

**Professional Competence of Teachers:
Structure, Development, and
the Significance for Students' Performance**

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SUMMARY

Today, the relevance of teachers for students' learning is widely accepted and supported by a broad body of empirical research. There is consensus that this relevance is not merely grounded in the knowledge of a teacher, but also in further different aspects. Both knowledge and these further aspects can be subsumed under the term *professional competence*. Despite the broad research base, up until now there is no consensus what in detail characterizes an effective teacher and how teachers can be supported in being effective. The dissertation at hand addresses these questions by referring to the professional competence of biology teachers. Four empirical studies had been conducted that are related to three research foci: (1) the structure of teachers' professional competence, (2) the development of teachers' professional competence, and (3) the significance of teachers' professional competence for students' performance. Two aspects of professional competence are considered: (1) content-related professional knowledge and (2) motivational orientations.

The first research focus aimed to clarify the *empirical structure of teachers' professional competence*. Although there are established theoretical models and several empirical studies that deal with teachers' professional competence, there is no consensus about the empirical structure to date. However, the clarification of this structure is an important step for the further examination of teachers' professional competence. Therefore, 134 biology teachers' from German secondary schools completed paper and pencil test related to their professional competence. Rasch-analyses and confirmatory factor analyses were conducted to examine the empirical structure of teachers' professional competence. The results reveal that teachers' content-related professional knowledge is comprised of three unique domains (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge. Moreover, the results indicate that teachers' motivational orientations embody the unique

domains (1) self-efficacy, (2) subject-related enthusiasm, and (3) enthusiasm for teaching the subject. These domains were considered for the further examination of teachers' professional competence. Study 1 and 2 are related to this first focus.

The second focus concentrated on the examination of the *development of teachers' professional competence*. More detailed, the aim of this part of the dissertation was the identification of beneficial opportunities for the development of teachers' professional competence to examine how teachers can be supported in being effective. Different aspects were considered to provide opportunities for the development of teachers' professional competence: (1) the teacher education program at university, (2) the attendance in professional development courses, (3) the conduction of self-study, and (4) the time spent in the profession (teaching experience). 134 biology teachers from German secondary schools participated and provided information about their professional competence and the above mentioned aspects (e.g., type of teacher education program or years of teaching experience). The results of a regression analysis suggest that the teacher education program at university, the attendance in professional development courses as well as the conduction of self-study act as beneficial opportunities for the development of professional competence. The results further indicate that the time spent in the profession does not directly contribute to the development of teachers' professional competence. Study 1 and 2 are related to this second focus.

The third research focus aimed to examine the *significance of teachers' professional competence for students' performance* to clarify which aspects in detail characterize an effective teacher. In order to do so, the relationship between teachers' professional competence and students' performance was analyzed. 48 biology teachers from German secondary schools participated together with their seventh and eighth grade students ($N = 1036$). Teachers' professional competence was assessed with paper and pencil tests. Paper and pencil tests and concept maps were applied to assess students' performance. Different doubly-latent multilevel models were specified to examine the relationship between the respective domains of content-related professional knowledge as well as teachers' motivational orientations and students' performance. The findings indicate that teachers' pedagogical content knowledge as well as their subject-specific enthusiasm and

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enthusiasm for teaching the subject are relevant for students' performance. Study 3 and 4 are related to this third focus.

The results of the three research foci support the assumption that an effective teacher is characterized by more than just knowledge. As the results reveal the important domains of professional competence and which aspects are beneficial to develop these domains, the findings of this dissertation help to improve pre- and in-service teacher education in terms of a tailored teacher education.

ZUSAMMENFASSUNG

Ziel der vorliegenden Dissertation ist es, die Struktur professioneller Kompetenz von Lehrkräften, ihre Entwicklung sowie ihre Bedeutung für die schulische Leistung von Schülerinnen und Schülern zu untersuchen. Dabei wird eine Stichprobe bestehend aus Biologielehrkräften betrachtet.

Professionelle Kompetenz von Lehrkräften

Baumert und Kunter (2006) beschreiben in ihrem Modell professioneller Kompetenz vier Kompetenzaspekte: (1) Professionswissen, (2) motivationale Orientierungen, (3) selbstregulative Fähigkeiten und (4) Überzeugungen und Werthaltungen. Die vorliegende Dissertation berücksichtigt das Professionswissen sowie die motivationalen Orientierungen von Lehrkräften.

Bezüglich des Professionswissens wird in dieser Arbeit ein Schwerpunkt auf die Untersuchung des fachbezogenen Professionswissens gelegt. Dabei werden die drei Domänen Fachwissen (content knowledge: CK), fachdidaktisches Wissen (pedagogical content knowledge: PCK) und curriculares Wissen (curricular knowledge: CuK) betrachtet. Das CK beinhaltet das Wissen über Fakten, Konzepte und Strukturen eines Faches. Das PCK beschreibt das Wissen, das es der Lehrkraft ermöglicht, fachliche Inhalte zu vermitteln (Shulman, 1986). Vor allem zwei Facetten des PCK werden in der Literatur beschrieben und hier berücksichtigt: das Wissen über Instruktionsstrategien und Repräsentationsformen sowie das Wissen über Schülerkognitionen (z. B. Schülervorstellungen) (Depaepe, Verschaffel, & Kelchtermans, 2013; Grossman, 1990; Lee & Luft, 2008; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008; Schmelzing et al., 2013; Shulman, 1986; Van Driel, Verloop, & De Vos, 1998). Das CuK wird in dieser Arbeit als Wissen über Bildungsstandards verstanden (vgl. Magnusson et al., 1999), genauer als das Wissen über die Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2004a).

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Neben dem fachbezogenen Professionswissen sind auch motivationale Orientierungen relevant, um den Anforderungen im professionellen Alltag zu begegnen (Baumert & Kunter, 2006; Lee, Cawthon, & Dawson, 2013; Stoeber & Rennert, 2008). Bei motivationalen Orientierungen handelt es sich um einen wichtigen Aspekt psychologischer Funktionsfähigkeit, der „für die psychologische Dynamik des Handelns, die Aufrechterhaltung der Intention und die Überwachung und Regulation des beruflichen Handelns über einen langen Zeitraum verantwortlich ist“ (Baumert & Kunter, 2006, S. 501). Drei Domänen motivationaler Orientierungen werden in der vorliegenden Arbeit angenommen: (1) die Selbstwirksamkeitserwartungen der Lehrkraft, (2) der Enthusiasmus der Lehrkraft für das Fach sowie (3) der Enthusiasmus der Lehrkraft für das Unterrichten dieses Faches.

Selbstwirksamkeitserwartungen repräsentieren die kognitive Domäne motivationaler Orientierungen (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011). Sie werden als die Erwartung eines Individuums beschrieben, aufgrund der eigenen Fähigkeiten in einer bestimmten Situation erfolgreich zu sein oder eine bestimmte Aufgabe erfolgreich zu lösen (Bandura, 1977).

Der Enthusiasmus einer Lehrkraft wird als die affektive Domäne der motivationalen Orientierungen verstanden (Baumert & Kunter, 2006; Kunter et al., 2011). Enthusiasmus wird in der Forschung entweder als Verhalten der Lehrkraft in Instruktionssituationen (Bettencourt, Gillet, & Gall, 1983; Brigham, Scruggs, & Mastropieri, 1992; Mc Kinney et al., 1983; Rosenshine, 1970; Williams & Ware, 1977) oder als Personenmerkmal (Baumert & Kunter, 2006; Kunter et al., 2008, 2011; Kunter, 2013) konzeptualisiert. In der vorliegenden Dissertation wird Enthusiasmus als Personenmerkmal, genauer als intrinsische motivationale Orientierung von Lehrkräften, berücksichtigt (Baumert & Kunter, 2006). Dabei werden zwei Facetten des Enthusiasmus unterschieden: der Enthusiasmus für das Fach und der Enthusiasmus für das Unterrichten des Faches (vgl. Kunter et al., 2008, 2011; Kunter, 2013).

Übersicht über die Forschungsschwerpunkte

Analog zu der oben genannten Zielsetzung, die Struktur und Entwicklung professioneller Kompetenz von Lehrkräften sowie deren Bedeutung für die Schülerleistung zu untersuchen, ist diese Arbeit durch drei Forschungsschwerpunkte strukturiert:

Forschungsschwerpunkt 1: Struktur professioneller Kompetenz von Lehrkräften

Forschungsschwerpunkt 2: Entwicklung professioneller Kompetenz von Lehrkräften

Forschungsschwerpunkt 3: Bedeutung professioneller Kompetenz von Lehrkräften für die Schülerleistung

Diese Forschungsschwerpunkte wurden in vier empirischen Studien bearbeitet und sollen im Folgenden mit den dazugehörigen Forschungsfragen zusammengefasst werden.

Forschungsschwerpunkt 1: Struktur professioneller Kompetenz von Lehrkräften

Da es sich bei dem oben beschriebenen Modell professioneller Kompetenz von Lehrkräften (Baumert & Kunter, 2006) um ein theoretisch postuliertes Modell handelt, muss überprüft werden, ob sich die theoretisch angenommene Struktur auch empirisch nachweisen lässt. Dabei stehen Fragen zur Eigenständigkeit der Konstrukte sowie deren Beziehung untereinander im Mittelpunkt.

Bisher gibt keinen Konsens darüber, ob die theoretisch angenommenen Domänen CK, PCK und CuK eigenständige Konstrukte darstellen. So beschreiben einige Arbeiten CK und PCK als eigenständig (Grossman, 1990; Großschedl, Harms, Kleickmann, & Glowinski, 2015; Jüttner, Boone, Park, & Neuhaus, 2013; Kleickmann et al., 2014; Magnusson et al., 1999), während andere ein integriertes Konstrukt berücksichtigen (Fernandez-Balboa, & Stiehl, 1995; Hill, Rowan, & Ball, 2005; Marks, 1990). Das CuK wurde von Shulman (1986) ursprünglich als eigenständige Domäne beschrieben, dennoch wird es in zahlreichen Arbeiten als integraler Bestandteil des PCK verstanden (Grossman, 1990; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Magnusson et al., 1999; Park & Chen, 2012). Befunde zum Verhältnis zwischen CK und CuK gibt es bisher nicht. Bezüglich der Domänen der motivationalen Orientierungen gibt es keine empirisch belegten Hinweise. Da die Selbstwirksamkeitserwartungen als kognitive Domäne der motivationalen Orientierungen verstanden werden, wohingegen der Enthusiasmus der Lehrkraft als affektive Domäne beschrieben wird (Baumert & Kunter, 2006; Kunter et al., 2011), lässt sich eine Eigenständigkeit jeweils annehmen. Kunter und Kollegen (2011) konnten darüber hinaus eine empirische Trennbarkeit zwischen dem Enthusiasmus für das Fach sowie dem Enthusiasmus für das Unterrichten des Faches zeigen.

Der Frage nach der empirischen Struktur professioneller Kompetenz von Lehrkräften widmet sich der erste Forschungsschwerpunkt:

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Forschungsfrage 1: In welcher Beziehung stehen die Domänen der professionellen Kompetenz von Lehrkräften zueinander?

