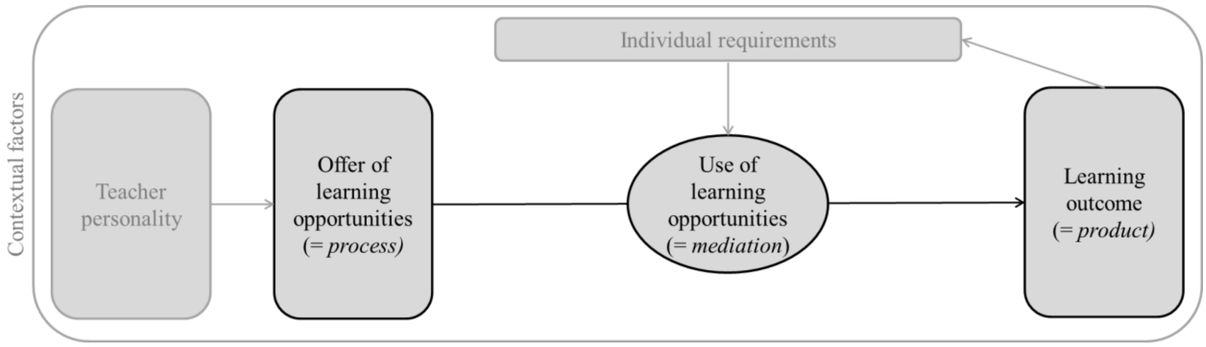

Fig. 2 *Supply-usage model* adapted from Helmke (2014)

Teaching effectiveness research determines features of instruction which are profitable for students regarding specific measurable criteria, e.g. achievement. Due to the amount of research on instructional quality features, different authors created lists and compilations of important and substantial instructional quality features (e.g. Brophy, 2000; Ditton, 2000; Helmke, 2014; Meyer, 2010; Slavin, 1997; Walberg & Paik, 2000). In this context, it is important to emphasize that successful instruction which leads to higher students' learning outcomes is not characterized by including a maximum amount of instructional quality features (Helmke & Schrader, 2008). Successful instruction is rather a meaningful and expedient orchestration of different instructional quality features (von Kotzebue et al., 2015; Wüsten, 2010).

1.1.1. Instructional Quality – Sight Structures and Deep Structures

Instructional quality is commonly differentiated between "sight structures" and "deep structures" (Kunter & Trautwein, 2013; Kunter & Voss, 2013; Oser & Baeriswyl, 2001). Kunter and Voss (2013) provide the following description for this differentiation:

> Sight structures relate to the overarching organizational characteristics of the classroom and include framework conditions, observable instructional arrangements, and teaching methods. Deep structures, in contrast, relate to characteristics of the immediate teaching and learning process and describe engagement with the learning material, students' interactions among themselves, and teachers' interactions with students. (p. 99)

Although the differentiation of sight structures and deep structures is not always distinct, it has proven to be valuable when describing the quality of instruction. Kunter & Voss (2013) concluded that "the presence of certain sight structures and the quality of deep structures vary largely independently from each other" (p. 99). Consequently, within the same sight structures completely different forms and qualities of deep structures may appear. Different independent studies on the quality of instruction (e.g. Hattie, 2009; Seidel & Shavelson, 2007; Wang, Haertel, & Walberg, 1993) have underlined that deep structures explain a greater amount of variance in student learning processes than sight structures (Kunter & Voss, 2013).

1.1.2. Instructional Quality – General and Subject-Specific Features

Instructional quality features can be divided into general and subject-specific features (Seidel & Shavelson, 2007; Wüsten, 2010; Wüsten et al., 2008, 2010). One reason for this division is that some instructional quality features are difficult to generalize or simply not transferable to other subjects (Neuhaus, 2007). Thus, general instructional quality features are suitable to describe the quality of teaching, independent of the content (Wüsten, 2010). For example, teacher feedback or direct versus problem-based instruction are general instructional quality features (Wüsten, 2010). In contrast, for subject-specific instructional quality features content is necessarily required (Dorfner, Förtsch, & Neuhaus, 2017). Neuhaus (2007) further separated subject-specific features into two categories:

(a) Features which need to be implemented in a subject-specific way but are nonetheless valid for most or more subjects. This means these features are content-specific, e.g. dealing with students' misconceptions.

(b) Features which are only specific for a single subject and subsequently are meaningless for most or all other subjects. For example, a proven instructional quality feature in biology is the intellectual change of system levels (molecule, cell, organism, population and ecosystem), which is meaningless for the majority of other subjects. (p. 247-249)

The increasing focus of empirical instructional research is on the examination of subject-specific instructional quality features as such features and their effects could vary across subjects (Neuhaus, 2007; Dorfner et al., 2017). Further, by conducting a meta-analysis of instructional quality features, Seidel and Shavelson (2007) examined that subject-specific quality features have a large effect on students' learning. To evaluate this result, further analyses of subject-specific instructional quality features are needed. For biology instruction, various subject-specific instructional quality features were identified and defined by Wüsten (2010) and Wüsten et al. (2008, 2010). Driven by the two questions of (a) how these subject-specific instructional quality features are implemented, and of (b) how effective these features are regarding to student outcomes, various analyses and studies in biology instruction referring to these features have been conducted. In Table 1, the identified subject-specific instructional quality features for biology instruction by Wüsten (2010) and Wüsten et al. (2008, 2010) with examples of analyses are presented. Research gaps within this field are missing both descriptive and deeper analyses in the form of replicating analyses which would add deeper and more precise knowledge about the occurrence and the effective use of subject-specific instructional quality features in biology instruction. In general, further or replicating analyses for the field of research on instructional quality are believed to gather deeper knowledge about the effectiveness of instructional quality features (Hellmich, 2010; Schramm, 2016).

Table 1 Subject-specific instructional quality features in biology instruction (cf. Wüsten, 2010; Wüsten et al., 2008, 2010), and examples of analyses

Subject-Specific Instructional Quality Features for Biology	Example of Analysis
The use of real or living objects	e.g. Wüsten, 2010
Making biological system levels explicit	e.g. Förtsch et al., 2018b
The competent handling of models	e.g. Werner, 2016
Sensible handling of students' conceptions	e.g. Förtsch et al., 2017
Sensible handling of anthropomorphism	e.g. von Kotzebue et al., 2019
Presence of core ideas	e.g. Heidenfelder, 2016
Orientation towards students' everyday life	e.g. Wüsten, 2010
Scientific inquiry in the lesson	e.g. Jatzwauk, 2007
The appropriate use of terminology	e.g. Wüsten, 2010
Technical accuracy and contextual coherence	e.g. von Kotzebue et al., 2019
Lucidity of content and organization of the content	e.g. Wüsten, 2010
The appropriate complexity of the lesson	e.g. Förtsch et al., 2018c
Use of cognitive challenging tasks	e.g. Jatzwauk et al., 2008
Use of subject-specific operators	e.g. Förtsch et al., 2018c

1.1.3. Instructional Quality – Basic Dimensions

Besides various analyses of single instructional quality features, there are efforts to bundle single instructional quality features. In Germany or German-speaking regions the approach of using the three basic dimensions of instructional quality is widely spread (Baumert et al., 2010; Klieme, Schümer, & Knoll, 2001; Lipowsky et al., 2009). This approach has substantially evolved by analyzing mathematics instruction (Schlesinger & Jentsch, 2016). The three basic dimensions of instructional quality are: *classroom management*, *supportive climate*, and *cognitive activation*.

Classroom management is concerned with the structure and organization of the instruction and management of students' behavior. Overall, the characteristics aim to generate time for students' learning activities (Allen et al., 2013; Klieme et al., 2001; Lenske et al., 2016; Pianta & Hamre, 2009; Pianta, Hamre, & Mintz, 2012; Praetorius, Pauli, Reusser, Rakoczy, & Klieme, 2014; Schlesinger & Jentsch, 2016). *Supportive climate* is defined by characteristics of a positive learning climate in the classroom which include instructional activities, which express a caring behavior of teachers, a positive teacher-student relationship and supportive approaches, e.g. constructive feedback (Klieme et al., 2001; Lipowsky et al., 2009; Praetorius et al., 2014; Schlesinger & Jentsch, 2016). *Cognitive activation* is the basic dimension, which to a great extent is defined through subject-specific characteristics of instruction (Dorfner et al., 2017; Schlesinger & Jentsch, 2016). Characteristics that define a cognitively activating instruction are: the application of higher order thinking skills, the fostering of students' in-depth understanding of the content, the consideration of students' prior knowledge, and the creation of content-related discourses (Allen et al., 2013; Förtsch, Werner, Dorfner, von Kotzebue, & Neuhaus, 2017; Lipowsky et al., 2009; Pianta & Hamre, 2009; Pianta et al., 2012; Praetorius et al., 2014; Schlesinger & Jentsch, 2016).

1.2. Instructional Quality – Video-Based Research

In general, instruction is a complex procedure in which many processes happen simultaneously and multidimensionally (Doyle, 2006). Thus, for an external observer it is a complex task to describe instructional processes (Kunter & Trautwein, 2013). Nowadays, video recordings of instruction present a well-established, modern and multi-perspective survey methodology which offers the possibility to observe instructional processes precisely (Janík, Seidel, & Najvar, 2009). The benefits of video recordings are that they are authentic and the entire process of lessons can be recorded (Jehle & Schluß, 2013; Pauli & Reusser, 2006; von Kotzebue et al., 2015). Starting from the first two extensive video studies in the context of the *TIMSS Studies*, the usage of video studies in research on instructional quality has largely evolved and grown, from serving as mere descriptions of instructional processes, to constituting a suitable and valuable tool for evaluating theoretical frameworks of instructional quality (Pauli & Reusser, 2006; Riegel, 2013).

Further, video studies offer the possibility to analyze the instructional quality of videotaped lessons quantitatively, qualitatively or as a combination of both methodologies, e.g. in the form of a mixed-method-design. Depending on the analyzed construct and the aim of the analysis, different quantitative and qualitative methods can be used. For quantitative analyses, time-based coding, event-based coding or ratings are commonly used (Wüsten, Schmelzing, Sandmann, & Neuhaus, 2013). The application of time-based coding requires the coding to be done by using fixed time-intervals (Wüsten et al., 2013). By applying the event-based coding, precise beginnings and endings of events, which are important and of interest for the analysis, have to be defined. Ratings can be used to assess the instructional quality of videotaped lessons (Wüsten et al., 2013). By using a rating, the expression of characteristics from a specific feature in the whole lesson is evaluated (Praetorius et al., 2012; Wüsten et al., 2013). For qualitative analyses, different strategies exist to analyze data, e.g. the inductive approach, grounded theory or discourse analysis (Thomas, 2006). Creswell (2012, p. 244) summarized and explained the commonly used qualitative coding method: the inductive approach. In this approach, the entire material is sighted in the first step, before important and relevant aspects are gradually identified which finally could lead to an identification of relevant topics (Creswell, 2012, p. 244; Thomas, 2006, pp. 241-242). Additionally, quantitative and qualitative survey methods could be used in combination to analyze videotaped lessons. A mixed procedure, in comparison to exclusively quantitative or qualitative approaches can lead to a more profound understanding of the underlying research problem or question (Creswell, 2012; Creswell & Plano Clark, 2011).

1.3. Research Gaps

1.3.1. Overview of Quantitative Video Studies and Conspicuous Instructional Quality Features

Nowadays, instead of simply accumulating results from research on instructional quality features it is required to systemize these results (Klieme, 2006). One way to implement such a systemization is by conducting a meta-analysis or a systematic literature review. Both methods can be used to get an overview of studies and their respective results. A meta-analysis summarizes and integrates statistical results from different studies and by this builds an integrated overall result. At the same time, the meta-analysis tries to explain the differences between the observed results. Existent research is thereby summarized and presented quantitatively (Eisend, 2014). In the field of research on instructional quality, some meta-analyses according to effective instructional quality features have already been conducted (e.g. Hattie, 2009; Kyriakides, Christoforou, & Charalambous, 2013; Seidel & Shavelson, 2007). Systematic reviews of research literature are a commonly used comparative method in many disciplines, e.g. in medical research or science education (Bennett, Lubben, Hogarth, & Campbell, 2005), with the aim to gain an understanding of the existing literature in a certain discipline and of how future research can add value to this field. In the field of quantitative video studies on instructional quality, a systematic review of the methodical and content-related orientation of existing studies is missing to date. So far, Praetorius et al. (2012) listed various video studies in the form of a table and fragmentarily named the analyses according to instructional quality features.

Qualitative research is a well-suited research method to address a research problem in which unknown variables have to be identified and explored. In some cases, the literature gives little information about a specific research problem or research question and through exploration of qualitative content a better understanding of the respective research problem or research question can be realized (Creswell, 2012). Therefore, a qualitative video analysis provides the opportunity to gain information about conspicuous instructional quality features. Furthermore, conducting a comparative qualitative multiple-case study of cases which have equal selection criteria could be useful to add information to the research field. The inductive coding process starts with a set of data which is systematically reduced by the identification of similar segments and by forming broader categories. For a short graphical illustration of the general inductive coding process, see Figure 3.

Stepwise reduction of data by identifying segments and forming categories

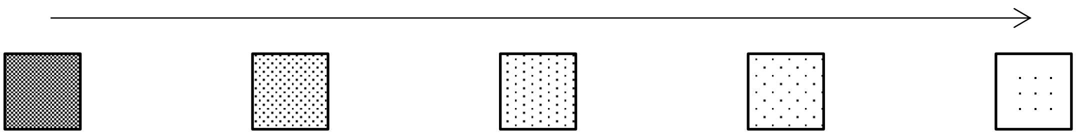

Fig. 3 General coding process in inductive analysis

1.3.2. Further or Replicating Video-Based Analyses of Instructional Quality Features in Biology Instruction

Based on the literature mentioned above, further or replicating video-based analyses seem to be valuable and necessary in the field of research on instructional quality. In short, deeper video analyses of the three basic dimensions of instructional quality in biology instruction are partially missing. Reviewing the conducted analyses of subject-specific instructional quality features for biology instruction by Wüsten (2010) and Wüsten et al. (2008, 2010) in detail, it became clear that *scientific inquiry in the lesson* (e.g. Jatzwauk, 2007) and *the appropriate use of terminology* (e.g. Wüsten, 2010) were analyzed only cursorily via video analyses in biology instruction. Thus, it can be assumed that further or replicating video analyses according to these features can be helpful to gain deeper knowledge about the occurrence and the effectiveness of these features in biology instruction. In the following, the theoretical background and possible future research activities on these features in biology instruction is described.

1.3.2.1. Basic Dimensions of Instructional Quality and Their Interplay

As mentioned above, making use of the three basic dimensions is a widely spread approach in classroom instruction in Germany and German-speaking regions (Baumert et al., 2010;

Klieme et al., 2001; Lipowsky et al., 2009). The three basic dimensions of instructional quality are: *classroom management*, *supportive climate*, and *cognitive activation* (Baumert et al., 2010; Klieme et al., 2001; Lipowsky et al., 2009). Various studies, as well as video studies, have shown effects of the three basic dimensions of instructional quality on different student outcome variables. However, several research gaps regarding to the analyses of the three basic dimensions of instructional quality in biology instruction exist. First, effects on students' situational interest were only examined fragmentarily. Second, many studies demonstrated effects of single basic dimensions, but did not consider all three basic dimensions in the same study. Third, a major research gap in research on instructional quality is that studies on the interplay of these three basic dimensions are missing (see Fig. 4). Considering the meta-analysis of Seidel and Shavelson (2007) which demonstrated that subject-specific features have larger effects on student outcomes than general instructional quality features, it could be assumed that the basic dimension *cognitive activation* which contains mostly subject-specific characteristics is more effective than the basic dimensions *classroom management* and *supportive climate* which include more general characteristics.

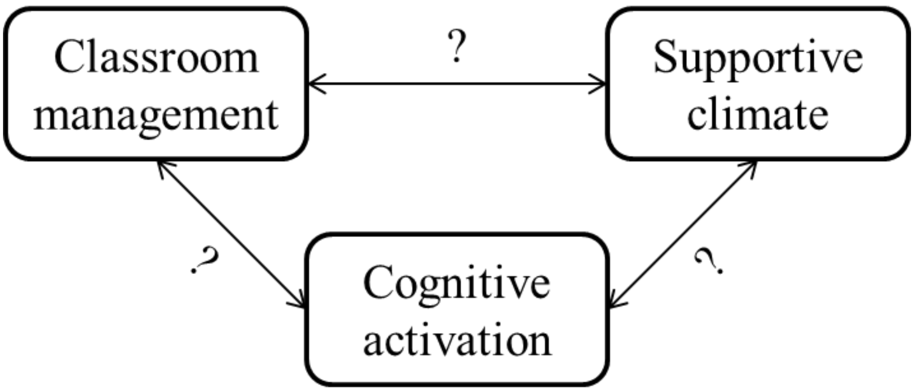

Fig. 4 Missing analyses on the interplay of the three basic dimensions of instructional quality

1.3.2.2. Fostering Students' Scientific Inquiry Skills

Scientific inquiry is a crucial subdimension of scientific literacy (Bybee, 2002; Kampa & Köller, 2016; Shavelson et al., 2008). Kampa and Köller (as cited in Shavelson et al., 2008) explained that the "procedural (step-by-step or condition-action) knowledge and reasoning with this knowledge" (p. 302) constitutes scientific inquiry. It follows that answering scientific questions can be seen as scientific inquiry (Nowak, Nehring, Tiemann, & Upmeier zu Belzen, 2013) but a homogeneous definition of this subdimension is not given until today (Lederman & Lederman, 2012; Nowak et al., 2013). Scientific inquiry, in turn, can be seen as a problem-solving task (Abd-El-Khalick et al., 2004; Klahr, 2000; Mayer, 2007; Nowak et al., 2013) with scientific reasoning as one crucial element thereof (Hartmann, Upmeier zu Belzen, Krüger, & Pant, 2015; Mayer, 2007; Nowak et al., 2013; Zimmerman, 2005). Further, Kampa and Köller (2016) found a high correlation between the subdimensions *content knowledge* and *scientific inquiry*. They concluded that "students could activate both subdimensions while solving scientific problems" (p. 918) and discussed that students may benefit from a knowledge transfer between those two subdimensions.

In the field of cognitive and developmental psychology, the constructs *scientific reasoning* and *argumentation* (SRA) have been studied for many years now (Chinn & Clark, 2013; Zimmerman, 2000). The basic intention for conducting studies in these disciplines has been to foster knowledge about the natural world and to support processes to explore, evaluate, revise, and communicate this knowledge (Klahr, Zimmerman, & Jirout, 2011). Scientific knowledge can be generated with various combinations of scientific process skills like observing or asking questions (Klahr & Dunbar, 1988; Kremer, Specht, Urhahne, & Mayer, 2013; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Roberts & Gott, 1999). During science instruction, skills of scientific inquiry are taken into account differently. For example, experiments are often implemented without asking questions or generating hypotheses (e.g. Bao et al., 2009; Hammann, 2004; Nehring, Stiller, Nowak, Upmeier zu Belzen, & Tiemann, 2016; Stiller, 2016). In biology lessons, little time is spent on using scientific working methods (e.g. experiments) (Berck & Graf, 2010; Füller, 1992; Gropengießer, 2013; Jatzwauk, 2007). In a first analysis of 45 videotaped biology lessons, Jatzwauk (2007, p. 133) found that questions and hypotheses were only generated in two of 45 lessons. Further, no experiments and scientific investigations were planned, but at least in four of these 45 lessons, experiments were conducted. However, a more interdisciplinary research to condense scattered knowledge on this topic over different research disciplines is needed (Fischer et al., 2014). Therefore, Fischer et al. (2014) developed and suggested a generic framework of SRA with eight epistemic activities to foster scientific reasoning skills domain-independently and interdisciplinarily. These eight epistemic activities are:

(1) Problem identification, (2) Questioning, (3) Hypothesis generation, (4) Construction and redesign of artefacts, (5) Evidence generation, (6) Evidence evaluation, (7) Drawing conclusions, and (8) Communicating and scrutinising (see Fig. 5).

The questions of interest are (a) how often these eight epistemic activities of SRA are already used in biology instruction, and (b) which of these epistemic activities are used in biology lessons. Furthermore, it is interesting to see whether these epistemic activities have an effect on students' achievement in biology.

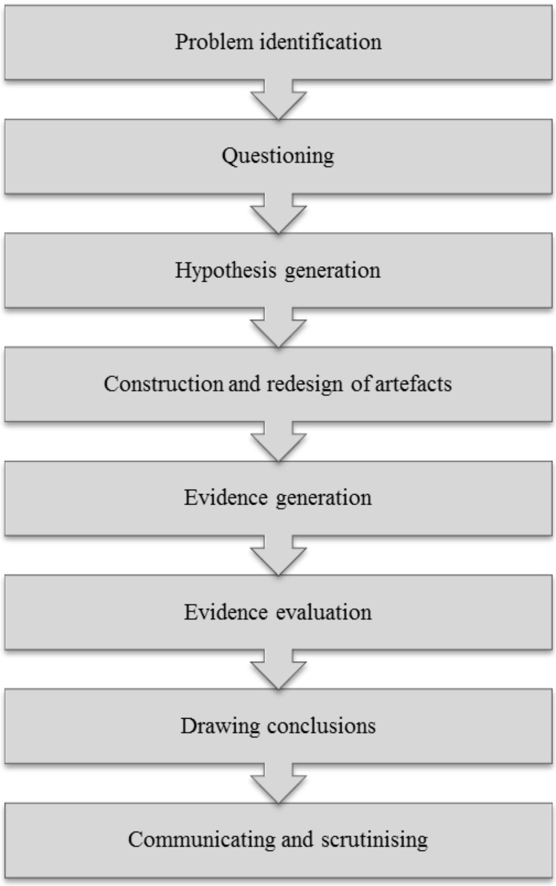

Fig. 5 The framework of SRA with eight epistemic activities from Fischer et al. (2014)

1.3.2.3. The Use of Technical Terms in Biology Instruction and its Effects on Student Outcome Variables

To foster students' scientific literacy, an increased, specialized support in reading, writing and science communication is needed (Krajcik & Sutherland, 2010; Nitz, Ainsworth, Nerdel, & Prechtl, 2014; Norris & Phillips, 2003; Yore, Pimm, & Tuan, 2007). Commonly, communicative processes are classified in everyday language and terminology (Nitz, 2016; Schaal, 2014). A certain terminology is necessary for a domain-specific communication and serves as an effective, context-independent and intersubjective exchange of information (Buhlmann & Fearns, 2000; Roelcke, 2010; Schmiemann, 2011; Wichter, 1994). Thereby, terminology in science ranges from verbal discourses and written texts to a variety of visual representations (e.g. graphs, diagrams, symbols, formulae) (Nitz et al., 2014). Technical terms can be seen as the smallest unit of terminology (Roelcke, 2010; Schmiemann, 2011) and have a decisive relevance in the context of terminology (Schmiemann, 2011). The German NES for the subject biology explicitly consider the use and handling of technical terms (KMK, 2005). Further, technical terms are suitable to describe concepts in science (McDonnell, Barker, & Wieman, 2016). Different studies showed that many technical terms are used in science textbooks (Graf & Berck, 1993; Groves, 1995; McDonnell et al., 2016; Yager, 1983), and that an unsystematic use of technical terms in biology classes overstrains students or negatively affects students' learning (Brown & Ryoo, 2008; Graf & Berck, 1993; Groves, 1995; Knippels, Waarlo, & Boersma, 2005; Lidbury & Zhang, 2008; McDonnell et al., 2016; Wandersee, 1988). A first video study of German biology instruction demonstrated that the percentage of technical terms during class discussions significantly reduces students' activity (Wüsten, 2010). This necessitates a more detailed research about the use and effects of technical terms on student outcome variables in biology instruction.

1.3.3. Orchestration of Effective Instructional Quality Features

1.3.3.1. Instructional Planning or Lesson Planning in General

Effective teaching starts with preparation in the form of instructional planning, also known as lesson planning (Greiman & Bedtke, 2008; Reiser & Dick, 1996). Planning the instruction gives the teacher "some control over what is going to happen as opposed to reacting only to what has happened" (Duke & Madsen, 1991, p. 11). Instructional planning, however, is a challenging and complex task (Meisert, 2013). First, all learning groups are heterogeneous, e.g. regarding to their interests, preconceptions or prior knowledge. Accessible learning pathways have to be created. Second, there are complex background requirements that derive from the educational system. For example, within the German NES or the curricula on the level of the Länder various aims are defined which should be achieved by instruction. Third, there is a great variety of possibilities to design instruction which are all based on different foci and learning theories (Meisert, 2013). Considering these aspects, Meisert (2013) concluded that the heart of planning instruction is to identify appropriate and possible learning pathways which fit to the prerequisites of the learners as well as to the aims which should be achieved by instruction.

The development of models for lesson planning has a long history and is a key aspect for the discipline of *pedagogy* (Kron, 2008; Meyer, 2014). More precise, a lesson planning model is a pedagogical instrument for analyzing and designing instructional actions (Jank & Meyer, 2002; Peterßen, 2006). The focus of these models is to make informed decisions about the learning goals, the content, the methods, and the media of the lesson (Jank & Meyer, 2002; Meyer & Meyer, 2007; Peterßen, 2006). There is a plethora of lesson planning models, most are established from the discipline of *pedagogy*. Jank and Meyer (2002) and Peterßen (2006) provide overviews of lesson planning models. In conclusion, there exist many lesson planning models for instructional planning in general from the discipline of *pedagogy* and *subject matter teaching*. With the introduction of the German NES, however, the question of how to implement these standards in regular instruction has been raised by educational researchers, practitioners, teacher educators, and curriculum developers. For biology instruction, the German NES strongly demand to foster students' conceptual knowledge (KMK, 2005). Thus, one main question is how to put the framework into practice. Until now, a lesson planning model which aims to foster students' conceptual knowledge in biology instruction has not been developed.