Das fachbezogene Professionswissen sowie die motivationalen Orientierungen von 134 Biologielehrkräften (Alter: $M = 43,7$ Jahre [$SD = 10,3$], Berufserfahrung: $M = 16,4$ Jahre [$SD = 11,7$], 75,4% weiblich) wurde mit Fragebögen erhoben. Der Fragebogen zur Erfassung des fachbezogenen Professionswissens bezog sich auf das Thema Ökosystem Wattenmeer mit einem Schwerpunkt auf die Lebensweise von *Mytilus edulis* (Miesmuschel).

Die empirische Struktur des fachbezogenen Professionswissens wurde untersucht, indem im Rahmen einer Rasch-Analyse unterschiedliche theoretisch angenommene Modelle auf ihre Passung überprüft wurden. Ein eindimensionales Modell berücksichtigt CK, PCK und CuK als integrierte Bestandteile eines gemeinsamen Konstrukts. Das zweite Modell nimmt CK als eigenständige erste Dimension sowie PCK und CuK als integriertes Konstrukt auf einer zweiten Dimension an. Das dritte Modell folgt der Tradition Shulmans (1986) und berücksichtigt CK, PCK und CuK als eigenständige Domänen des fachbezogenen Professionswissens. Der Vergleich der drei Modelle zeigt, dass das dreidimensionale Modell am besten zu den Daten passt. Dieses Ergebnis wird von den oben genannten Befunden zumindest bezüglich des CK und des PCK unterstützt (Grossman, 1990; Großschedl et al., 2015; Jüttner et al., 2013; Kleickmann et al., 2014; Magnusson et al., 1999). Die Betrachtung des CuK als eigenständige Domäne entspricht der ursprünglichen Konzeptualisierung von Shulman (1986). Park und Chen (2012) betrachten CuK zwar als integralen Bestandteil des PCK, fanden aber nur eine geringe Korrelation zwischen dem CuK und den anderen angenommenen Facetten. Diese geringe Korrelation unterstützt die Annahme einer Eigenständigkeit des CuK. Im weiteren Verlauf der Dissertation werden also CK, PCK und CuK als eigenständige Domänen betrachtet.

Um die theoretisch postulierte Struktur der motivationalen Orientierungen zu überprüfen, wurden unterschiedliche Modelle im Rahmen einer konfirmatorischen Faktorenanalyse spezifiziert und anschließend verglichen. Das erste Modell versteht die motivationalen Orientierungen von Lehrkräften als eindimensionales Konstrukt. Die Selbstwirksamkeitserwartungen sowie die Facetten des Enthusiasmus stellen hier also keine eigenständigen Konstrukte dar. Ein zweidimensionales Modell, welches eine kognitive Dimension mit den Selbstwirksamkeitserwartungen sowie eine affektive Dimension mit dem Enthusiasmus der

Lehrkraft annimmt, wurde spezifiziert. Das dritte Modell folgt der zu Beginn getroffenen theoretischen Annahme und berücksichtigt die Selbstwirksamkeitserwartungen der Lehrkraft sowie ihren Enthusiasmus für das Fach und ihren Enthusiasmus für das Unterrichten dieses Faches als eigenständige Dimensionen. Der Vergleich der Modelle zeigt die beste Passung für das dritte Modell. Für die weiteren Untersuchungen im Rahmen dieser Dissertation werden folglich die Selbstwirksamkeitserwartungen, der Enthusiasmus für das Fach sowie der Enthusiasmus für das Unterrichten des Faches als eigenständige Konstrukte berücksichtigt. Dieses Ergebnis entspricht den oben genannten theoretischen Annahmen (Baumert & Kunter, 2006; Kunter et al., 2011) sowie dem Befund von Kunter und Kollegen (2011) bezüglich der Eigenständigkeit des Enthusiasmus für das Fach sowie des Enthusiasmus für das Unterrichten des Faches.

Neben der Eigenständigkeit der Domänen standen auch die Zusammenhänge zwischen den Domänen im Fokus des ersten Schwerpunktes. Im Rahmen der oben beschriebenen Analysen wurde festgestellt, dass es sowohl Zusammenhänge innerhalb der Kompetenzaspekte gibt (also beispielsweise zwischen den Domänen des Professionswissens) als auch Zusammenhänge zwischen den Kompetenzaspekten (also zwischen den Domänen des fachbezogenen Professionswissens und den Domänen der motivationalen Orientierungen).

Studie 1 und Studie 2 sind diesem Forschungsschwerpunkt zugeordnet.

Forschungsschwerpunkt 2: Entwicklung professioneller Kompetenz von Lehrkräften

Der zweite Forschungsschwerpunkt widmet sich der Entwicklung professioneller Kompetenz von Lehrkräften. Dabei werden analog zu den Befunden aus Forschungsschwerpunkt 1 drei Domänen des fachbezogenen Professionswissens (CK, PCK und CuK) sowie drei Domänen der motivationalen Orientierungen (Selbstwirksamkeitserwartungen, Enthusiasmus für das Fach und Enthusiasmus für das Unterrichten des Faches) als eigenständige Konstrukte betrachtet. Im Mittelpunkt dieses Forschungsschwerpunktes steht die Identifikation von Gelegenheiten zur Entwicklung der professionellen Kompetenz von Lehrkräften.

Die universitäre Ausbildung sowie die Teilnahme an Fortbildungsveranstaltungen werden als wichtige Faktoren für die Entwicklung professioneller Kompetenz betrachtet (Bettencourt et al., 1983; Brunner et al., 2006; Clermont, Krajcik, & Borko, 1993; Campbell, 1996; Collins, 1978; Kleickmann & Anders, 2013; Roness, 2011; Schmidt et al., 2007; Tatto &

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Senk, 2011), wohingegen sich die Forschungslage bezüglich der Bedeutung der Berufserfahrung uneinheitlich darstellt (Brunner et al., 2006; Carleton, Fitch, & Krockover, 2008; Clermont, Borko, & Krajcik, 1994; Friedrichsen et al., 2009; Grossman, 1990; Kunter et al., 2011; Lederman, Gess-Newsome, & Latz, 1994; Schmelzing et al., 2013; Schmitz, 1998). Die Relevanz dieser Entwicklungsgelegenheiten für das fachbezogene Professionswissen scheint intuitiv, da der Großteil der genannten Aspekte auf die Vermittlung von Wissen zielt (z. B. das Lehramtsstudium) (KMK, 2008). Bezüglich der Relevanz für die Entwicklung motivationaler Orientierungen können theoretische Überlegungen Hinweise geben. Sowohl für die Selbstwirksamkeitserwartungen (Bandura, 1977) als auch für den Enthusiasmus, der in konzeptueller Nähe zur intrinsischen Motivation steht (Baumert & Kunter, 2006), lassen sich das Erleben des eigenen Erfolgs bzw. das Erleben der eigenen Kompetenz als wichtige Quellen für die Entwicklung dieser Domänen beschreiben (Bandura, 1977; Deci & Ryan, 2000). Das fachbezogene Professionswissen kann das Erleben von Erfolg bzw. Kompetenz ermöglichen.

Die folgende Forschungsfrage soll im Rahmen dieses Forschungsschwerpunkts beantwortet werden.

Forschungsfrage 2: Welchen Zusammenhang gibt es zwischen der professionellen Kompetenz von Lehrkräften und den unten genannten Gelegenheiten zur Entwicklung professioneller Kompetenz?

Als förderlich angenommen werden (1) die Lehramtsausbildung an der Universität, (2) die Teilnahme an Fortbildungsveranstaltungen, (3) das Selbststudium (z. B. das Lesen von Fachzeitschriften) sowie (4) die Berufserfahrung der Lehrkräfte (Jahre im Beruf).

134 Biologielehrkräfte (Alter: $M = 43,7$ Jahre [$SD = 10,3$], Berufserfahrung: $M = 16,4$ Jahre [$SD = 11,7$], 75,4% weiblich) bearbeiteten Fragebögen zur Erfassung ihres fachbezogenen Professionswissens sowie zur Erfassung ihrer motivationalen Orientierungen (vgl. Forschungsschwerpunkt 1). Darüber hinaus wurden Informationen über das Studium der Lehrkräfte sowie über weitere Entwicklungsgelegenheiten (s.o.) erhoben.

Die Ergebnisse von Regressionsanalysen weisen darauf hin, dass sowohl die Phase des universitären Lehramtsstudiums als auch die Zeit im Beruf Möglichkeiten bieten, die die Entwicklung professioneller Kompetenz unterstützen können. Das Lehramtsstudium sowie

die Teilnahme an Fortbildungen und das Selbststudium stehen in positivem Zusammenhang mit dem fachbezogenen Professionswissen und den motivationalen Orientierungen. Dieses Ergebnis wird von Befunden vorheriger Studien sowie theoretischen Überlegungen unterstützt (Bandura, 1977; Bettencourt et al., 1983; Brunner et al., 2006; Clermont et al., 1993; Campbell, 1996; Collins, 1978; Deci & Ryan, 2000; Kleickmann & Anders, 2013; Roness, 2011; Schmidt et al., 2007; Tatto & Senk, 2011). Bezüglich der Bedeutung des Selbststudiums stehen bisher keine Befunde aus anderen Studien zur Verfügung. Weiterhin wird deutlich, dass es sich bei dem Enthusiasmus für das Fach um ein eher stabiles Konstrukt handelt, da sich keine Zusammenhänge zu den angenommenen Gelegenheiten zeigen. Auch Kunter (2013) identifizierte diese Domäne als eher stabiles Merkmal. Die Berufserfahrung der Lehrkräfte scheint keine Bedeutung für das fachbezogene Professionswissen sowie für die motivationalen Orientierungen zu haben. Eine Annahme ist, dass die reine Erfassung der Jahre im Beruf zu wenig Auskunft über die Qualität dieser Zeit gibt. Die Bedeutung der Berufserfahrung wird in der Literatur ebenfalls kontrovers diskutiert (Brunner et al., 2006; Carleton et al., 2008; Clermont et al., 1994; Friedrichsen et al., 2009; Grossman, 1990; Kleickmann et al., 2013; Kunter et al., 2011; Lederman et al., 1994; Schmelzing et al., 2013; Schmitz, 1998).

Die Ergebnisse dieses Schwerpunktes betonen die Bedeutung des Lehramtsstudiums sowie der Weiterbildung im Beruf für die Entwicklung professioneller Kompetenz und zeigen auf, welche Gelegenheiten besonders gewinnbringend sind.

Studie 1 und Studie 2 sind diesem Forschungsschwerpunkt zugeordnet.

Forschungsschwerpunkt 3: Bedeutung professioneller Kompetenz von Lehrkräften für die Schülerleistung

Ein wichtiger Indikator für die Wirksamkeit der Lehrkraft ist ihre Bedeutung für die Schülerleistung. Dem Zusammenhang zwischen der professionellen Kompetenz von Lehrkräften und der Schülerleistung widmet sich der dritte Forschungsschwerpunkt der vorliegenden Dissertation.

Vor allem das PCK (Baumert et al., 2010; Fennema et al., 1996; Lange et al., 2015; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013), die Selbstwirksamkeitserwartungen (Abernathy-Dyer, Ortlieb, & Cheek, 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb,

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1986; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Ross, 1992) und der Enthusiasmus der Lehrkraft (Brigham et al., 1992; Brophy & Good, 1984; Rosenshine, 1970; Williams & Ware, 1977; Wood, 1989) werden in der Literatur als bedeutsam für die Schülerleistung beschrieben. Bezüglich des CK ist die Forschungslage kontrovers (Baumert et al., 2010; Carlisle, Correnti, Phelps, & Zeng et al., 2009; Hill, Rowan, & Ball, 2005; Lange et al., 2015; Ohle, Fischer, & Kauertz, 2011; Rowan, Chiang, & Miller, 1997; Sadler et al., 2013). Da das CuK in empirischen Studien bisher nicht als eigenständiges Konstrukt betrachtet wurde (Grossman, 1990; Loughran et al., 2001; Magnusson et al., 1999; Park & Chen, 2012), stehen keine empirischen Befunde bezüglich seiner Bedeutung für die Leistung von Schülerinnen und Schülern zur Verfügung.