1.3.3.2. Designing a Lesson Planning Model to Foster Students' Conceptual Knowledge in Biology Instruction

More than ten years have passed since the introduction of the German NES. Within the subdimension *content knowledge*, it is proposed that core ideas are used to interconnect and foster students' conceptual knowledge. Conceptual knowledge can be described in different ways. De Jong and Ferguson-Hessler (1996) refer to conceptual knowledge as follows: "Conceptual knowledge is static knowledge about facts, concepts and principles that apply within a certain domain. Conceptual knowledge functions as additional information that problem solvers add to the problem and that they use to perform the solution" (p. 107). Additionally, Krathwohl (2002) emphasized that conceptual knowledge deals with "interrelationships among the basic elements within a larger structure that enable them to function together" (p. 214). Further, Krathwohl (2002) defines factual knowledge as "the basic elements that students must know to be acquainted with a discipline or solve problems in it" (p. 214). It can thus be derived that factual knowledge is the prerequisite for conceptual knowledge. The intention of the German NES for biology is to structure single facts by using three core ideas: structure and function, system, and development (Beyer, 2006; KMK, 2005; Neuhaus, Nachreiner, Oberbeil, & Spangler, 2014). Kampa and Köller (2016) describe content knowledge as knowledge about facts and concepts. Therefore, this subdimension deals with "declarative (factual, conceptual) knowledge… and being able to reason with this knowledge" (Shavelson, et al., 2008, p. 302). Further, content knowledge is not a simple recall of knowledge; it rather describes an active dealing and working with scientific content in order to solve problems (Kampa & Köller, 2016; Pant, et al., 2012). Students should have the ability to apply their knowledge in different situations and contexts. To this day no agreement on how to implement core ideas in regular biology instruction has been found. A first correlative video study analyzing regular German biology instruction showed positive effects of linking biological facts on students' conceptual knowledge, their willingness to make an effort, and their interest (Wadouh, 2007; Wadouh et al., 2014; Wadouh, Sandmann, & Neuhaus, 2009). Meanwhile, a further correlative video study and an intervention study which both were conducted in Germany outlined that fostering students' conceptual knowledge (Förtsch et al., 2018a) and using core ideas (Förtsch, Heidenfelder, Spangler, & Neuhaus, 2018b; Heidenfelder, 2016) have positive effects on students' conceptual knowledge. However, there is no stepwise description and systemization of effective instructional quality features that could be used for planning biology lessons which would primarily aim to foster students' conceptual knowledge.

1.3.4. Synopsis

In the following, the three research gaps are presented under consideration of conducted and missing analyses in research on instructional quality for biology instruction. Different analyses of several instructional quality features for other subjects, e.g. mathematics or physics, were conducted. Especially the three basic dimensions of instructional quality were frequently analyzed (cf. Dorfner et al., 2017). The intention of conducting a synopsis by exclusively considering research results on instructional quality for biology instruction was to present the state of the art of research in this specific field, and thereby substantiate the importance of filling the three derived research gaps with this dissertation. For the synopsis, the classification into three basic dimensions of instructional quality which consider more general instructional quality features (Dorfner et al., 2017) and subject-specific-instruction quality features which were adapted and supplemented by the work of Wüsten (2010) and Wüsten et al. (2008, 2010) is used (see Fig. 6). First, an overview of video-based research on instructional quality and conspicuous instructional quality features is missing. Second, deeper analyses of video-based analyses of instructional quality features and their effects on students' outcomes are not provided profoundly. In detail, the basic dimensions *classroom management* and *supportive climate* have not been thoroughly analyzed by using quantitative video studies in biology instruction. Further, *the use of living objects, making biological system levels explicit, presence of core ideas, scientific inquiry in the lesson,* and an *appropriate use of terminology* have not been considered for quantitative video analyses in biology instruction. Three of those missing deeper analyses were conducted within this dissertation. The theoretical background for these three missing deeper analyses is described within previous sections: *basic dimensions of instructional quality and their interplay* (see Section 1.3.2.1.), *fostering students' scientific inquiry skills* (see Section 1.3.2.2.), and *the use of technical terms in biology instruction and its effects on student outcome variables* (see Section 1.3.2.3.). Third, there are various practically oriented approaches of instructional planning in biology instruction. Those approaches have a specific focus on several instructional quality features, e.g. *presence of core ideas* (Förtsch et al., 2018b; Heidenfelder, 2016) or *engaging students in* *constructing scientific explanations* (Nawani et al., 2018). A lesson planning model that orchestrates theoretical, empirical and practical pieces of work on instructional quality features is missing to this day.

	① Overview?	② Further analyses?	③ Orchestration?
	Instructional Quality Features	**Deeper Analyses of Effects of Instructional Quality Features on Students' Outcome Variables from Quantitative Video Studies in Biology Instruction**	**Practically Oriented Approaches of Instructional Planning in Biology Instruction**
Basic dimensions of instructional quality	Classroom management	?	?
	Supportive climate	?	?
	Cognitive activation	Förtsch et. al, 2017; Förtsch et al., 2016	?
Subject-specific instructional quality features (supplemented and adapted list from Wüsten, 2010; Wüsten et al., 2008, 2010)	The use of real or living objects	?	?
	Making biological system levels explicit	?	Förtsch et al., 2018b; Heidenfelder, 2016
	The competent handling of models	Förtsch et al., 2018d; Werner, 2016	?
	Sensible handling of students' conceptions	Förtsch et al., 2017	?
	Sensible handling of anthropomorphism	von Kotzebue et al., 2019	?
	Presence of core ideas	?	Förtsch et al., 2018b; Heidenfelder, 2016
	Orientation towards students' everyday life	Nawani et al., 2017	Förtsch et al., 2018b; Heidenfelder, 2016
	Scientific inquiry in the lesson	?	?
	Appropriate use of terminology	?	?
	Technical accuracy and contextual coherence	von Kotzebue et al., 2019	?
	Lucidity of content and organization of the content	Nawani et al., 2018	Förtsch et al., 2018b; Heidenfelder, 2016
	The appropriate complexity of the lesson	Förtsch et al., 2018c; Nawani et al., 2016	?
	Use of cognitive challenging tasks	Förtsch et al., 2018c; Nawani et al., 2016	?
	Use of subject-specific operators	Förtsch et al., 2018c; Nawani et al., 2016	?
	Using focus questions	Nawani et al., 2017	?
	Engaging students in constructing scientific explanations	Nawani et al., 2018	Nawani et al., 2018
	Exploring students' prior knowledge	Förtsch et al., 2018a	?
	Dealing with students' ideas	Förtsch et al., 2018a	?
	Knowledge linking	Förtsch et al., 2018a; Wadouh, 2007; Wadouh et al., 2014	?

Fig. 6 Synopsis of the three research gaps with conducted and missing analyses in research on instructional quality for biology instruction

2. Aims

The three main aims of this dissertation were (1) to get an overview of video-based research on instructional quality and conspicuous instructional quality features, (2) to conduct further or replicating video analyses of instructional quality features in biology instruction and (3) to orchestrate effective instructional quality features meaningfully in the form of a lesson planning model. Since a lesson planning model to foster students' conceptual knowledge in biology instruction is not existent so far, the focus was to develop such a lesson planning model. To reach these aims, the following analyses were conducted:

a) Systematic overview of video analyses according to instructional quality features in science subjects and mathematics

(Publication I: **Dorfner, T.**, Förtsch, C., & Neuhaus, B. J. (2017). Die methodische und inhaltliche Ausrichtung quantitativer Videostudien zur Unterrichtsqualität im mathematisch-naturwissenschaftlichen Unterricht. Ein Review. *Zeitschrift für Didaktik der Naturwissenschaften, 23*(1), 261-285. doi: 10.1007/s40573-017-0058-3)

b) Video-based qualitative analysis of conspicuous instructional quality features by using data of three different video studies in biology instruction

(Publication II: **Dorfner, T.**, Förtsch, C., Boone, W., & Neuhaus, B. J. (2017). Instructional quality features in videotaped biology lessons: Content-independent description of characteristics. *Research in Science Education.* doi: 10.1007/s11165-017-9663-x)

c) Quantitative analyses of the three basic dimensions of instructional quality in videotaped biology lessons and their interplay

(Publication III: **Dorfner, T.**, Förtsch, C., & Neuhaus, B. J. (2018). Effects of three basic dimensions of instructional quality on students' situational interest in sixth-grade biology instruction. *Learning and Instruction, 56,* 42-53. doi: 10.1016/j.learninstruc.2018.03.001)

d) Video-based analyses and practical implementations according to students' scientific inquiry skills in biology instruction

(Publication IV: **Dorfner, T.**, Förtsch, C., Germ, M., & Neuhaus, B. J. (2018). Biology instruction using a generic framework of scientific reasoning and argumentation with suggested lessons. *Teaching and Teacher Education, 75,* 232-243. doi: 10.1016/j.tate.2018.07.003)

e) Video transcript analysis of use and effects of technical terms and their consequences for biology instruction

(Manuscript I: **Dorfner, T.**, Förtsch, C., & Neuhaus, B. J. (2018). *Use of technical terms in German biology lessons and its effects on students' conceptual learning*. Manuscript submitted for publication.)

f) Finally, for designing the lesson planning model which aimed to foster students' conceptual knowledge in biology instruction the results from the mentioned analyses were used. Besides, empirical results from prior video studies and intervention studies in biology instruction that reflect the outcome of fostering students' conceptual knowledge were taken into account. Those studies were conducted over the last ten years within the working group of Prof. Neuhaus.

(Manuscript II: **Dorfner, T.**, Förtsch, C., Spangler, M., & Neuhaus, B. J. (in press). Wie plane ich eine konzeptorientierte Biologiestunde? Ein Planungsmodell für den Biologieunterricht – Das Schalenmodell. *Der mathematische und naturwissenschaftliche Unterricht (MNU).*)

In conclusion, the aims of this dissertation were achieved as follows:

1) First aim: Describing the actual state of video analyses according to instructional quality features and exploring conspicuous instructional quality features.

→ Publication I and Publication II.

2) Second aim: Conducting deeper analyses of instructional quality features and their effects on different student outcome variables.

→ Publication III, Publication IV and Manuscript I.

3) Third aim: Designing a lesson planning model to foster students' conceptual knowledge in biology instruction by considering empirical results from the working group of Prof. Neuhaus over the last ten years.

→ Manuscript II.

A complete overview of the aims of this dissertation including graphically interrelations of each publication or manuscript is given in Figure 7.

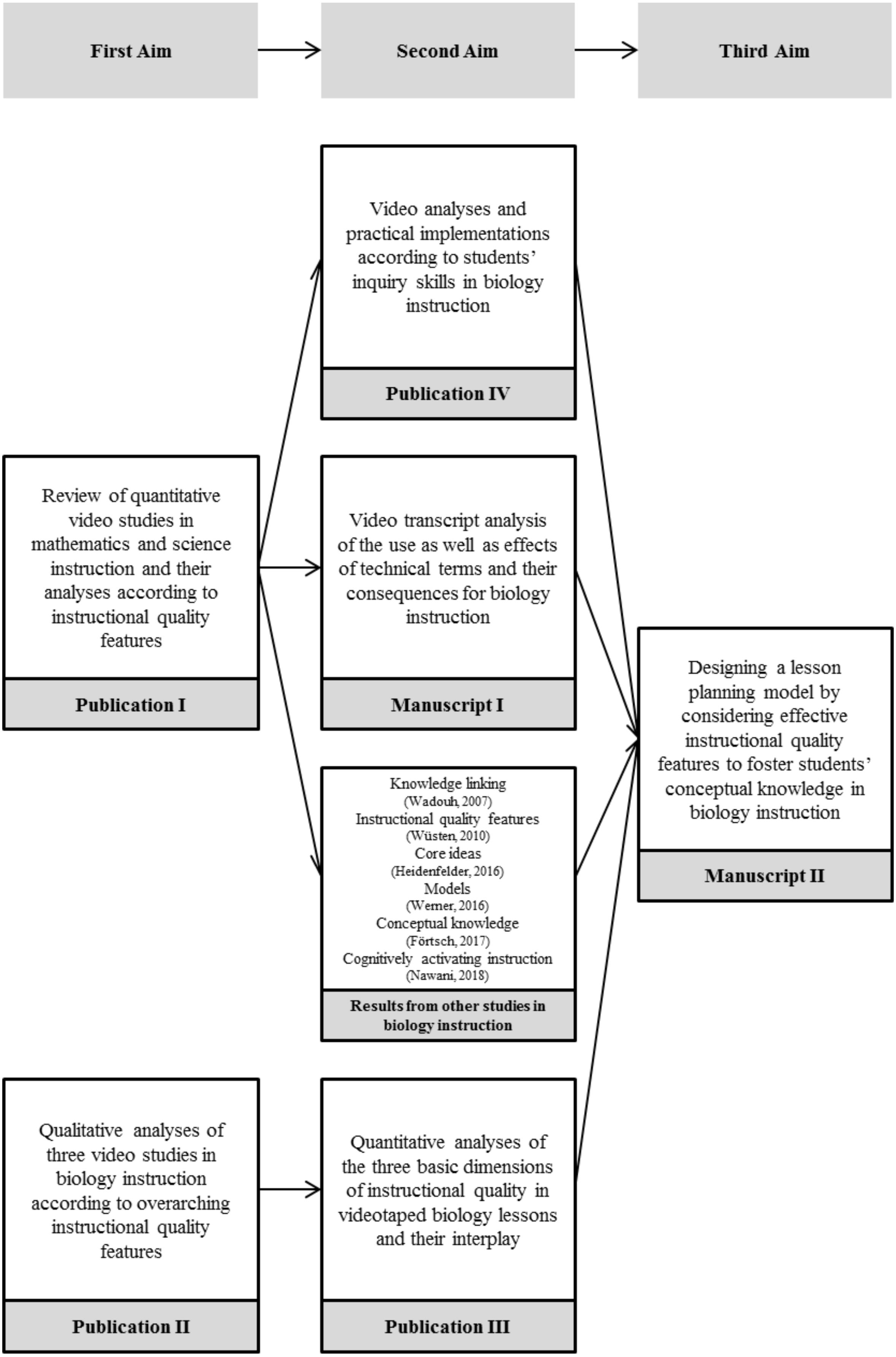

Fig. 7 Overview of the aims of the dissertation

For all video analyses data from the following three projects were used:

1) German Research Foundation (DFG)-funded project Teaching and Learning of Science (*nwu Essen* [German acronym for the project]) (Jatzwauk, Rumann, & Sandmann, 2008; Nawani, Rixius, & Neuhaus, 2016; Wadouh et al., 2014)

2) DFG-funded project Competence-orientation and Task Culture in Nature and Science Instruction (*LerNT* [German acronym for the project]) (Förtsch et al., 2017; von Kotzebue et al., 2015)

3) BMBF-funded project Professional Knowledge of Science Teachers (*ProwiN* [German acronym for the project]) (Förtsch, Werner, von Kotzebue, & Neuhaus, 2016; Jüttner, Boone, Park, & Neuhaus, 2013; Tepner et al., 2012; von Kotzebue et al., 2015; Werner, 2016; Werner, Förtsch, Boone, von Kotzebue, & Neuhaus, 2017)

All three projects *nwu Essen*, *LerNT* and *ProwiN* are cross-sectional quantitative video studies. Additionally, different questionnaires and achievement tests were used. The design of the video studies and the relevant students' variables are presented in Figure 8.

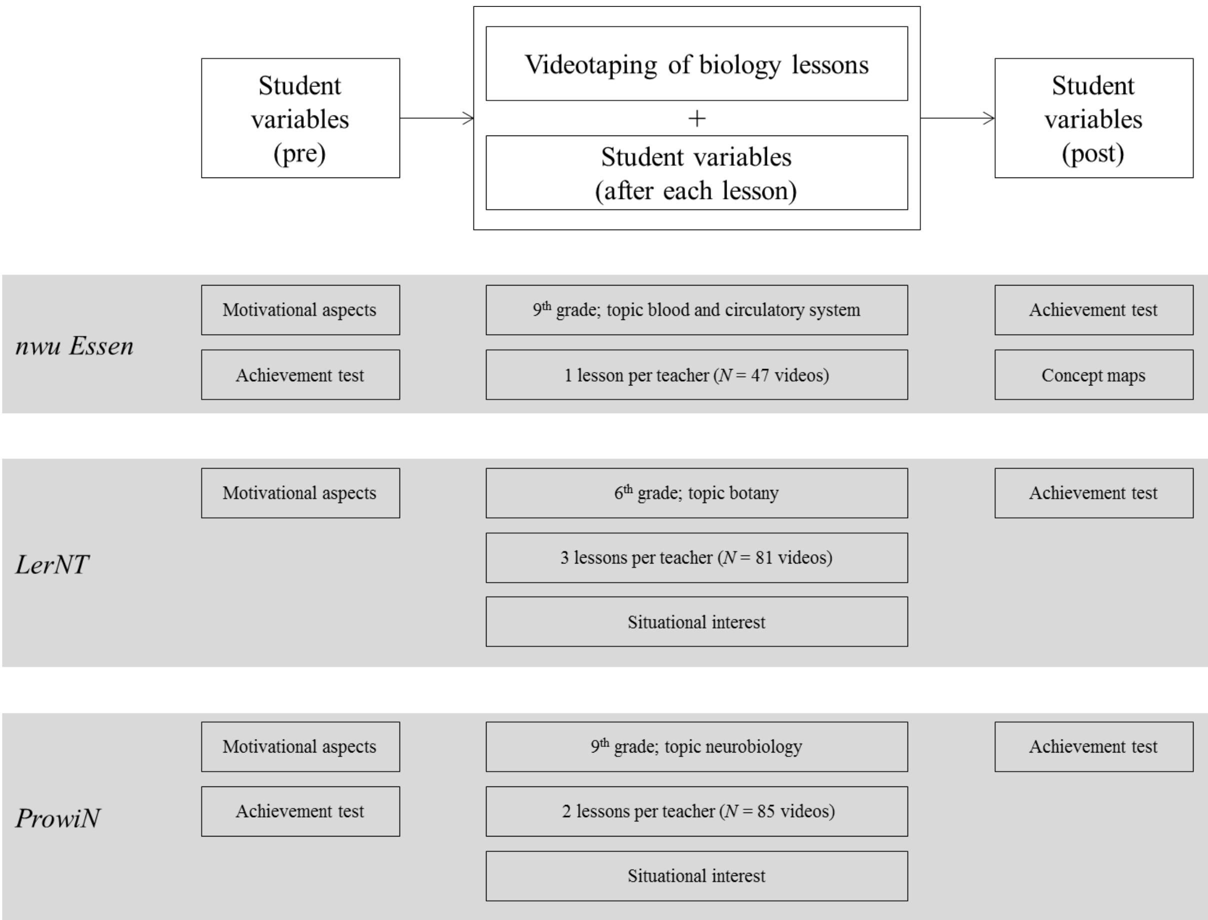

Fig. 8 Overview of the design of the video studies and the relevant students' variables

In the project *nwu Essen*, 47 biology teachers from German secondary schools (Gymnasium) participated. Of each teacher, one lesson with the topic *blood and circulatory system* in grade nine was videotaped (N = 47 videos). In the project *LerNT*, three lessons in German secondary schools (Gymnasium) from 28 biology teachers were videotaped (N = 81 videos). The topic was *botany* with the subtopic *growth and generation of energy* and the lessons were taught in grade six. In the project *ProwiN*, two lessons in grade nine with the topic *neurobiology* from 43 biology teachers in German secondary schools (Gymnasium) were videotaped (*N* = 85 videos).

Before the videotaping the participating students of all three projects answered a questionnaire about motivational aspects and completed different achievement tests before and/or after the videotaping. Additionally, the students who participated within the projects *LerNT* and *ProwiN* completed a questionnaire about their situational interest directly after each videotaped lesson.

3. Results

3.1. Publication I

Tobias Dorfner, Christian Förtsch, and Birgit J. Neuhaus

Die methodische und inhaltliche Ausrichtung quantitativer Videostudien zur Unterrichtsqualität im mathematisch-naturwissenschaftlichen Unterricht. Ein Review.

accepted for publication in

Zeitschrift für Didaktik der Naturwissenschaften

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2017). Die methodische und inhaltliche Ausrichtung quantitativer Videostudien zur Unterrichtsqualität im mathematisch-naturwissenschaftlichen Unterricht. Ein Review. *Zeitschrift für Didaktik der Naturwissenschaften, 23*(1), 261-285. doi: 10.1007/s40573-017-0058-3

3.2. Publication II

Tobias Dorfner, Christian Förtsch, William Boone, and Birgit J. Neuhaus

Instructional quality features in videotaped biology lessons: Content-independent description of characteristics

accepted for publication in

Research in Science Education

Dorfner, T., Förtsch, C., Boone, W., & Neuhaus, B. J. (2017). Instructional quality features in videotaped biology lessons: Content-independent description of characteristics. *Research in Science Education.* doi: 10.1007/s11165-017-9663-x

3.3. Publication III

Tobias Dorfner, Christian Förtsch, and Birgit J. Neuhaus

Effects of three basic dimensions of instructional quality on students' situational interest in sixth-grade biology instruction

accepted for publication in

Learning and Instruction

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2018). Effects of three basic dimensions of instructional quality on students' situational interest in sixth-grade biology instruction. *Learning and Instruction, 56,* 42-53. doi: 10.1016/j.learninstruc.2018.03.001

3.4. Publication IV

Tobias Dorfner, Christian Förtsch, and Birgit J. Neuhaus

Biology instruction using a generic framework of scientific reasoning and argumentation with suggested lessons

accepted for publication in

Teaching and Teacher Education

Dorfner, T., Förtsch, C., Germ, M., & Neuhaus, B. J. (2018). Biology instruction using a generic framework of scientific reasoning and argumentation with suggested lessons. *Teaching and Teacher Education, 75,* 232-243. doi: 10.1016/j.tate.2018.07.003

3.5. Publication V

Tobias Dorfner, Christian Förtsch, and Birgit J. Neuhaus

Use of technical terms in German biology lessons and its effects on students' conceptual learning

accepted for publication in

Research in Science & Technological Education

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2019). Use of technical terms in German biology lessons and its effects on students' conceptual learning. *Research in Science & Technological Education*. doi:10.1080/02635143.2019.1609436

3.6. Publication VI

Tobias Dorfner, Christian Förtsch, Michael Spangler, and Birgit J. Neuhaus

Wie plane ich eine konzeptorientierte Biologiestunde? Ein Planungsmodell für den Biologieunterricht – Das Schalenmodell

accepted for publication in

MNU Journal

Dorfner, T., Förtsch, C., Spangler, M., & Neuhaus, B. J. (2019). Wie plane ich eine konzeptorientierte Biologiestunde?: Ein Planungsmodell für den Biologieunterricht - Das Schalenmodell. *MNU Journal*, *4*, 300-306.

4. Discussion

In the following, the results of all four publications and two manuscripts are summarized and discussed, with regard to the three aims of this dissertation. In the beginning, the actual state of video analyses according to instructional quality features and conspicuous instructional quality features is discussed. The presented further or replicating video analyses of instructional quality features in biology instruction are subsequently considered for discussion. Thereupon, the design of the lesson planning model which aimed to foster students' conceptual knowledge in biology instruction is shortly described and discussed. Additionally, limitations of this dissertation are outlined, before possible follow-up studies for future research are explained. Finally, implications of this dissertation are drawn and clarified.

4.1. Summary of Results

The aims of this dissertation were (1) to get an overview of video-based research on instructional quality and conspicuous instructional quality features, (2) to conduct further or replicating video analyses of instructional quality features in biology instruction, and (3) to orchestrate effective instructional quality features meaningfully in the form of a lesson planning model. Therefore, the current state of video analyses according to instructional quality features was considered first, resulting in a literature review about video-based research. Furthermore, a qualitative video analysis was conducted to generate a deeper understanding of conspicuous instructional quality features. Using this approach, conspicuous instructional quality features were identified. These first two steps were followed by the conduction of three different deeper analyses of instructional quality features with video data and the examination of effects of these instructional quality features on different student outcome variables. First, the basic dimensions and their interplay in biology instruction were analyzed. Second, the effective use of scientific inquiry skills in biology instruction was examined, and third, the effective use of terminology in biology instruction was investigated. In a last step, effective instructional quality features were sorted and orchestrated in the form of a lesson planning model to foster students' conceptual knowledge in biology instruction. The core findings according to the three aims of this dissertation are presented in Figure 9.