Die Forschungsfrage, die im Rahmen dieses Forschungsschwerpunktes beantwortet werden soll, lautet:

Forschungsfrage 3: Welchen Zusammenhang gibt es zwischen der professionellen Kompetenz von Lehrkräften und der Schülerleistung?

Für diesen dritten Schwerpunkt wurde eine Teilstichprobe der oben beschriebenen Lehrerkohorte von 48 Lehrkräften (Alter: $M = 40,9$ Jahre [$SD = 11,0$], Berufserfahrung: $M = 11,6$ Jahre [$SD = 10,5$], 75,0% weiblich) untersucht. Diese Lehrkräfte nahmen gemeinsam mit ihren Schülerinnen und Schülern der siebten (20,1%) und achten Klassenstufe (79,9%) ($N = 1036$, Alter: $M = 15,50$ Jahre [$SD = 0,7$]) teil. Zuerst wurden das fachbezogene Professionswissen sowie die motivationalen Orientierungen mithilfe von Fragebögen erhoben (s.o.). Anschließend planten die Lehrkräfte eine kurze Unterrichtseinheit zu dem Themenbereich, der auch dem Instrument zur Erfassung des fachbezogenen Professionswissens zugrunde liegt (Ökosystem Wattenmeer). Die Schülerleistung wurde als Leistung im Bereich des Systemdenkens konzeptualisiert und vor und nach der Unterrichtseinheit erhoben. Systemdenken beschreibt die Fähigkeit, Systeme als Funktionseinheit ihrer Elemente zu begreifen sowie die Stabilität eines Systems als abhängig von den Beziehungen zwischen seinen Elementen zu verstehen (Assaraf & Orion, 2005). Das Systemdenken der Schülerinnen und Schüler wurde sowohl mit einem Fragebogen als auch mit Concept Maps erfasst.

Der Zusammenhang zwischen der professionellen Kompetenz von Lehrkräften und der Schülerleistung wurde aufgrund der hierarchischen Datenstruktur (Schülerinnen und Schüler

in Klassen) im Rahmen einer Mehrebenenanalyse (Doubly-latent-Modellierung; Marsh et al., 2009) untersucht. Als abhängige Variable fungierte dabei die Schülerleistung, die nach der Unterrichtseinheit erhoben wurde. Die Domänen des fachbezogenen Professionswissens sowie der motivationalen Orientierungen stellen die unabhängigen Variablen dar. Als Kontrollvariablen wurden zusätzlich das Vorwissen der Schülerinnen und Schüler sowie deren kognitive Fähigkeiten und die Schulform berücksichtigt.

Die Ergebnisse zeigen einen positiven Zusammenhang zwischen dem PCK und der Schülerleistung, wohingegen kein Zusammenhang zwischen dem CK und der Schülerleistung oder dem CuK und der Schülerleistung gefunden wurde. Das Ergebnis deutet darauf hin, dass das PCK der Lehrkraft bedeutsam für die Schülerleistung ist. Dies entspricht dem aktuellen Stand der Forschung (Baumert et al., 2010; Fennema et al., 1996; Lange et al., 2015; Sadler et al., 2013) und unterstützt die besondere Rolle von Lehrkräften. Reines CK, welches auch einen Fachwissenschaftler auszeichnen würde, reicht offenbar nicht aus, die Leistung der Schülerinnen und Schüler zu verbessern. Bezüglich des fehlenden Zusammenhangs zwischen dem CuK und der Schülerleistung wird angenommen, dass die Konzeptualisierung des Konstrukts als reines Faktenwissen über die Bildungsstandards für das Fach Biologie problematisch ist. Eine unterrichtsnähere Konzeptualisierung könnte helfen, die Rolle des CuK der Lehrkraft besser zu verstehen.

Bezüglich der motivationalen Orientierungen von Lehrkräften zeigt sich ein positiver Zusammenhang zwischen dem Enthusiasmus der Lehrkraft für das Fach und der Schülerleistung. Außerdem weisen die Ergebnisse zumindest auf eine positive Tendenz für den Zusammenhang zwischen dem Enthusiasmus für das Unterrichten und der Schülerleistung hin. Die Bedeutsamkeit des Enthusiasmus der Lehrkraft entspricht der oben beschriebenen Forschungslage (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Brigham et al., 1992; Brophy & Good, 1984; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Rosenshine, 1970; Ross, 1992; Williams & Ware, 1977; Wood, 1989). Allerdings ist dabei wichtig zu betonen, dass bisher nur sehr wenige Studien den Enthusiasmus als Persönlichkeitsmerkmal betrachten, so wie es in dieser Dissertation der Fall ist (Kunter et al., 2008, 2011; Kunter, 2013).

Es wurde kein Zusammenhang zwischen den Selbstwirksamkeitserwartungen der Lehrkraft und der Schülerleistung gefunden. Dieses Ergebnis widerspricht dem oben

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beschriebenen Stand der Forschung, der eine Relevanz der Selbstwirksamkeitserwartungen für die Schülerleistung nahelegt. Ein Erklärungsansatz für das unerwartete Ausbleiben eines Zusammenhangs betrifft die Auswahl des Instruments. Das gewählte Instrument von Schmitz & Schwarzer (2001) bezieht sich auf kein bestimmtes Fach und erfasst Selbstwirksamkeitserwartungen bezogen auf ein sehr breites Aufgabenspektrum. Ein Instrument, welches sich deutlicher auf die Selbstwirksamkeitserwartungen bezüglich des Unterrichtens von Biologie bezieht, könnte helfen, die Rolle des CuK weitergehend zu untersuchen.

Studie 3 und Studie 4 sind diesem Forschungsschwerpunkt zugeordnet.

Limitationen

Limitationen ergeben sich vor allem bezüglich des querschnittlich angelegten Forschungsdesigns. Ein querschnittlich angelegtes Forschungsdesign lässt keine kausalen Schlüsse zu. So können mögliche wechselseitige Effekte nicht ausgeschlossen werden. Die angenommenen Wirkrichtungen waren jedoch jeweils durch eine breite theoretische und empirische Grundlage gestützt.

Weiterhin problematisch ist, dass die Instrumente, die zur Erfassung des CuK sowie der Selbstwirksamkeitserwartungen von Lehrkräften entwickelt wurden, aufgrund ihrer Unterrichtsferne (s.o.) nicht geeignet scheinen, um die Rolle dieser Domänen für die Schülerleistung zu untersuchen.

Der fehlende Einblick in das konkrete Unterrichtshandeln der Lehrkräfte stellt eine weitere Limitation dar. Zwar wurden die Lehrkräfte gebeten, ein Unterrichtsraaster auszufüllen, diese waren aber von so unterschiedlicher Qualität, dass sie nicht weiter berücksichtigt werden konnten. So fehlt ein Einblick in den Unterricht, der es ermöglicht hätte zu untersuchen, wie sich die professionelle Kompetenz im konkreten Unterrichtshandeln widerspiegelt.

Ein weiterer Punkt, den es zu berücksichtigen gilt, ist die fehlende Beobachtung der Lehrkräfte durch Testleiter. So kann eine Nutzung externer Hilfsmittel nicht ganz ausgeschlossen werden. Die Items zur Erfassung des fachbezogenen Professionswissens waren allerdings so konzipiert, dass eine Recherche seitens der Lehrkräfte in einem adäquaten Zeitaufwand nicht möglich war.

Implikationen

Die Integration der Ergebnisse aller drei Schwerpunkte gibt sowohl wichtige Hinweise für weitere Forschungsfragen als auch für die Verbesserung der Lehramtsausbildung.

Implikationen für zukünftige Forschung

Die Daten, die den Auswertungen dieser Dissertation zugrunde liegen, wurden in einem querschnittlichen Design erhoben. Aus diesem Grund ist es nicht möglich, kausale Schlüsse zu ziehen. Eine Untersuchung in einem längsschnittlichen Design würde eine weitergehende Untersuchung der professionellen Kompetenz von Lehrkräften ermöglichen. So könnte bezüglich des ersten Forschungsschwerpunkts untersucht werden, ob und wie sich die empirische Struktur der professionellen Kompetenz über die Zeit verändert. So lässt sich beispielsweise eine stärkere Integration der Wissensdomänen über die Zeit annehmen (Berliner, 2001). Für den zweiten Forschungsschwerpunkt böte eine längsschnittliche Untersuchung ebenfalls neue Möglichkeiten. Auch wenn die Bedeutung von Gelegenheiten während des Studiums und des Berufs für die Entwicklung professioneller Kompetenz in der Literatur breit belegt ist (Bettencourt et al., 1983; Brunner et al., 2006; Campbell, 1996; Clermont et al., 1993; Collins, 1978; Kleickmann & Anders, 2013; Roness, 2011; Schmidt et al., 2007; Tatto & Senk, 2011), kann ein wechselseitiger Effekt nicht ausgeschlossen werden. So wäre beispielsweise anzunehmen, dass enthusiastische Lehrkräfte sich auch eher für die Teilnahme an einer Fortbildung entscheiden. Eine ähnliche Logik gilt für den Zusammenhang zwischen der professionellen Kompetenz und der Schülerleistung. So ist die Bedeutung des fachbezogenen Professionswissens sowie der motivationalen Orientierungen für die Schülerleistung durch Befunde anderer Studien gestützt (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Baumert et al., 2010; Brigham et al., 1992; Brophy & Good, 1984; Fennema et al., 1996; Hill et al., 2005; Lange et al., 2015; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Ohle et al., 2011; Rosenshine, 1970; Ross, 1992; Rowan et al., 1997; Sadler et al., 2013; Williams & Ware, 1977; Wood, 1989). Dennoch lässt sich annehmen, dass sich die Leistungsstärke der Schülerinnen und Schüler auch positiv auf die motivationalen Orientierungen von Lehrkräften auswirken kann.

Eine zusätzliche Berücksichtigung indirekter Effekte könnte weiteren Aufschluss darüber geben, welche Bedeutung die professionelle Kompetenz von Lehrkräften für die Schülerleistung hat. So könnte beispielsweise die Rolle des CK genauer untersucht werden.

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Es kann ein indirekter Effekt zwischen dem CK und der Schülerleistung angenommen werden, der von dem PCK der Lehrkraft mediiert wird. Diese Annahme wird von Forschungsarbeiten unterstützt, die das CK als wichtige Voraussetzung für das PCK der Lehrkraft beschreiben (Ball et al., 2001; Großschedl et al., 2015; Ma, 1999; Magnusson et al., 1999; Riese & Reinhold, 2012).

Wie in den Limitationen beschrieben, erscheint eine unterrichtsnähere Erfassung des CuK der Lehrkraft sinnvoll, um ihre Bedeutung für die Schülerleistung weiter zu untersuchen. Dieses Instrument müsste über die Erfassung des reinen Faktenwissens hinausgehen und vor allem die Umsetzung der Standards im konkreten Planungs- und Unterrichtshandeln berücksichtigen. Zurzeit steht kein Instrument zur Verfügung, sodass eine Neuentwicklung notwendig ist.