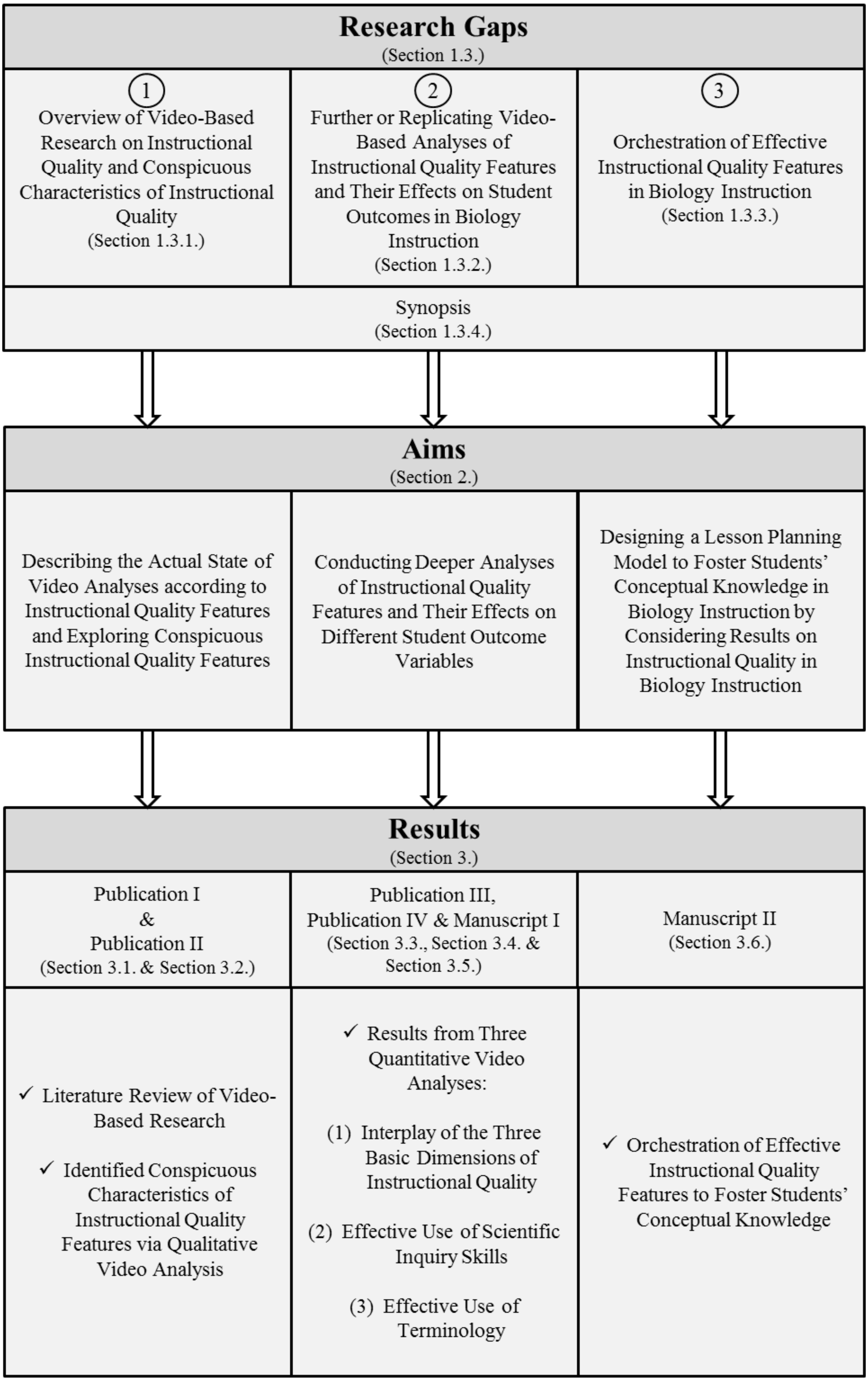

Fig. 9 Summary of the core findings of this dissertation

As a result of the literature review it has been shown that the three basic dimensions of instructional quality, *classroom management*, *supportive climate*, and *cognitive activation* (Baumert et al., 2010; Klieme et al., 2001; Lipowsky et al., 2009) were analyzed in many video studies. In addition to these often-conducted video analyses, many single general and subject-specific instructional quality features were analyzed by using video data. Further, the comparative qualitative video analyses showed that a higher level of characteristics of the three basic dimensions occur in higher achieving classes. Still, to this day the research on the interplay of these basic dimensions has not come to distinct results. Inspired by these results and aspects, the three basic dimensions of instructional quality and their interplay were analyzed. These analyses showed that *classroom management* and *supportive climate* are prerequisites to design cognitively activating instruction. Further, two video analyses of subject-specific instructional quality features for biology instruction were conducted, filling an important gap of knowledge. Therefore, the framework of SRA by Fischer et al. (2014) and the usage of technical terms in biology instruction were analyzed. The analysis of the framework of SRA by Fischer et al. (2014) showed that this framework is an effective methodical tool to foster students' learning. The analysis of technical terms in biology instruction showed that the reduced usage of technical terms seems necessary to foster students' conceptual knowledge. In the end, the results of these analyses and previous insights of the working group of Prof. Neuhaus from the last ten years were considered and orchestrated in the form of a lesson planning model. This lesson planning model can be used to foster students' conceptual knowledge in biology instruction. The findings of each publication or manuscript of this dissertation are summarized in Figure 10. Additionally, the interrelations of these results and previous research results, which lead to the design of the lesson planning model, are graphically illustrated. In the following, the results are described in further detail.

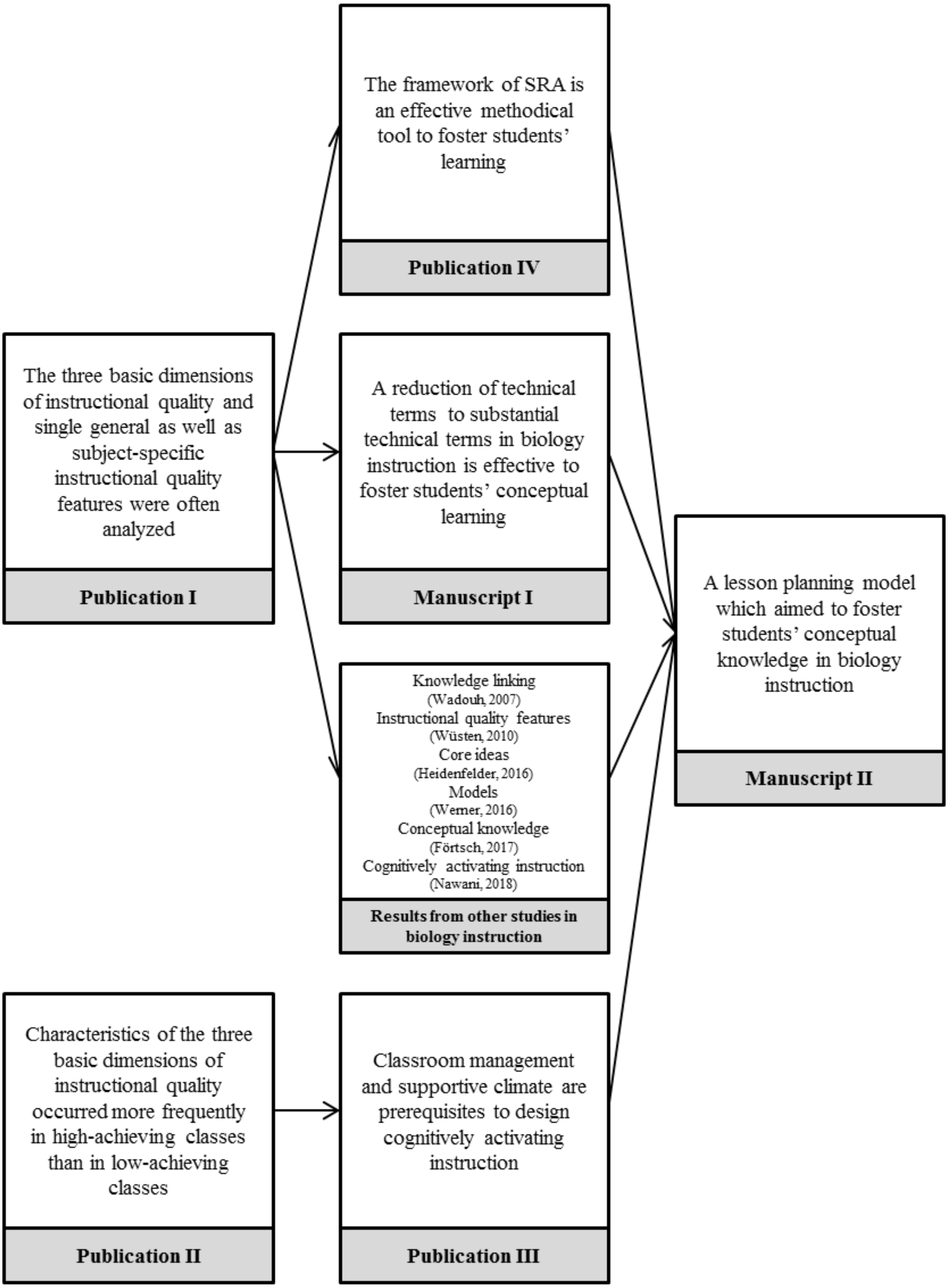

Fig. 10 Summary of the results of this dissertation and the interrelations of results, as well as previous research results which lead to the design of the lesson planning model

4.1.1. Overview of Video-Based Research on Instructional Quality and Conspicuous Instructional Quality Features

In summary, the review about quantitative video studies suggests that descriptive or statistical correlation analyses of instructional quality features and student outcome variables were often reported. Besides superficial sight structures, the three basic dimensions *classroom management*, *supportive climate* and *cognitive activation* (Baumert et al., 2010; Klieme et al., 2001; Lipowsky et al., 2009) were mainly analyzed as deep structures. Although many studies analyzed similar instructional quality features, the operationalization of these instructional quality features differed between the studies. Thus, a more systematic relation to the operationalization of previous studies is recommended for future studies as to use a more similar operationalization of instructional quality features. Further, future studies should systematically report statistical correlations between instructional quality features and student outcome variables to enable the implementation of meta-analyses about key findings from video analyses. Therefore, it is advisable to consistently report effect sizes within the statistical results. Additionally, most studies were more strongly focusing on describing the videotaped instruction than on suggesting further improvements for teaching. Hence, a more specific focus should be set on how instruction can be improved based on the results of video analyses.

The conducted qualitative study showed that observed characteristics of the three basic dimensions *classroom management*, *supportive climate*, and *cognitive activation* occurred more frequently in high-achieving classes than in low-achieving classes. From this it can be derived that the three basic dimensions are useful to describe a part of the instructional quality in biology instruction. Additionally, the study provides further information about the independence of the three basic dimensions of instructional quality from the content in biology instruction. Two limitations of this study are that no statements could be made (a) about how the three basic dimensions depend on each other and (b) if they influence students' learning in a direct or indirect way. Further, with the approach of using three basic dimension of instructional quality the complete instructional quality can not be displayed. Thus, it is not possible to adequately analyze subject-specific characteristics, like using experiments or using models in biology instruction, with the described approach.

The review as well as the qualitative study outlined that the approach of using three basic dimensions is commonly used and well-suited to describe a part of the instructional quality in science instruction. However, three main research gaps exist. First, the basic dimension *supportive climate* has not yet been analyzed for biology instruction. Second, the interplay of these basic dimensions is not clarified until now. Third, the approach using three basic dimensions of instructional quality does not sufficiently cover subject-specific instructional quality features in biology instruction. Consequently, current and further analyses regarding subject-specific instructional features need to be conducted using video data.

4.1.2. Further or Replicating Video-Based Analyses of Instructional Quality Features and Their Effects on Student Outcomes in Biology Instruction

Three video analyses according to instructional quality features and their effects on different student outcome variables were conducted. Considering their results, partly initial and additional information about effective instructional quality features in biology instruction could be derived. In the following, reasons for conducting these analyses are explained, and the results of the analyses are discussed.

In order to close the research gap of not understanding the interplay of the basic dimensions, analyses according to the well-established approach using three basic dimensions of instructional quality, *classroom management, supportive climate* and *cognitive activation*, were conducted. Second, as required by different authors (e.g. Hellmich, 2010; Schramm, 2016) two further or replicating video analyses were conducted to gain deeper insights into *scientific inquiry in the lesson* (e.g. Jatzwauk, 2007) and *the appropriate use of terminology* (e.g. Wüsten, 2010) which both were analyzed only cursorily using video data until now. Therefore, the use of a generic framework of scientific reasoning and argumentation (SRA) in biology instruction was analyzed to get further information about fostering students' scientific inquiry skills. The reasons for conducting this analysis were that (a) SRA is seen as a crucial element of the subdimension *scientific inquiry* (Hartmann et al., 2015; Mayer, 2007; Nowak et al., 2013; Zimmerman, 2005), and that (b) the two subdimensions *content knowledge* and *scientific inquiry* highly correlate. Thus, students are able to activate both for solving scientific problems which means that students may benefit from a knowledge transfer between both subdimensions (Kampa & Köller, 2016). Further, the use of technical terms in biology instruction was studied to make more precise statements about the effectiveness for students' conceptual knowledge. Within the framework of the German NES for biology, the use and handling of technical terms are explicitly mentioned (KMK, 2005). Additionally, technical terms are viewed as necessary for describing concepts in science (McDonnell et al., 2016). In the following, the results of these analyses are discussed.