Implikationen für die Lehrerbildung

Die Integration der Ergebnisse ermöglicht wichtige Erkenntnisse darüber, wie professionelle Kompetenz von Lehrkräften im Sinne einer maßgeschneiderten Lehrerbildung gefördert werden kann. So liefern die Ergebnisse Hinweise, welche Domänen besonders gefördert werden sollten und ermöglichen weiterhin die Identifikation wichtiger Gelegenheiten für die Entwicklung dieser Domänen.

Das PCK und der Enthusiasmus von Lehrkräften wurden als besonders bedeutsam für die Schülerleistung identifiziert und erscheinen demnach besonders förderwürdig. Veranstaltungen, die die Vermittlung fachdidaktischer Inhalte zum Ziel haben, sollten folglich einen Schwerpunkt der Lehreraus- und Fortbildung darstellen. Da vor allem im Lehramtsstudium die Aneignung von Professionswissen eine übergeordnete Rolle spielt, ist die Entwicklung von zusätzlichen Veranstaltungsformaten sinnvoll, die auch motivationale Aspekte berücksichtigen und eine explizite Förderung des Enthusiasmus der (angehenden) Lehrkräfte ermöglichen. Weitere Forschung wäre hier notwendig, um zu untersuchen, in welchem Veranstaltungsrahmen Enthusiasmus direkt gefördert werden kann.

Da die professionelle Kompetenz von Lehrkräften nicht aus einzelnen isolierten Kompetenzaspekten besteht, können integrierte Veranstaltungen weitere wertvolle Möglichkeiten für die Entwicklung professionellerer Kompetenz bieten. Ein Beispiel für eine integrierte Veranstaltungsform wäre ein Kurs im Rahmen der universitären Lehramtsausbildung, der

neben der Vermittlung eines Fachinhalts (z. B. Photosynthese) auch damit verbundene Schülervorstellungen oder geeignete Repräsentationsformen für die Vermittlung dieses Fachinhalts berücksichtigt.

1 INTRODUCTION

“He who can, does. He who cannot, teaches.”

Shulman (1986) chose this pessimistic quote from the play “Man and Superman” of George Bernard Shaw to start his fundamental article about the professional knowledge of teachers. This quote reflects the concerns about the educational system and about the quality and recruitment of teachers in the USA (e.g., Gardner, Larsen, Baker, Campbell, & Crosby, 1983), which were current in the time his article was published. Shulman stood up for the improvement of teacher quality and the reputation of teachers. With his initial work (1986), he initiated a renaissance of research on teaching with a stronger focus on the identification of knowledge and abilities that are necessary for effective teaching (Gess-Newsome, 1999).

Due to this new focus of research, nowadays it is widely accepted that teachers have a great influence on the quality of education (Tenorth, 2006) and in the learning of their students (Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000b; Hattie, 2009). The Hattie-study (Hattie, 2009), for instance, reveals that a teacher has more impact on the learning of students than class size or the financial situation of a given school have; both factors that had been politically assumed to be especially important. According to this relevance of teachers, two core questions arise:

- (1) What are the characteristics of an effective teacher?
- (2) How do these characteristics develop?

Answering these questions enables the targeted improvement of teacher education and helps to ensure the quality of education in school. Despite the crucial importance of these questions, there is no consensus to date which factors in detail characterize an

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effective teacher and which opportunities are indeed important for the development of teacher effectiveness.

My dissertation aims at contributing to the clarification of these issues by examining a sample of biology teachers.

An effective teacher is characterized by a broad body of knowledge and a bundle of different skills, which can be subsumed under the term *professional competence* (Baumert & Kunter, 2006). I refer to the model of professional competence developed by Baumert and Kunter (2006), a theoretical model which considers different competence aspects that are important to master the demands of the teaching profession and which provides a fruitful basis for empirical research.

My dissertation seeks to contribute to three research foci that concern (1) the structure of professional competence, (2) opportunities for the development of professional competence, and (3) the significance of professional competence for students' performance.

(1) The clarification of the structure is an important groundwork for the detailed examination of teachers' professional competence. Within the model of teachers' professional competence (Baumert & Kunter, 2006), the different competence aspects and the domains included in these aspects were set due to theoretical considerations. That does not imply, however, that this structure also occurs when considering real teacher data. Before teachers' professional competence can be further examined, a clarification of the empirical structure of teachers' professional competence is necessary.

(2) A broad body of research supports the assumption that teachers' professional competence develops over the teaching career (Bettencourt, Gillet, & Gall, 1983; Brunner et al., 2006; Campbell, 1996; Collins, 1978; Clermont, Krajcik, & Borko, 1993; Kleickmann & Anders, 2013; Roness, 2011; Schmidt et al., 2007; Tatto & Senk, 2011). Nevertheless, there is no consensus to date what in detail provides opportunities for the development of professional competence. The second focus of my dissertation aims to identify aspects that provide these opportunities.

(3) One crucial indicator for effective teaching is the performance of students. Several studies dealt with this issue (e.g., Abernathy-Dyer, Ortlieb, & Cheek, 2013; Allinder, 1995; Baumert et al., 2010; Fennema et al., 1996; Lange et al., 2015; Rosenshine, 1970), but there

is no agreement to date what causes the significance of teachers. Hence, the third focus of my dissertation concerns the significance of teachers' professional competence for students' performance. The aim is to identify the domains of teachers' professional competence which indeed characterize an effective teacher.

To begin with, my dissertation starts with an overarching theoretical background on teachers' professional competence. After that, the current state of research according to my research foci is provided. As a next step, the description of my research questions and hypotheses as well as an overview of my research design follows. Lastly, after the presentation of four empirical studies, their results will be summarized and discussed in terms of implications for further research and for a tailored teacher education.

2 THEORETICAL BACKGROUND AND CURRENT STATE OF RESEARCH

This chapter provides considerations about the status of teaching as a profession and an introduction into different paradigms of respective research. The following section outlines the topical model of professional competence in German educational research. Subsequently, the state of research related to the three above mentioned research foci is summarized.

2.1 Teaching as a Profession

The engagement in research on teachers' professional competence includes the ground assumption that teaching has to be understood as a profession. This section seeks to clarify why teaching can indeed be understood as a profession. Furthermore, it presents different aspects that support the professional status of teaching.

The traditional understanding of the term "profession" refers to "free" professions, which were represented by the traditional faculties at universities (e.g., law and medicine) (Terhart, 2011). In order to decide whether teaching has to be regarded as a profession, educational researchers referred to the findings of the social sciences, which have a long tradition of research on professions (Myers, 2008; Terhart, 2011). Especially four indicators are consistently considered to clarify the status of teaching: (1) the service orientation (Baumert & Kunter, 2013; Myers, 2008, Shon, 2006; Shulman, 1998), (2) a broad base of profession-specific knowledge (Baumert & Kunter, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shulman, 1998; Shon, 2006), (3) institutionalized training programs, which concern a relatively long time span and lead to a certain type of certification (Baumert & Kunter, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shulman, 1998), and (4)

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autonomy (Ingersoll & Merrill, 2011; Myers, 2008; Shon, 2006). The following section further discusses these indicators in terms of teaching.

(1) *The service orientation* of a profession concerns the ground assumption that the provision of service to others is the core aim of a professional (Baumert & Kunter, 2013; Myers, 2008; Shon, 2006; Shulman, 1998). The service that is provided supports clients in existential aspects (e.g., their health) (Terhart, 2011). This principle stands above monetary motives (Myers, 2008). Teaching matches this service orientation by providing education as a service to clients (students). The existential aspect can be described as the ability to participate in society. The weak focus of teachers on monetary motives is supported by Pohlmann and Möller (2010) who examined the motivation of students for choosing to become a teacher. Their results suggested that prospective teachers more often draw on interest in the content or in pedagogical issues than on extrinsic monetary aspects when arguing for their professional choice.

(2) Beyond a service obligation, professionals are characterized by a *profession-specific base of knowledge* (Baumert & Kunter, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shulman, 1998; Shon, 2006). This body of knowledge makes the professional a specialist in their field (Ingersoll & Merrill, 2011). Accordingly, the behavior of a professional is not of an intuitive nature, but based on cognitive aspects like knowledge (Baumert & Kunter, 2013). This indicator again stresses the classification of teaching as a profession. Teachers are characterized by a specific body of knowledge which distinguishes teachers from other specialists (e.g., pedagogical content knowledge: Baumert & Kunter, 2006; Shulman, 1986). Important to mention is that for a long time only secondary teachers – in contrast to primary school teachers – were considered to have this profession-specific body of knowledge (Terhart, 2011).

(3) The previously mentioned broad knowledge base is acquired in an institutionalized context (Baumert & Kunter, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shulman, 1998). This *training* is highly standardized (Myers, 2008) and takes a relatively high amount of time of the adult socialization phase (Myers, 2008). Also, prospective teachers have to pass an institutionalized and highly standardized teacher education program. This program includes teacher education at university, a trainee phase (*Referendariat*) and ongoing mandatory professional development for in-service teachers (e.g., Cortina & Thames, 2013; KMK, 2008).

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As this aspect is unambiguous for Germany with its highly standardized teacher education, it could be critically reviewed for other countries.

(4) A further characteristic of a profession concerns the level of *autonomy* of a professional community (Ingersoll & Merrill, 2011; Myers, 2008; Shon, 2006). It is common for a professional community that it is not controlled by a higher-order authority, but on the contrary self-governed by the members of the profession (Ingersoll & Merrill, 2011; Myers, 2008). The fitting of teaching to this indicator is debatable as teaching in schools is strictly controlled by state authorities, which does not necessarily include the participation of teachers. This makes some authors question the classification of teachers as professionals in a classical manner (e.g., Myers [2008] classifies teachers as *service professionals* indicating that teaching meets the characteristics of a profession only in part). However, despite government guidelines, teachers have a high amount of autonomy in their everyday occupational life (e.g., due to competence-oriented educational standards [KMK, 2004a], which enable teachers to be relatively free in their lesson planning and the conduction of lessons). Terhart (2011) also states that the traditional free professions (e.g., law, medicine) have changed over time due to stricter government regulations and that the strict regulations professions have to fulfill have led to the fact that the condition of freedom does no longer fit.

Beyond the aspects which characterize teaching as a profession, it is also important to consider aspects that are unique for the teaching profession. In this context, the dual character (Kunter, 2013) of the teaching profession is of crucial importance. In contrast to a scientist, whose main activities are related to a specific content or subject, or to a pedagogue, whose main activities are related to the interaction with children or adolescents, the teacher has to cope with both the content and the interaction with students.

2.2 Paradigm Shifts in Respective Research

Research on teacher effectiveness is characterized by different paradigm shifts. The consideration of teaching as a profession had important implications on the recent orientation of respective research. Three paradigms become apparent when comparing the different research strands (Kennedy, Ahn, & Choi, 2008; Mayr & Neuweg, 2006).

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(1) Early research (until the beginning of the 1970s) particularly dealt with the personality of a teacher (cf. Helmke, 2009; Helmke & Klieme, 2008; Kennedy et al., 2008; Mayr & Neuweg, 2006). Accordingly, this early paradigm is termed as *personality-paradigm*. Here, individual characteristics or the individual aptitude of teachers were the main focus, thus mainly non-occupation-specific and relatively stable personal characteristics were considered to characterize an effective teacher (e.g., openness, emotional stability) (cf. Kennedy et al., 2008; Kunter, Kleickmann, Klusmann, & Richter 2013a; Mayr & Neuweg, 2006). This focus implies that an individual enters the occupational life with certain favorable characteristics (as for example 'bright person': Kennedy et al., 2008). Moreover, the consideration of solely non-occupation-specific characteristics indicates that teaching was not considered as a profession with its own learnable body of knowledge and capabilities.

(2) As there was no consensus on individual non-teaching-specific characteristics and their predictive power for teacher effectiveness (cf. Helmke, 2009; Helmke & Klieme, 2008; Mayr & Neuweg, 2006), the 1970s were characterized by a paradigm shift in research on teacher effectiveness. This new paradigm is described as *product-process paradigm* (Bromme, 1992; Helmke, 2009; Mayr & Neuweg, 2006) as it focuses on processes that are related to products (Helmke, 2009). The process level concerns certain teacher behaviors (Brophy & Good, 1984; cf. Helmke, 2009; Mayr & Neuweg, 2006). The product, or in other words the indicator of teaching effectiveness, is the performance of students (Helmke, 2009). An example for research conducted in this period is the research on teacher enthusiasm. Teacher enthusiasm was regarded as instructional behavior and was assumed to have a positive impact on students' learning (e.g., Bettencourt et al., 1983; Collins, 1978). Further teacher behaviors that were in the focus of research were related to the questioning of students (e.g., the amount of challenging questions the teacher provides [Helmke, 2009], the selection of a respondent [Brophy & Good, 1984] or the reaction to students' responses as for instance the reaction to no response or an incorrect response [Brophy & Good, 1984]). This paradigm only considered teacher behaviors and neglected that these behaviors are to a large extent not intuitive, but based on knowledge and other cognitive aspects (cf. Mayr & Neuweg, 2006). This again neglects the teaching-specific body of knowledge as well as the meaning of institutionalized training to develop this body of knowledge, two important characteristics of professionals.

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(3) The second change in research on teacher effectiveness that became apparent by the end of the 1980s should not be understood as shift, but rather as an expansion of the process-product paradigm (Helmke, 2009). The aim was to find characteristics that are more predictive than teacher behaviors (Mayr & Neuweg, 2006). What characterized this new orientation is the ground assumption that the teacher should be regarded as a professional and thus needs several capabilities to meet the demands of the teaching profession. This paradigm can be termed as *expert-paradigm* (Helmke, 2009). Now, the teacher was characterized as a professional and the focus of research was related to the characteristics that are necessary to master the specific demands of the teaching profession. A large focus was set on the professional knowledge of teachers (e.g., Baumert et al., 2010; Bromme, 1992; Großschedl et al., 2015; Hill, Rowan, & Ball, 2005; Lange et al., 2015; Ohle, Fischer, & Kauertz, 2011; Rowan, Chiang, & Miller, 1997; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013; Shulman, 1986, 1987). In addition to this, there was a further important development within this paradigm. Whereas the first studies particularly referred to proxy variables to assess knowledge (e.g., the amount of university courses), later studies used paper and pencil tests to gather a deeper insight into teacher knowledge (cf. Helmke, 2009). The focus on knowledge was widened up by characterizing a teacher not only as knowledgeable but also as competent. Beyond knowledge, other aspects like motivational orientations or beliefs were also considered as necessary to characterize an effective teacher (Baumert & Kunter, 2006; Kunter et al., 2008; Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011; Kunter, 2013). To sum up, this paradigm aimed to find characteristics that are specific for the teaching profession and that are more predictive for instructional quality and students' performance than the consideration of personal characteristics or behavior. The understanding of teachers as professionals also included the consideration of teacher education as an important source for teacher effectiveness (e.g., Bettencourt et al., 1983; Campbell, 1996; Carleton, Fitch, & Krockover, 2008; Clermont, Borke, & Krajcik, 1994; Collins, 1978; Grossman, 1990; Kunter et al., 2011; Kleickmann & Anders, 2013; Lederman, Gess-Newsome, & Latz, 1994; Roness, 2011; Schmelzing et al., 2013; Schmidt et al., 2007; Tatto & Senk, 2011).

My dissertation refers to the latter paradigm, which currently is the prominent one in research on teachers' profession in Germany. Thus, my studies consider the teacher as a professional owning a profession-specific body of competencies, which develops in the course of teacher education and the professional life.

2.3 Teachers' Professional Competence

This subchapter provides a detailed introduction into the concept of teachers' professional competence.

2.3.1 Introduction Into the Concept of Teachers' Professional Competence

For a deep insight into the concept of teachers' professional competence, a clarification of the term *competence* is necessary. I follow the considerations of Weinert (2001a, b) to which a broad body of research on teachers in Germany refers to (e.g., Baumert & Kunter, 2006, 2013; Frey, 2004; Klieme, 2004; Lipowski, 2006; Mayr, 2006; Riese & Reinhold, 2010). Weinert (2001a, b) described competence to include the cognitive as well as the related motivational, volitional, and social prerequisites that enable an individual to meet the demands of a certain situation. In contrast to e.g. the intelligence concept, these prerequisites are assumed to be learnable (Weinert, 2001b). This general definition is not specifically formulated to define the competence of a professional – in this case the teacher. In this context, Weinert's expanded definition (2001a) of *action competence* is important (cf. Baumert & Kunter, 2006, 2013). Action competence combines knowledge, abilities, skills, routines and strategies as well as further volitional and motivational aspects that enable individuals to have success in particular fields of action. Transferred to the professional competence of teachers, the mentioned field of action concerns the professional life of teachers (e.g., lesson planning, teaching).

Weinert's (2001 a, b) considerations allow three conclusions that are crucial for the understanding of the concept of professional competence in my dissertation. (1) Competence is derived from the demands of a certain profession and includes the conditions necessary to master these. Thus, it is important to identify the central demands of the teaching profession. (2) More detailed, teachers' professional competence comprises

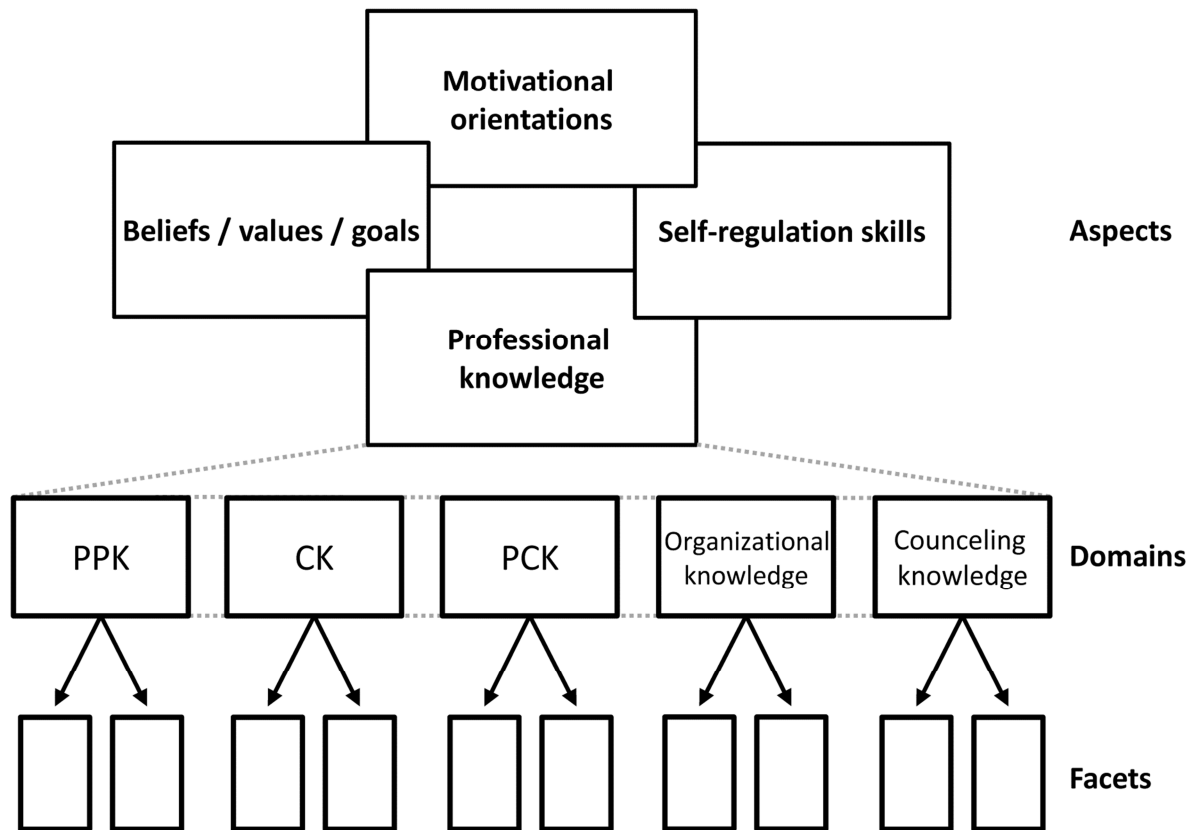
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cognitive aspects as well as motivational, ethical, volitional, and social aspects. Thus, the term *competence* goes beyond knowledge. (3) Finally, competence is assumed to be learnable and teachable.

The underlying theoretical model to which I refer in my dissertation is the prominent model of *teachers' professional competence* developed by Baumert and Kunter (2006, 2013) (see Fig. 2-1), which has an important impact on educational research in Germany.

The core demand for teachers is the planning and conduction of cognitively activating and motivating lessons that enable students to develop core competencies (Baumert & Kunter, 2013). According to these demands, Baumert and Kunter (2006) present a bundle of skills an effective teacher should have. They widen up the considerations of Shulman (1986, 1987) and consider four competence aspects in their model (1) professional knowledge (e.g., content knowledge), (2) motivational orientations (e.g., teacher enthusiasm), (3) self-regulation skills (e.g., the individual's responsible treatment of the own resources), and (4) beliefs, values and goals (value commitments, epistemological beliefs, subjective theories of teaching and learning as well as goals for teaching and the curriculum) (see Fig. 2-1). It is important to note that the model is non-hierarchical (Baumert & Kunter, 2013), meaning that none of the competence aspects is more important than another. This theoretical model is meant to found empirical research on teacher effectiveness and because of its generic description it is adaptable to various domains (e.g., the examination of mathematics or biology teachers' professional competence) (Baumert & Kunter, 2013).

Within the model, professional knowledge is described as the key aspect of teachers' professional competence (Baumert & Kunter, 2013). Research on teachers' professional knowledge has a long tradition (e.g., Baumert et al., 2010; Bromme, 1992; Fennema et al., 1996; Shulman, 1986, 1987). Nevertheless, as teachers are caught in a crossfire of demands in their professional lives and as many teachers suffer from job stress (Stoeber & Rennert, 2008), professional knowledge is not sufficient to characterize an effective teacher. Hence, also teachers' motivational orientations are of crucial importance. Accordingly, I focus on two competence aspects: (1) teachers' professional knowledge and (2) teachers' motivational orientations.



Note. PPK = pedagogical-psychological knowledge; CK = content knowledge; PCK = pedagogical content knowledge.