First, the results according to the interplay of the three basic dimensions of instructional quality are discussed. Descriptively, the analyses of the three basic dimensions showed that the more general constructs *classroom management* and *supportive climate* were well established in the analyzed videotaped biology lessons. In contrast, the more subject-specific construct *cognitive activation* was not often implemented in these lessons. There was a large variance of occurrence of all three basic dimensions of instructional quality across the videotaped lessons. Further, possible dependences of these three basic dimensions were shown graphically. In this study, *cognitive activation* has a higher dependence on *classroom management* than on *supportive climate*. However, several strict provisions were made to preserve the interdependence of measurements of these three basic dimensions. It was found that all three basic dimensions had direct positive effects on students' situational interest. These findings are in line with those of other research (Fauth, Decristan, Rieser, Klieme, & Büttner, 2014; Förtsch et al., 2017; Kunter et al., 2013; Lipowsky et al., 2009; Seidel, Rimmele, & Prenzel, 2003; Waldis, Grob, Pauli, & Reusser, 2010; Ziegelbauer, Gläser-Zikuda, & Girwidz, 2010). Additionally, the regression model in which all three basic dimensions of instructional quality could predict students' situational interest provides evidence that only *cognitive activation* is a predictor of students' situational interest (cf. Fauth et al., 2014). Thus, it was hypothesized that the basic dimension *cognitive activation* that contains the most subject-specific characteristics mediates the effects of the two other basic dimensions, *classroom management* and *supportive climate*, on students' situational interest. Therefore, multilevel analyses of three mediation models were conducted that confirmed the hypothesis. It can thus be concluded that *classroom management* and *supportive climate* can be interpreted as basic conditions that have to be established before implementing cognitively activating strategies during instruction (see Fig. 11). Hence, teachers need to provide good *classroom management* and positive *supportive climate* to the students at first, for that they can then cognitively activate the students.

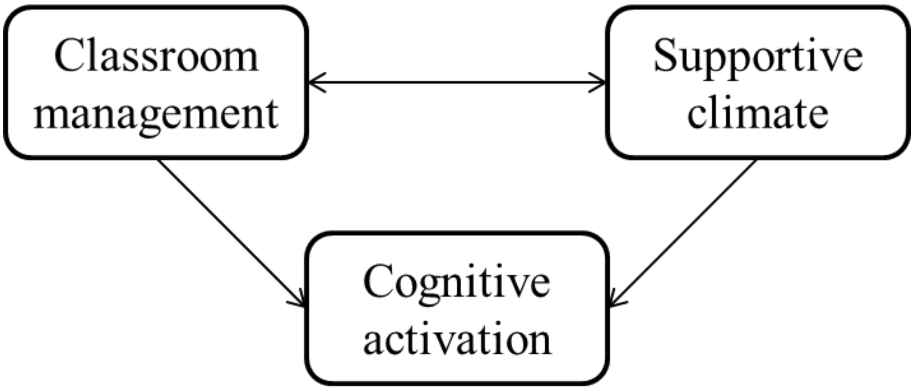

Fig. 11 Interplay of the three basic dimensions of instructional quality

These findings fill a gap in research on general and subject-specific dimensions of teaching that sets the basis for future studies. It can be concluded that subject-specific characteristics are necessary to foster students' situational interest. Although *cognitive activation* includes mostly subject-specific characteristics of instructional quality and is an effective basic dimension of instructional quality, not all subject-specific characteristics are covered with this interdisciplinarily valid basic dimension (Dorfner et al., 2017; Kunter & Trautwein, 2013). This study strengthens the sensitivity for and the more detailed investigation of subject-specific instructional quality features.

Second, the results from the analysis according to the use of a generic framework of scientific reasoning and argumentation (SRA) in biology instruction are discussed. In this study, it was first examined how often the epistemic activities of the framework by Fischer et al. (2014) were used in videotaped biology lessons. It has been shown that the epistemic activities were not used at all in some of the analyzed lessons, and that not all eight epistemic activities were observed in any of the lessons. Thus, using more epistemic activities to illustrate the students how to work as a scientist could be beneficial. It was then shown which epistemic activities were used in the lessons. In most of the lessons, the two epistemic activities *evidence generation* and *evidence evaluation* were used. Few of the epistemic activities *problem identification*, *questioning* or *hypothesis generation* were identified. These results were in line with other studies which concern the scientific inquiry process (Hammann, 2004; Nehring et al., 2016; Sodian, Zaitchik, & Carey, 1991; Stiller, 2016). Further, two lacks of linkage were being detected. The first one was between the epistemic activities *questioning* and *hypothesis generation* that intend to show students why evidence has to be generated, as well as the activities in which evidence is generated and evaluated. The second lack was between the two epistemic activities *construction and redesign of artefacts* which constitutes an activity to plan evidence generation, and *evidence generation*. In conclusion, students might not got an idea of how to plan evidence generation, they simply conducted scientific methods. The last two activities *drawing conclusions* and *communicating and scrutinizing* were occasionally observed in the videotaped lessons. It is remarkable that in spite of minor levels of epistemic activities used in a continuous way during the videotaped lessons, a positive significant effect of the epistemic activities on students' achievement, which included both subdimensions *content knowledge* and *scientific inquiry* of the German NES, was resulting. This result can be interpreted similarly to how Kampa and Köller (2016) discussed their results. During the problem-solving process, students activate elements from both subdimensions. Consequently, students can benefit from a knowledge transfer from one subdimension to the other, and the use of elements from one subdimension might foster students' learning in both subdimensions. In conclusion, the framework of SRA with eight epistemic activities from Fischer et al. (2014) is a possible and feasible methodical tool to foster students' learning in both subdimensions.

Third, the use and effects of technical terms on student outcomes in biology lessons with the specific topic *reflex arc* were examined. For the analyses, these lessons are comparable regarding the taught content so that more detailed conclusions about the use and effects of technical terms on student outcomes can be drawn. It has been found that many different technical terms were used in the biology lessons under study, and that teachers used more technical terms than students. The received results of the unsystematic use and large number of technical terms during teaching are in line with results from older studies in science instruction (e.g. Graf & Berck, 1993; Groves, 1995; Wandersee, 1988; Yager, 1983). Regarding the fact that the German NES explicitly emphasize the professional use and handling of technical terms (KMK, 2005), the obtained results are quite worrying since over the past two decades only little change in the use of technical terms in biology instruction has been perceived. Further, it was examined in detail which technical terms were used in the biology lessons with the specific topic *reflex arc*. In addition, the effects of the number of different technical terms used in the lessons on the student outcome variables, students' achievement and students' situational interest, were examined. In both cases, negative effects of a higher number of different technical terms on the two outcome variables were found. These results reinforce the interpretation of the descriptive results as students may struggle with the handling of too many different technical terms, and therefore, conceptual knowledge can not be fostered. In conclusion, reducing the usage of technical terms to essential technical terms, and interrelating familiarized technical terms in the form of a schema, are two beneficial ways to foster students' conceptual knowledge (Craik & Lockhart, 1972; Förtsch et al., 2018b; Klauer & Leutner, 2007; Nachreiner, Spangler, & Neuhaus, 2015; Schneider &

Hardy, 2013; Sweller, van Merriënboer, & Paas, 1998; van Merriënboer & Sweller, 2005; Wouters, Paas, & van Merriënboer, 2008).

4.1.3. The Orchestration of Effective Instructional Quality Features in Biology Instruction

A large number of lesson planning models exist to describe instructional planning in general (cf. Peterßen, 2006). With the introduction of the German NES, practical instructions for implementing these standards in regular instruction are desired by practitioners, teacher educators, curriculum developers and educational researchers. Until now, a lesson planning model for biology instruction that aimed to foster students' conceptual knowledge as required by the German NES has not been developed. Therefore, a lesson planning model to foster students' conceptual knowledge in biology instruction was systematically designed by considering results from this dissertation and results from previous studies according to effective instructional quality features. General and subject-specific instructional quality features were arranged in a meaningful order which has also been required by several authors (Dorfner et al., 2017; von Kotzebue et al., 2015; Wüsten, 2010). Therefore, three layers (*relationship layer*, *linking layer*, and *content layer*) were defined. These three layers were drawn on a time axis. It is vital to mention that the time frames on the time axis should definitively not be read as fixed time frames for teaching. Within the *relationship layer* an increased number of general instructional quality features is considered, within the *linking layer* and the *content layer* an increased number of subject-specific instructional quality features are included. The general structure of the lesson planning model is summarized in Figure 12. The basic structure of this lesson planning model was first mentioned by Neuhaus and Spangler (2018) in an interview article about core ideas and cumulative learning in biology instruction. However, the structure and the instructional actions of this lesson planning model were not described until this point.

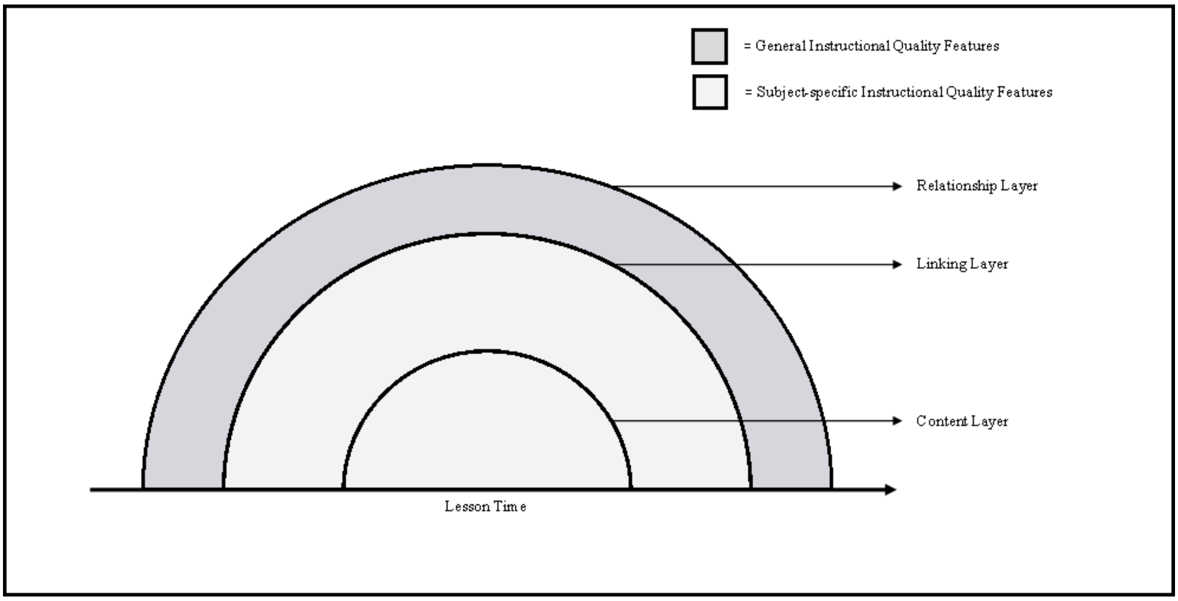

Fig. 12 General structure of the lesson planning model with three layers: *relationship layer*, *linking layer*, and *content layer* (adapted from Neuhaus & Spangler, 2018)

Some important conclusions for research as well as for teacher education can be drawn from the lesson planning model. First, general and subject-specific instructional quality features are not mutually exclusive but need to be harmonized in a specific way. It is not possible that only general as well as only subject-specific instructional quality features reflect the entire instructional quality within a lesson. Thus, the discussion in research about effective instructional quality features should finally consider the aspect of harmonizing instructional quality features, because effects and influences of some instructional quality features (e.g. classroom management) on student outcome variables are partly sufficiently evaluated, whereas their interplay has still not been sufficiently investigated (Dorfner et al., 2017). Second, not all instructional quality features named within the lesson planning model can be considered to the exact same extent in lessons that are planned with this model. The lesson planning model represents a pattern which has to be applied individually, depending on students' prior knowledge, skills and constitution. Third, the lesson planning model does not generally fit for all biology lessons. For example, students require prior knowledge to understand several biological topics and to connect biological knowledge. Further, students need to understand how to conduct biological methods, e.g. how to conduct experiments or how to use models. Considering the fact that the learning of conceptual knowledge requires a high level of cognitive load from the students (Förtsch et al., 2018b; Heidenfelder, 2016), an imprudent and unsystematic use of the lesson planning model could lead to cognitive overload. Consequently, the application of the lesson planning model should be well-considered, taking the students' abilities into account. Therefore, the lesson planning model needs to be evaluated in further studies and has to be tested according to its practicability for teaching biology.

Moreover, this lesson planning model may be adapted for other subjects as it includes several instructional quality features that are valid for other subjects, too (e.g. classroom management). One possibility for the adaption can be that the structure of this lesson planning model remains, whilst adapting the model by cancelling valid subject-instructional quality features for biology, e.g. using models, and adding or replacing appropriate subject-specific instructional quality features which are specifically valid for the corresponding subject. Still, this is a vague hypothesis which should be precisely verified by future research.