Figure 2-1. Model of Professional Competence (adapted from Baumert & Kunter, 2013 [p. 29]) with Competence Aspects as well as Domains and Facets of Professional Knowledge.

2.3.2 Conceptualization of Competence Aspects and Domains

Teachers' professional knowledge

Professional knowledge is described as the “core of professionalism” (Baumert & Kunter, 2013, p. 28) and is one of the key characteristics of a professional (Baumert, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shon, 2006; Shulman, 1998). It provides the knowledge base necessary to master the demands of the teaching profession (Baumert et al., 2010; Shulman, 1986). Baumert and Kunter (2013) summarized different aspects that characterize professional knowledge. For this purpose, they used the findings of research on the differences between the knowledge of laypersons and experts (cf. Berliner, 1994, 2001; Bromme, 2004; Palmer, Stough, Burdenski, & Gonzales, 2005). Professional knowledge is described as domain-specific, well-organized (around key concepts) and hierarchically

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structured (Baumert & Kunter, 2013). It can be flexibly adapted to different situations as it integrates different application contexts (Baumert & Kunter, 2013).

Shulman (1986) initially distinguished between four domains of professional knowledge: (1) pedagogical knowledge, (2) content knowledge, (3) pedagogical content knowledge, and (4) curricular knowledge. He further expanded the domains by considering (5) the knowledge of learners, (6) the knowledge of the educational content, and (7) the knowledge of the philosophical and historical aims of education (1987). Available research particularly focuses on the initially described domains of knowledge (e.g., Baumert et al., 2010; Fennema et al., 1996; Grossman, 1990; Großschedl et al., 2015; Lange et al., 2015; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Jüttner et al., 2013; Magnusson, Krajcik, & Borko 1999; Ohle et al., 2011; Park & Chen, 2012; Sadler et al., 2013; Shulman, 1986). Within this description, it becomes apparent that two categories of teachers' professional knowledge can be distinguished: (1) non-content-related professional knowledge and (2) content-related professional knowledge (Baumert & Kunter, 2013; Shulman, 1986).

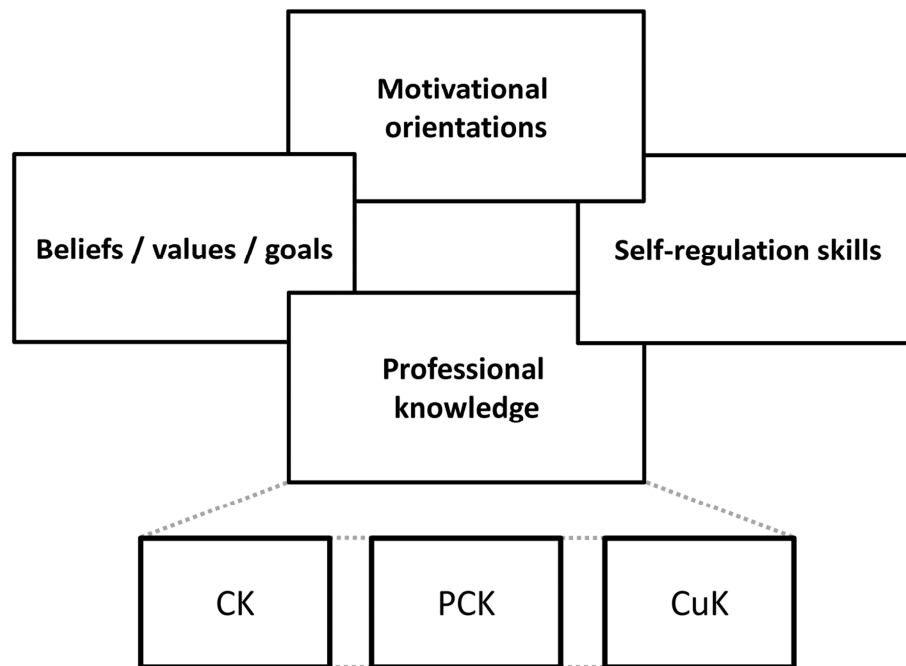
Non-content-related professional knowledge. According to Shulmans (1986) initial conceptualization, non-content-related professional knowledge is represented by pedagogical knowledge (PK). The initial definition of PK covers particularly knowledge of classroom management (Shulman, 1987). In recent conceptualizations, this focus is widened up by facets that also concern knowledge related to educational psychology (e.g., knowledge of students' learning processes) (Voss & Kunter, 2013). According to this broader focus, this domain of professional knowledge is termed as pedagogical/psychological knowledge (PPK) (Hohenstein, Kleickmann, Zimmermann, Köller, & Möller, in press; Voss & Kunter, 2013).

Content-related professional knowledge. In the 1980s, there was dissatisfaction concerning teachers' academic qualities (Gardener et al., 1983). One concern was that teacher education programs too strongly focused on the acquisition of pedagogical knowledge and neglected the relevance of the school subject and its content (Gardner et al., 1983). Shulman (1986) stresses this assumption and strongly calls for a new focus on the content. Hashweh (1987) supports the relevance to consider the content by describing teaching as a complex interaction between (1) the teacher, (2) the subject taught, and (3) the student. Shulman (1986) initially distinguished three domains of *content-related professional knowledge*:

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(1) content knowledge - CK, (2) pedagogical content knowledge - PCK, and (3) curricular knowledge - CuK (see Fig. 2-2).

According to the previously described significance of the content for teaching, I focus on teachers' content-related professional knowledge and refer to CK, PCK, and CuK in my studies.



Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge.

Figure 2-2. Aspects of Teachers' Professional Competence with the Aspect of Professional Knowledge Specified in Terms of Content-Related Professional Knowledge (cf. Baumert & Kunter, 2006, 2013; Shulman, 1986).

CK. CK is the domain of knowledge which is not exclusively important for teachers since content specialists also draw on CK. By stating that teachers have to understand *what* they teach, Ball and Mc Diarmid (1989) stressed the relevance of CK for teachers. CK is assumed to be a central domain of teachers' professional knowledge and to be an important basis for effective teaching (Cochran & Jones, 1998).

CK covers not only factual knowledge (Ball & Mc Diarmid, 1989), but also a deep understanding of the structure of a specific domain (Shulman, 1986). This understanding includes knowledge about the identification and organization of central concepts and

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principles (Shulman, 1986) as well as an epistemological understanding. The latter refers to the knowledge of how validity and invalidity are established and the knowledge of how to deal with competitive opinions (e.g., the decision for the more warranted opinion) (Cochran & Jones, 1998; Shulman, 1986). Moreover, CK concerns the awareness of different assumable organizations of a domain (e.g., biology as science of molecules vs. biology as science of ecosystems: Shulman, 1986). In summary, CK represents a deep understanding of the domain, which does not only concern an understanding *that* something is so, but also an understanding *why* something is so (Shulman, 1986). This deep understanding of the content is necessary as supporting students in the acquisition of content knowledge requires more than the provision of incoherent facts and information (Ball & Mc Diarmid, 1989).

PCK. PCK as a further domain of teachers' professional knowledge covers the knowledge that makes the teacher unique and distinguishable from the content specialist (who in particular has CK) (Shulman, 1987). The term PCK was initially introduced by Shulman in his talk at the American Educational Research Association meeting in 1985, which was the basis for Shulman's fundamental article on teachers' professional knowledge (1986). The introduction of this concept occurred at a time when there was great dissatisfaction with the educational system and teacher preparation in the US (Carlsen, 1999; Gardner, 1983). The introduction of the concept of PCK revived research on teachers' professional knowledge (Gess-Newsome, 1999). Moreover, the consideration of a domain of knowledge that is exclusive for teachers stresses the understanding of teaching as a profession (Carlsen, 1999; Shulman, 1987).

PCK is the knowledge which enables the teacher to make the subject matter comprehensible to the students (Shulman, 1986). In more detail, Shulman (1986) described two facets of teachers' PCK, namely (1) the knowledge that allows the teacher to represent and formulate the subject matter in a manner that makes it comprehensible to students, and (2) the knowledge of students' (pre)conceptions. After the initial work of Shulman (1986, 1987), several scholars engaged in research on PCK. Grossman (1990), for instance, further described Shulman's first facet as *knowledge of instructional strategies*. Beyond these two initial facets, different scholars added further facets as, for instance, the knowledge of assessment (Magnusson et al., 1999), the knowledge related to media (e.g., multimedia, science magazines) (Lee & Luft, 2008) or the knowledge of the science curriculum

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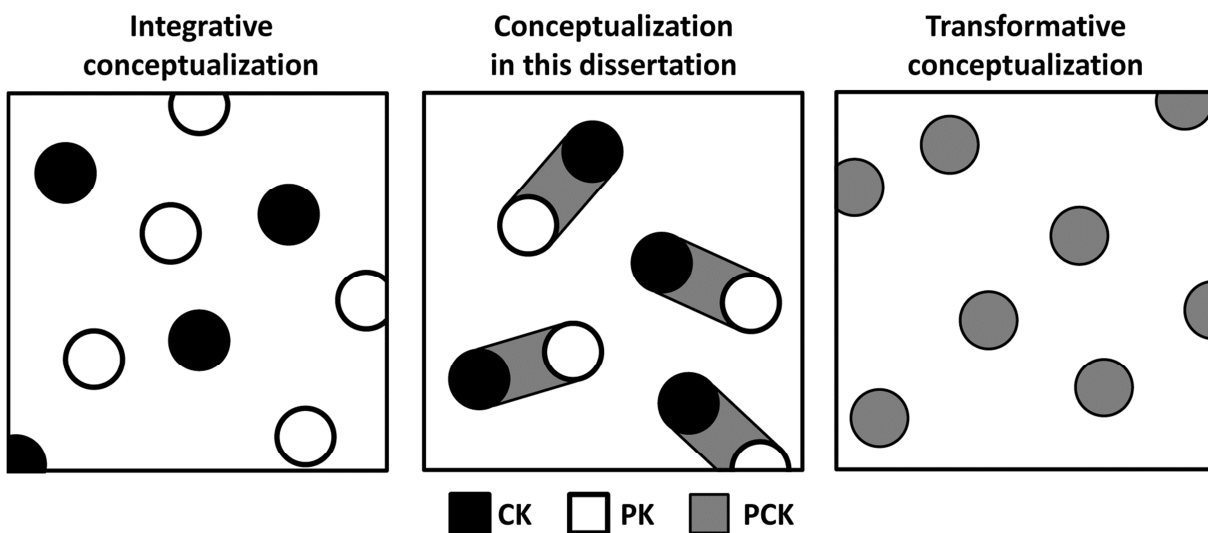
(Magnusson et al., 1999). This leads to different conceptualizations which include different facets of PCK. These differences make the conceptualization of PCK a bit vague. Nevertheless, when reviewing the literature it becomes apparent that in particular two core facets of PCK are described: (1) the knowledge of the representation of subject matter and instructional strategies (hereinafter: *knowledge of instructional strategies for teaching*) and (2) the knowledge of students' (pre)conceptions or students' understanding (hereinafter: *knowledge of students' understanding*) (Depaepe, Verschaffel, & Kelchtermans, 2013; Grossman, 1990; Hill, Ball, & Schilling, 2008; Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2008; Schmelzing et al., 2013; Shulman, 1986; Van Driel, Verloop, & De Vos, 1998). *The knowledge of instructional strategies for teaching* comprises both subject-specific strategies which are broadly applicable (e.g., the triggering of a cognitive conflict) as well as topic-specific strategies (e.g., to support the students' understanding of a specific science concept [Magnusson et al., 1999] like energy). Representations are seen as an effective tool to support students' learning (Magnusson et al., 1999; Shulman, 1986) and are thus in the focus of this facet of PCK. Examples for representations are illustrations, models, examples or analogies (Magnusson et al., 1999; Shulman, 1986). Beyond the knowledge of representations the knowledge of adequate subject-related activities is also important (e.g., experiments [Magnusson et al., 1999]). *The knowledge of students' understanding* as a further facet of PCK includes knowledge of the requirements of learning (e.g., required prior knowledge [Magnusson et al., 1999] as well as knowledge of specific learning difficulties (e.g., the knowledge which concepts are especially difficult to understand due to their abstractness, the knowledge of misconceptions [Magnusson et al., 1999]). Considering the broad literature base, I conceptualize teachers' PCK to comprise the facets (1) *knowledge of instructional strategies for teaching* and (2) *knowledge of students' understanding*.

As the term PCK indicates, both knowledge of the content as well as knowledge related to pedagogical issues play a role for this domain of professional knowledge. There are different assumptions which role PCK plays in the interaction between content and pedagogy. Gess-Newsome (1999) distinguishes between two models: (1) the integrative model and (2) the transformative model. The *integrative model* assumes that PCK as a unique domain does not exist but represents the integration of CK and PK. Gess-Newsome (1999) compares this conceptualization of PCK as a mixture of CK and PK, indicating that the

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ingredients (CK and PK) are still visible (e.g., by the reflection of lesson planning or the conducted lesson). The *transformative model*, in contrast, considers PCK as a unique domain of knowledge, i.e., the synthesis of CK and PK. PCK is understood as compound, which indicates that the original ingredients are not detectable anymore (Gess-Newsome, 1999). This understanding implies that there have to be several specific PCKs for different topics and different audiences because drawing on CK and PK in a flexible manner is not possible (as these domains do not exist as separate domains in this conceptualization) (Gess-Newsome, 1999). These models both represent extremes. The conceptualization of PCK that provides the basis for the studies in this dissertation lies between these two models.

I assume PCK to be a unique domain which is related to CK and PK, but is more than a synthesis of these two domains. Moreover, I assume CK and PK to not be absorbed by PCK, but to be unique as well. The assumption that CK and PK are not absorbed by PCK is supported by findings that show CK, PCK, and PK to be empirically separable and unique (e.g., Großschedl et al., 2015; Kleickmann et al., 2014). See Figure 2-3 for a comparison of the models.



Note. CK = content knowledge; PK = pedagogical knowledge; PCK = pedagogical content knowledge.

Figure 2-3. Comparison of Different Conceptualizations of Pedagogical Content Knowledge (PCK) (cf. Gess-Newsome, 1999).

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CuK. *CuK* represents a further domain of content-related professional knowledge that is specific for the teaching profession. It was initially defined as the knowledge of the programs and materials that serve as “tools of the trade” for teachers (i.e., the programs and materials that are necessary for effective teaching) (Shulman, 1987, p. 8). This definition was extended by adding the knowledge of the articulation of topics, the knowledge of the goals of a subject, the knowledge of the vertical curriculum (i.e., the topics that surround the current topic) (Grossman, 1990) as well as the knowledge of political programs and documents like national educational standards (Magnusson et al., 1999). In summary, the conceptualizations concerning *CuK* are very different. For the conceptualization of *CuK* in my dissertation, I focus on the latter facet: the knowledge of national educational standards. National educational standards play an important role in the educational system of Germany and other countries. My intention is to illustrate the important position of national educational standards by using science standards as an example: To ensure the quality of science education, several countries implemented national science standards (e.g., ACARA, 2013 [Australia]; DfE, 2013 [Great Britain]; EDK, 2011 [Switzerland]; KMK, 2004a [Germany]; NGSS, 2013 [USA]). A lack of well-qualified personnel in science-related professions (KMK, 2004a; NGSS, 2013) as well as disappointing results in international studies (OECD, 2014; Schiepe-Tiska, Schöps, Rönnebeck, Köller, & Prenzel, 2012) show the urgent need of high quality science education. Science standards consider findings of science education research to identify mandatory abilities that are necessary for a fundamental understanding of science (e.g., ACARA, 2013; DfE, 2013; EDK, 2011; KMK, 2004a; NGSS, 2013). Moreover, science standards simplify the comparability within one country concerning assessment standards and educational requirements (EDK, 2011; KMK, 2004a). Science standards draw on concepts that have superordinate importance for science education. An example for such a superordinate concept is the concept *system* which is considered as a basic concept in the *German National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2004a) and in science standards of several other countries (ACARA, 2013; DfE, 2013; EDK, 2011; KMK, 2004a; NGSS, 2013). See 4.2 for a further clarification of this concept.

In my dissertation, I refer to *CuK* as knowledge of the *German National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2004a).

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Type of knowledge. This section briefly illustrates to which type of knowledge I refer to in my dissertation. Fenstermacher (1994) stated that *names* and *types* should be carefully distinguished when thinking about knowledge. Several different names (e.g., strategic knowledge, propositional knowledge, craft knowledge, case knowledge, personal knowledge; Fenstermacher, 1994) can be found in the literature representing not necessarily discrete knowledge types. Two examples that indeed represent discrete types of knowledge are formal (or theoretical) knowledge and practical knowledge (Fenstermacher, 1994). In terms of teachers' professional knowledge, *formal knowledge* covers particularly CK as well as PCK in part (Baumert & Kunter, 2013). Formal knowledge has a mental representation, therefore it is described to be mentally represented by semantic networks (Baumert & Kunter, 2013). *Practical knowledge* is premised on theoretical knowledge and experience and is related to specific contexts or situations (e.g., a communicative situation during teaching) (Baumert & Kunter, 2013). This type of knowledge is commonly implicit but can also be mentally represented, for instance during the activity of lesson planning (Baumert & Kunter, 2013). Also, Bromme (1992) stated that professional knowledge draws on theoretical elements as well as practical experiences.

I refer to the first type – formal knowledge – in my conceptualization of professional knowledge.

Teachers' motivational orientations

Competence is – related to the definition of Weinert (2001a) – not only the ability but also the willingness (see also Kunter, 2013) to cope with a situation. Accordingly, I refer to a further aspect of professional competence: motivational orientations. Motivational orientations represent important characteristics of psychological functioning. They are related to the "psychological dynamics of behavior, the maintenance of intentions, and the monitoring and regulation of occupational behavior" (Baumert & Kunter, 2013, p. 38; see also Schiefele & Schaffner, 2015; Woolfolk, 2008).

Different domains of teachers' motivational orientations can be distinguished. In the framework of the model of teachers' professional competence three domains are described: (1) self-efficacy, (2) control beliefs, and (3) enthusiasm (Baumert & Kunter, 2013). I decided to focus on two of these domains to gather a deep insight into both cognitive as well as

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affective parts of teachers' motivational orientations. *Self-efficacy* represents the cognitive domain of motivational orientations, whereas *enthusiasm* of teachers embodies the affective domain of teachers' motivational orientations (Kunter et al., 2011). In order to learn more about what teachers are enthusiastic about and what the implications of that enthusiasm are, I will pay special attention to two facets, namely (1) subject-related enthusiasm, and (2) enthusiasm for teaching the subject (Kunter et al. 2011; Kunter, 2013). In summary, I refer to (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching the subject in my dissertation (see Fig. 2-4).

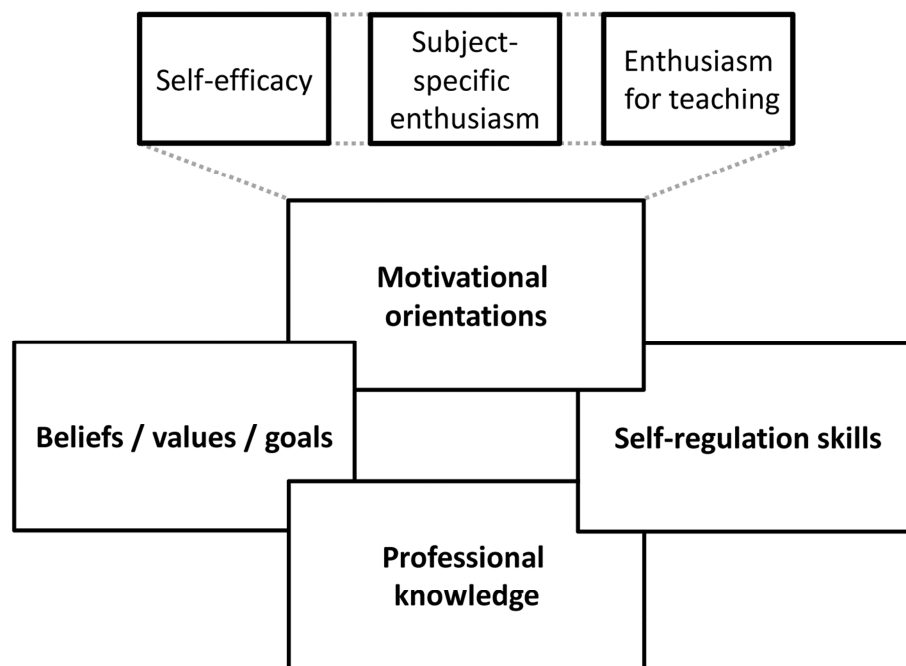


Figure 2-4. Aspects of Teachers' Professional Competence with a Detailed Consideration of Teachers' Motivational Orientations (cf. Baumert & Kunter, 2006, 2013; Kunter et al., 2008, 2011; Kunter, 2013).

The expectancy value theory helps to understand why self-efficacy and enthusiasm are such important domains of teachers' professional competence. This theory (Wigfield & Eccles, 2000) stresses two main factors which are related to the choice of a specific activity as well as the performance and the persistence in this activity. The first factor concerns the individual's expectancy of how well they perform in a certain activity (Wigfield & Eccles, 2000). Self-efficacy, as defined by Bandura (1977), is very closely related to this first factor (Wigfield & Eccles, 2000). The second factor concerns the extent to which one values this

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specific activity (Wigfield & Eccles, 2000). Valuing has, beyond others, an intrinsic component, which is closely related to intrinsic motivation and thus enthusiasm (Kunter, 2013). Intrinsic values are defined as the enjoyment of engaging in the specific activity (Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 2000). Transferred to the teaching profession, self-efficacy and teacher enthusiasm are important domains of motivational orientations that concern the whole professional life of teachers, more detailed the choice to become a teacher as well as the performance and the persistence in the teaching profession. Moreover, Moè, Pazzaglia, and Ronconi (2001) further stress the importance of self-efficacy and teacher enthusiasm by empirically proving the necessity of self-efficacy and teacher enthusiasm for the job satisfaction of teachers.

The following paragraphs provide the definitions of the considered domains and further clarify how these are conceptualized in this dissertation.