4.1.4. Synopsis

In the following, the results are discussed by considering conducted and missing analyses in research on instructional quality for biology instruction. As mentioned in the introduction section, this synopsis serves as a kind of assistance to classify the research results from this dissertation within the context of biology instruction. There are research results on instructional quality features, e.g. the basic dimensions of instructional quality, for several subjects. In particular, instructional quality features were analyzed in mathematics and in physics instruction (cf. Dorfner et al., 2017). However, it has been outlined that instructional quality features and their arrangement vary across subjects. Especially subject-specific instructional quality features are not valid across subjects (Neuhaus, 2007). This means, further research on instructional quality in each subject is needed to gain precise knowledge about the occurrence and the effectivity of instructional quality features. This dissertation hence makes a significant contribution towards filling knowledge gaps in the field of instructional quality. The achieved results offer new insights on instructional quality features and their effects for biology instruction. As mentioned above, this synopsis was created by using the classification of the three basic dimensions of instructional quality and subject-specific instructional quality features by supplementing and adapting the work of Wüsten (2010) and Wüsten et al. (2008, 2010). In this overview, the mentioned research gaps are now filled with results from this dissertation (see Fig. 13). An overview of video-based research on instructional quality and conspicuous instructional quality features is given. Further, three detailed video analyses were conducted according to the three basic dimensions, scientific inquiry, and terminology in biology instruction. Furthermore, a lesson planning model which considers theoretical and empirical as well as practical work about instructional quality features from the working group of Prof. Neuhaus from the last ten years has been developed.

It can be seen that deeper analyses using video data are still missing, but two of those instructional quality features (*making biological system levels explicit* and *presence of core ideas*) have already been analyzed with an intervention study (Förtsch et al., 2018b; Heidenfelder, 2016). Their effects have already been determined although video analyses are not yet provided. Further, *the use of real or living objects* has not yet been analyzed in secondary schools, but Kohlhauf, Rutke and Neuhaus (2011) conducted an intervention study for preschools. The results provide important information about the effectiveness of these instructional quality features but future video analyses for secondary schools would result in specific knowledge about their effectiveness.

In summary, there are three instructional quality features which have not yet been analyzed using video data, and the majority of instructional quality features has not yet been analyzed with practical approaches. Furthermore, replicating analyses of all results according to the effectiveness of instructional quality features in biology instruction have to be conducted to substantiate these results. Thus, this dissertation draws a more holistic picture of research on instructional quality in biology instruction. As already suggested, further research within this research field is necessary and indispensable in order to get deeper insights about the occurrence of features in biology instruction as well as about their effects on students' outcomes. Thus, the education and training of biology teachers could be effectively improved in applying these instructional quality features.

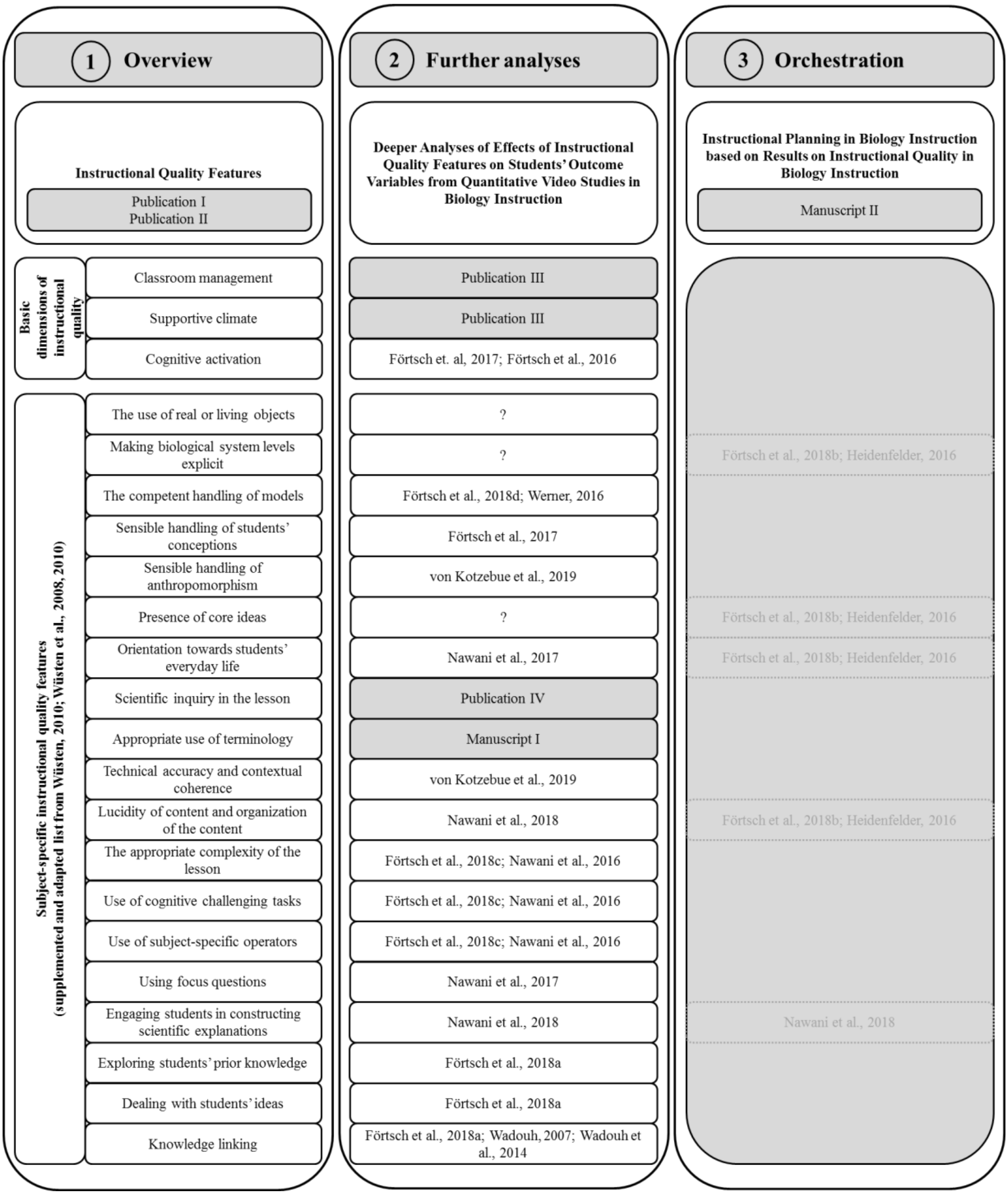

Fig. 13 Synopsis of results by considering conducted and missing analyses in research on instructional quality for biology instruction

4.2. Limitations

There are some limitations of this dissertation. A first limitation appears in the selection of the participating teachers in all three video studies. All teachers were asked to participate voluntarily on these video studies. Thus, it can be assumed that the three samples consist of highly motivated and engaged teachers. A positive pre-selection of teachers could hence not be prevented. However, in two of the three video studies (*LerNT* and *ProwiN*) participating teachers and students were asked to rate the authenticity of the videotaped lessons directly after each videotaping. Both groups of participating teachers rated the videotaped lessons as typical for their regular instruction which is similar to reports from other video studies. Hence, it seems that cameras in the classroom have a negligible effect on instruction (Riegel, 2013).

As a second limitation it emerges that the three video studies were videotaped in only two of 16 federal states in Germany. One video study (*nwu Essen*) was conducted in the federal state of North-Rhine Westphalia, and two video studies (*LerNT* and *ProwiN*) were conducted in the federal state of Bavaria. Thus, the results according to effective instructional quality features can hardly be generalized for German biology instruction. In order to provide more general conclusions about instructional quality features and their effects, biology teachers in further regional areas and additional biological topics need to be analyzed.

A third limitation concerning the measure of instructional quality is that primarily teachers' actions, e.g. using elements of SRA, have been coded. However, not only the teachers' actions during instruction are important for being effective for students, but also the students' use of such offered learning opportunities is of great relevance (e.g. Helmke, 2014). Thus, even if instruction offers learning opportunities, it can not be guaranteed to have positive effects on students' learning. To make clearer statements about the effectivity of instruction, students' use of learning opportunities has to be taken into account by future studies.

Fourth, the lesson planning model is developed theoretically. Therefore, the practical functionality of this model has to be tested in further studies in order to get tangible results and draw profound conclusions about effects on students' conceptual knowledge using this lesson planning model. This limitation is addressed by the discussion of two follow-up studies, which are presented in the following paragraph.

4.3. Future Research

The results of this dissertation add several new aspects to the field of research on instructional quality which are suggested to be further examined in the future. First, the review about quantitative video studies and their analyses is a first approach to systemize results of video-based research on instructional quality. In future research, a meta-analysis can provide more detailed information about the effectiveness of instructional quality features in single subjects. This leads to a second aspect for future research, because all results, according to the deeper analyses of instructional quality features, have to be replicated and analyzed for other grades and other school forms (e.g. primary school) in order to draw more generalized conclusions about their effectiveness. Third, regarding the developed lesson planning model to foster students’ conceptual knowledge in biology instruction, two ideas for possible follow-up studies aroused. In general, the follow-up studies aim to reinforce the intention of the lesson planning model: fostering students’ conceptual knowledge. The separate aims of the two studies are shortly described in Figure 14. In the following, the aims and the procedure of the two follow-up studies are exemplified, described and discussed.

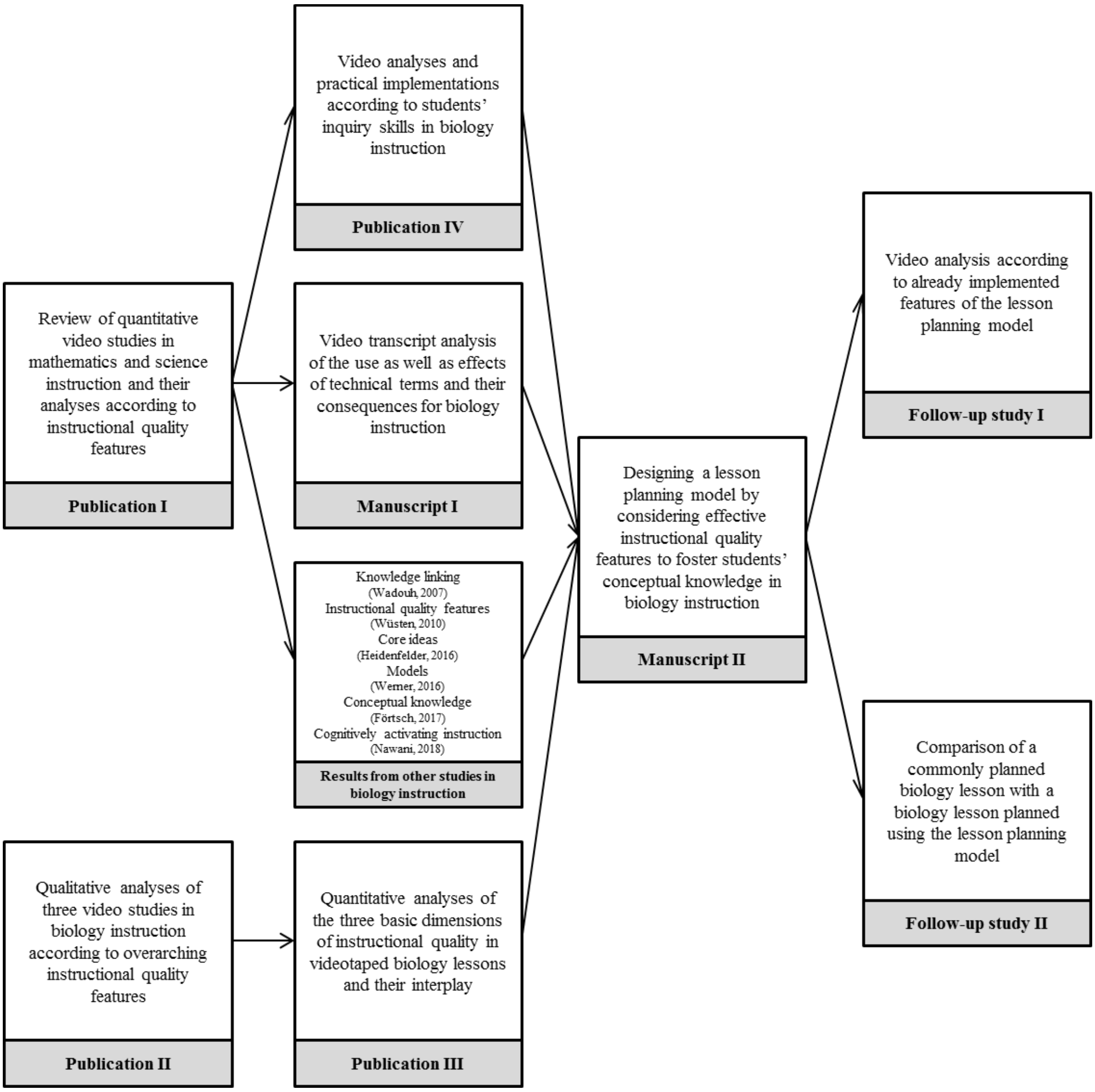

Fig. 14 Two follow-up studies which result from the lesson planning model

First, since biology teachers apply some of the model’s features unconsciously and intuitively, a description of the actual state of the use of elements of the lesson planning model in regular biology lessons would be of interest. By describing the already used elements of the lesson planning model it could be shown which of them need to be addressed specifically in teacher trainings. Additionally, the quality of already implied features could be described. In order to address these aims, video analyses would be an appropriate methodical tool. Videotaped regular biology lessons could be coded quantitatively according to the time spent on the main phases of the lesson planning model. Additionally, the occurring features within each phase could be coded qualitatively as well. By extracting qualitative examples, biology teachers could be provided with practical examples which are at this time theoretically described in the lesson planning model.

Further, it is suggested that specific effects on different student outcome variables (e.g. situational interest or conceptual understanding) of the presented lesson planning model have to be evaluated. Therefore, a comparison of two biology lessons which are planned and conducted using two different approaches seems appropriate. For the first lesson, a voluntarily participating teaching person (e.g. an advanced student teacher) could plan a biology lesson without prior knowledge about the lesson planning model. Hence, the teaching person plans a biology lesson using his acquired knowledge about teaching, especially teaching biology. For the first biology lesson, no advice about how to teach using the lesson planning model is given. For the second biology lesson, the teaching person would explicitly be provided with specific information about how to use and apply the presented lesson planning model and would be required to implement the features of the lesson planning model. For both lessons, the same or at least a closely related biological topic, e.g. mitosis and meiosis, should be used. In order to compare the two lessons, the lesson plans could be used for comparison, applying a coding scheme. Further, the lessons could be conducted in real classrooms. By this, different student outcome variables, e.g. their situational interest or their conceptual understanding could be evaluated with a questionnaire. By using this approach, resulting effects of the lesson planning model on student outcome variables could be shown.

4.4. Implications

The question about effective instruction has been under study for a long time. Therefore, many instructional quality features have been identified, analyzed, and evaluated (e.g. Hattie, 2009; Helmke, 2014; Seidel & Shavelson, 2007). In research on instructional quality, video analyses have made a substantial and profitable contribution to identify instructional quality features and draw conclusions about their effectiveness on student outcome variables (von Kotzebue et al., 2015). Despite of the long existence of the research field of instructional quality, research gaps do exist. With this dissertation, three main research gaps could have been filled. The results of the present work have several implications for theory and practice. In short, the results (a) of the overview of video-based research on instructional quality and about conspicuous instructional quality features, (b) of the three further or replicating video analyses of instructional quality features in biology instruction, and (c) of the lesson planning model for fostering students' conceptual knowledge can be used for teaching biology and improving biology instruction. Thus, findings of this dissertation have implications for educational research, educational practice as well as for teacher educators and curriculum developers as explained in the following sections.

First, the review about quantitative video studies on instructional quality in mathematics and science instruction can be of great help for educational researchers to identify research gaps within this research field. Overall, this review should encourage researchers to conduct a meta-analysis about quantitative video studies on instructional quality within these subjects. A meta-analysis within this field could provide more detailed information about the effectiveness of instructional quality features. The qualitative approach of analysis provides useful insights about the three basic dimensions of instructional quality. Characteristics of these basic dimensions seem to be more conspicuous in higher achieving classes than in lower achieving classes, but the approach of using three basic dimensions can definitely not explain the entire effect of instructional quality in biology. For example, using models, conducting experiments or using terminology are not covered by this approach. Additionally, the approach of using three basic dimensions rather covers general instructional quality features than subject-specific instructional quality features. Further, the study of Seidel and Shavelson (2007) displayed that subject-specific instructional quality features have greater effects on students' achievement than general instructional quality features. Considering these aspects, the qualitative study allows and prompts researchers to identify single instructional quality features and their effects on student outcomes more accurately and precisely, and extends the theoretical research by not only using the approach of three basic dimensions of instructional quality. With respect to the high effectiveness of subject-specific instructional quality features on student outcomes, research on these features has to be expanded and intensified by educational research. Additionally, the developed rating manuals of all analyses could be used for further research in order to replicate these findings for biology instruction in other grades or other school forms, e.g. in primary schools. Further, as already mentioned above, follow-up studies using the designed lesson planning model need to be conducted to draw a more holistic picture of the use and effectiveness of this lesson planning model in biology instruction.

Second, the results of this dissertation have implications for educational practice. Using the lesson planning model for biology lessons as well as using results from the findings according to the instructional quality features are major tasks for practitioners. Especially teacher educators are required to develop possibilities of assistance for practitioners to show how features of the rating manuals or of the lesson planning model could be implemented during biology instruction. In particular, practitioners need assistance for linking single biological facts with each other during classroom discourse, e.g. by using appropriate questions. In this context, a frequently asked question is which competences teachers need to educate students more effectively. Blömeke, Gustafsson, and Shavelson (2015) developed a teaching competence model in which teachers' disposition, e.g. their pedagogical content knowledge, mediated specific skills according to the situation. More precisely, perception, interpretation, and decision-making lead to an observable teaching performance. One example is the project *UNI-Klassen* (Förtsch et al., 2016) which uses empirical tested rating manuals to improve pre-service teachers' disposition and their noticing and professional vision, which are specific skills in action that are used situationally. Noticing consists of three key aspects:

> (a) identifying what is important or noteworthy about a classroom situation; (b) making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent; and (c) using what one knows about the context to reason about classroom interactions (van Es & Sherin, 2002, p. 573).

Professional vision includes "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (Goodwin, 1994, p. 606). Therefore, for the project *UNI-Klassen*, a biology classroom was equipped with permanently installed video cameras which transmit the videotaped biology instruction to an observation room in real time. This project setting is used for seminars at university in which pre-service teachers conduct biology lessons, while other participants of this seminar observe and evaluate the instruction by using empirical tested rating manuals. In this setting, not only the rating manuals, but also the lesson planning model could be used to analyze pre-service teachers' instruction. With this approach constructive feedback according to elements of the lesson planning model could be given. Applying this setting, pre-service students get an evidence-based, criteria-based, and comprehensible feedback on their biology lessons. Finally, several external frame conditions must be provided in order to implement effective instructional quality features, e.g. the cognitive activation of students, or elements of the lesson planning model in regular biology lessons. Although educational standards, e.g. the German NES, require fostering students' conceptual knowledge in biology, this requirement needs to be considered in curricula by scheduling enough time for biology instruction, which would allow teaching biology to use effective instructional quality features or elements of the lesson planning model in regular instruction. This is due the fact that the useful consideration of instructional quality features or elements of the lesson planning model during regular biology instruction needs some time.

Overall, this dissertation has made a substantial contribution by filling three main research gaps in research on instructional quality: (a) provide an overview of video-based research on instructional quality and conspicuous instructional quality features, (b) conduct further or replicating video analyses of instructional quality features in biology instruction, and (c) orchestrate effective instructional quality features in the form of a needed lesson planning model to foster students' conceptual knowledge in biology instruction as required by the German NES.

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6. Abbreviations

BMBF	German Federal Ministry of Education and Research
DFG	German Research Foundation
KMK	Standing Conference of the Ministers of Education and Cultural Affairs of the Länder
LerNT	Competence-orientation and Task Culture in Nature and Science Instruction
NES	National Education Standards
nwu Essen	Teaching and Learning of Science
ProwiN	Professional Knowledge of Teachers in Science
SRA	Scientific Reasoning and Argumentation
TIMSS	Third International Mathematics and Science Study

Erklärung über die Eigenanteile bei Ko-Autorenschaft

Hiermit wird bestätigt, dass die folgenden vier Publikationen und die zwei Manuskripte federführend von Herrn Tobias Dorfner im Rahmen seiner Dissertation abgefasst wurden. Dies geschah mit folgenden Anteilen:

Publication I

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2017). Die methodische und inhaltliche Ausrichtung quantitativer Videostudien zur Unterrichtsqualität im mathematisch-naturwissenschaftlichen Unterricht. Ein Review. *Zeitschrift für Didaktik der Naturwissenschaften, 23*(1), 261-285. doi: 10.1007/s40573-017-0058-3

Herr Tobias Dorfner hat die Recherchetätigkeit nach quantitativen Videostudien durchgeführt, die benutzten Kodierungsmanuale entwickelt, die Daten statistisch ausgewertet, die Daten für die Publikation aufgearbeitet, den Artikel konzipiert und ihn federführend geschrieben.

Die Koautorin und der Koautor entwickelten das Studiendesign, wirkten bei der Weiterentwicklung der Kodierungsmanuale mit, unterstützten bei der Datenerhebung und -deutung und trugen substantiell zur Überarbeitung der Publikation bei.

Publication II

Dorfner, T., Förtsch, C., Boone, W., & Neuhaus, B. J. (2017). Instructional quality features in videotaped biology lessons: Content-independent description of characteristics. *Research in Science Education.* doi: 10.1007/s11165-017-9663-x

Herr Tobias Dorfner hat die Studie federführend bewerkstelligt, die qualitative Datenauswertung konzipiert und durchgeführt, die Daten statistisch ausgewertet, die Daten für die Publikation aufgearbeitet, den Artikel konzipiert und ihn federführend geschrieben.

Die Koautorin und die beiden Koautoren entwickelten das Studiendesign, stellten die Fragebögen zusammen, unterstützten bei der Datenerhebung und -deutung und trugen substantiell zur Überarbeitung der Publikation bei.

Publication III

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2018). Effects of three basic dimensions of instructional quality on students' situational interest in sixth-grade biology instruction. *Learning and Instruction, 56*, 42-53. doi: 10.1016/j.learninstruc.2018.03.001

Herr Tobias Dorfner hat die Studie federführend durchgeführt, die Ratingmanuale weiterentwickelt, die Daten statistisch ausgewertet, die Daten für die Publikation aufgearbeitet, den Artikel konzipiert und ihn federführend geschrieben.

Die Koautorin und der Koautor entwickelten das Studiendesign, stellten die Fragebögen zusammen, unterstützten bei der Datenerhebung und -deutung und trugen substantiell zur Überarbeitung der Publikation bei.

Publication IV

Dorfner, T., Förtsch, C., Germ, M., & Neuhaus, B. J. (2018). Biology instruction using a generic framework of scientific reasoning and argumentation with suggested lessons. *Teaching and Teacher Education, 75,* 232-243. doi: 10.1016/j.tate.2018.07.003

Herr Tobias Dorfner hat die Studie federführend durchgeführt, die Ratingmanuale weiterentwickelt, die Daten statistisch ausgewertet, die Daten für die Publikation aufgearbeitet, die Beispielunterrichtsstunden für Biologieunterricht erarbeitet, den Artikel konzipiert und ihn federführend geschrieben.

Die Koautorin und die beiden Koautoren entwickelten das Studiendesign, stellten die Fragebögen zusammen, unterstützten bei der Datenerhebung und -deutung und trugen substantiell zur Modifizierung der Beispielunterrichtsstunden für Biologieunterricht und zur Überarbeitung der Publikation bei.

Publication V

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2019). Use of technical terms in German biology lessons and its effects on students' conceptual learning. *Research in Science & Technological Education*. doi:10.1080/02635143.2019.1609436

Herr Tobias Dorfner hat die Studie federführend durchgeführt, die Ratingmanuale weiterentwickelt, die Daten statistisch ausgewertet, die Daten für die Publikation aufgearbeitet, den Artikel konzipiert und ihn federführend geschrieben.

Die Koautorin und der Koautor entwickelten das Studiendesign, stellten die Fragebögen zusammen, unterstützten bei der Datenerhebung und -deutung und trugen substantiell zur Überarbeitung der Publikation bei.

Publication VI

Dorfner, T., Förtsch, C., Spangler, M., & Neuhaus, B. J. (2019). Wie plane ich eine konzeptorientierte Biologiestunde?: Ein Planungsmodell für den Biologieunterricht - Das Schalenmodell. *MNU Journal, 4,* 300-306.

Herr Tobias Dorfner entwickelte das beschriebene Unterrichtsplanungsmodell und hat federführend den Artikel konzipiert, geschrieben und überarbeitet.

Die Koautorin und die Koautoren entwickelten das beschriebene Unterrichtsplanungsmodell und trugen substantiell zur Überarbeitung der Publikation bei.

München, den 01.08.2019 ....
(Tobias Dorfner)

München, den 01.08.2019 ....
(Prof. Dr. Birgit J. Neuhaus)

Eidesstattliche Erklärung

Ich versichere hiermit an Eides statt, dass die vorgelegte Dissertation von mir selbstständig und ohne unerlaubte Hilfe angefertigt ist.

München, den 01.08.2019 ....
(Tobias Dorfner)

Erklärung

Hiermit erkläre ich,

dass die Dissertation nicht ganz oder in wesentlichen Teilen einer anderen Prüfungskommission vorgelegt worden ist.

dass ich mich anderweitig einer Doktorprüfung ohne Erfolg nicht unterzogen habe.

München, den 01.08.2019 ....
(Tobias Dorfner)