Self-efficacy. Self-efficacy of teachers represents the cognitive domain of teachers' motivational orientations (Kunter et al., 2011). Self-efficacy is also described as a kind of self-related cognition (Baumert & Kunter, 2006, 2013). The underlying cognitive process concerns the consideration of information to gain an expectancy of the own efficacy (Bandura, 1977). I follow the conceptualization of Bandura (1977) who defined self-efficacy as an individual's belief that he or she is capable to execute behavior that is necessary to produce a certain outcome. In contrast to more general aspects like self-esteem, self-efficacy is task-related (Moulding, Stewart, & Dunmeyer, 2014). Accordingly, teachers' self-efficacy can be defined as teachers' expectancy to successfully perform actions related to a particular teaching task (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). Tasks that occur in the teaching profession are particularly related to (1) the professional practice (Allinder, 1994; Schmitz & Schwarzer, 2001; Schriver & Czerniak, 1999; Tschannen-Moran et al., 1998), (2) the relationship and interaction with students, parents, & colleagues (Ashton, 1984; Schmitz & Schwarzer, 2001; Schriver & Czerniak, 1999), (3) emotional aspects like job stress (Allinder, 1994; Ashton, 1984; Klusmann, Kunter, Trautwein, & Baumert, 2006; Moè et al., 2001; Schmitz & Schwarzer, 2001) as well as (4) the professional development of the own skills (Schmitz & Schwarzer, 2000).

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Self-efficacy has to be carefully distinguished from the related theoretical approaches (1) outcome expectancies (Bandura, 1977), and (2) expectancies for internal versus external control (or locus of control [Rotter, 1966]).

(1) Bandura (1977) distinguishes efficacy expectancies (self-efficacy) and outcome expectancies. Outcome expectancies cover an individual's belief that a particular behavior will lead to a particular outcome (Bandura, 1977). The valuation of *the own capabilities* to perform this behavior is not inherent in this kind of expectancies. In other words, outcome expectancies alone are not responsible for the change in behavior. Although an individual believes that a certain behavior leads to a certain outcome, their behavior will not be influenced if the individual has doubts concerning the own capabilities to perform this behavior (Bandura, 1977). Accordingly, outcome expectancies are found to be less predictive for performance compared to efficacy expectancies (Wigfield & Eccles, 2000).

(2) The second theoretical approach, which refers to the individual expectancies for internal versus external control (locus of control; Rotter, 1966), pertains to the individual's belief that a specific outcome (e.g., successful learning of students) is caused by the individual (*internal control*), by environmental factors or by chance (e.g., socioeconomic status; *external control*) (Rotter, 1966, 1990). This approach is particularly distinguishable from Bandura's (1977) conceptualization in two points. First, the definition of Rotter (1966) foreshadows that only one state at a time becomes apparent (Moore & Esselmann, 1992). In contrast, in the understanding of self-efficacy as it is defined by Bandura (1977), feeling capable to produce a desired outcome – although (external) obstacles occur – is an important aspect of this conceptualization. The second difference concerns a lack of task-relation. Whereas self-efficacy is related to a specific task, the expectancies in Rotter's (1966) conceptualization are rather general (e.g., locus of control = internal: "Becoming a success is matter of hard work, luck has little or nothing to do with it."; locus of control = external: "Getting a good job depends mainly on being at the right place at the right time." [Rotter, 1966, p.11]).

Bandura (1977) identified different aspects that are important for the manifestation of self-efficacy. As already mentioned, information is used to generate an efficacy expectancy. The first and most meaningful aspect is termed as *performance accomplishments* (also: *enactive attainment*, Woolfolk Hoy, 2000). The basis here are mastery experiences, in other

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words the success one has in a certain situation (Bandura, 1977). Success in a certain situation raises efficacy expectations (Bandura, 1977). *Vicarious experiences* are the second source of self-efficacy. The experiences of others are used to generate efficacy expectations. The success of others makes an individual expect to have success in comparable situations. Nevertheless, the own mastery experiences are the strongest predictor for efficacy expectations; accordingly, vicarious expectations are described to be a weaker source (Bandura, 1977). A further aspect that impacts on the development of self-efficacy is *verbal persuasion* which comprises the verbal support of others concerning the expected success in a certain situation (Bandura, 1977). Again, verbal persuasion is less effective than the own experience of success. The last source which Bandura (1977) considers is *emotional arousal*. Emotional arousal gives information individuals use to judge their own competence, which in turn influences the expectancies of efficacy.

Teacher enthusiasm. Teacher enthusiasm comprises the affective domain of teachers' motivational orientations (Baumert & Kunter, 2006; Kunter et al., 2011). Available research considers teacher enthusiasm as (1) personality trait or (2) instructional behavior.

(1) Kunter and colleagues (Kunter et al., 2008, 2011; Kunter, 2013) conceptualize teacher enthusiasm as a *personality trait* and focus on internal processes, more detailed teachers' positive affective experience (Keller et al., 2014; Kunter et al., 2008). Teacher enthusiasm is defined as the enjoyment, excitement and pleasure for both a specific school-subject as well as for teaching this subject (Kunter et al., 2011). Inherent in this definition are two facets of teacher enthusiasm: (1) subject-specific enthusiasm, and (2) enthusiasm for teaching the subject. Both facets can be described as special forms of person-object-relations.

Subject-specific enthusiasm concerns the enjoyment related to a specific (school-) subject (Kunter et al., 2011). In terms of the person-object-relation, a teacher-subject-relation is the core of this facet of teacher enthusiasm. The second facet, *enthusiasm for teaching the subject*, is accordingly described to concern the enjoyment that teachers experience when teaching a specific subject. In contrast to the first facet the object in the person-object-relation is not the subject but the activity of teaching this subject (Kunter et al., 2011).

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What is special about this conceptualization is that it does not only consider if a teacher is enthusiastic, but it also states what exactly they are enthusiastic for. This allows more detailed findings concerning the enthusiasm of teachers.

Teacher enthusiasm is very closely related to both the concept of intrinsic motivation as well as individual interest. All three concepts include a positive experience while engaging in a certain activity or while being occupied with a certain topic (Kunter et al., 2011). Hereinafter, I want to illustrate the similarities and the differences of intrinsic motivation and individual interest when compared to teacher enthusiasm.

If an individual is intrinsically motivated, they will start an activity because of interest and without specific consequences (Deci & Ryan, 2000). According to this definition, both enthusiasm and intrinsic motivation concern positive emotional experiences related to a certain activity (Kunter et al., 2008). Kunter and colleagues (2008) nevertheless note that teacher enthusiasm and intrinsic motivation should not be assumed as completely identical. In the case of intrinsic motivation positive experience is assumed as the “ultimate reason” for a behavior (Kunter et al., 2008, p. 470; see also Eccles & Wigfield, 2002). As teacher enthusiasm is related to the professional lives of teachers, the underlying reasons may also be partially extrinsic (Kunter et al., 2008).

Another very closely related construct is individual interest (Krapp, 2002; Schiefele & Krapp, 1996). Analogous to teacher enthusiasm, individual interest concerns a person-object-relation, more detailed “a relatively stable tendency to occupy oneself with an object of interest” (Krapp, 2002, p. 388). In contrast to enthusiasm, which is an unambiguously affective orientation, individual interest also includes cognitive aspects (Krapp, 2002; Kunter et al., 2008, 2011). More detailed, an integrative part of individual interest concerns the tendency to deal with a specific topic and to acquire additional topic-related knowledge (Kunter et al., 2008; Long & Hoy, 2006). Moreover, individual interest particularly refers to the occupation with a specific topic, thus the interaction with students, which is also an important part of effective teaching, is not adequately considered in the definition of individual interest (Kunter et al., 2011).

(2) Especially in older research on teacher enthusiasm another understanding of teacher enthusiasm becomes apparent (see Rosenshine, 1970 for a review). Here, teacher enthusiasm is understood as *instructional behavior*. As a broad base of research refers to this

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conceptualization (e.g., Bettencourt, Gillet, & Gall, 1983; Brigham, Scruggs, Mastropieri, 1992; Collins, 1978; Mc Kinney et al., 1983; Williams & Ware, 1977; Wood, 1989), I will briefly subsume the important core considerations. Instructional behavior is understood to include the transportation of the positive value of a certain learning matter to the students (Patrick, Turner, Meyer, & Midgley, 2003). Research in this tradition evaluates the level of enthusiasm by observing the behavior of a teacher. Collins (1978) identified a canon of behaviors, which can be understood as indicators for an enthusiastic teacher. These indicators are further described in order to illustrate how teacher enthusiasm is understood by many scholars. Eight indicators were identified, which can be assigned to four groups. Indicators related to the first group concern the face of the teacher and include facial expressions that show the feelings of the teacher (e.g., surprise or sadness), the movement of the eyes and eyebrows, and the eye-contact with the students. The second group concerns the body language of the teacher. Both gestures (e.g., hands, head) as well as larger body movements (e.g., change in pace, bending movements) are considered. The third group includes the speaking in general and the voice of the teacher. Variance in volume, speed, tone, and pitch are defined as enthusiastic. Furthermore, this third group covers the word selection. A high variety as well as a vivid language are related to enthusiasm. The fourth group covers overarching indicators like the reaction to students' ideas and responds (e.g., encouraging students) as well as the level of overall energy.

I refer to the first conceptualization and consider teacher enthusiasm as personality trait. This decision is grounded in the concern that the observation of enthusiasm leads to biased results. In the classroom context, the teachers tend not to show negative feelings as they feel forced to show positive emotions (Sutton, Mudrey-Camino, & Knight, 2009). Moreover, the mere observation of teacher behavior generates no findings what exactly the teacher is enthusiastic about (e.g., enthusiastic about the subject vs. enthusiastic about teaching the subject: Kunter et al., 2008).

2.4 Structure of Teachers' Professional Competence

Research on the structure of teachers' professional competence is very important because it allows evaluating theoretical models. This represents the groundwork for further research (e.g., addressing the development of teachers' professional competence).

This subchapter gives an overview of the current state of research concerning the structure of teachers' professional competence. Most of the available research considers either (content-related) professional knowledge or motivational orientations. Accordingly, this subchapter starts with a summary of available findings on the structure of content-related professional knowledge and findings on the structure of teachers' motivational orientations. Afterwards, it provides the state of research which considers both teachers' professional knowledge and motivational orientations as well their interaction.

2.4.1 Structure of Content-Related Professional Knowledge

Reviewing the literature related to the structure of teachers' content-related professional knowledge shows that particularly two questions are in the focus. The first question concerns the relationship between teachers' CK and PCK, the second involves the relationship between PCK and CuK. Although Shulman's (1986) initial conceptualization was trinomial, research which considers all three domains when examining the structure is lacking.

Findings are available for both in-service as well as pre-service teachers' content-related professional knowledge. To begin with, I will present the findings concerning in-service teachers.

The assumptions concerning the relationship between CK and PCK are mixed. Whereas several studies consider CK and PCK as unique and separable constructs (Baumert et al., 2010; Großschedl, Harms, & Glowinski, 2013; Großschedl et al., 2015; Krauss, Baumert, & Blum, 2008a; Jüttner et al., 2013; Phelps & Schilling, 2004; Schmidt et al., 2007; Shulman, 1986), other scholars state that CK and PCK have to be regarded as integrated constructs (Fernandez-Balboa, & Stiehl, 1995; Hill, Ball, Blunk, Goffney, & Rowan 2007; Hill et al., 2005; Hill, Schilling, & Ball, 2004; Marks, 1990). Although the research base which supports the separability of CK and PCK seems large, there is no consensus within this

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research base concerning the correlations among the constructs. Jüttner et al. (2013) found a relatively small correlation ($r = .22$), while other scholars reported higher correlations (Baumert et al., 2010: $r = .79$). The reason for the notably weaker correlation between CK and PCK found by Jüttner and colleagues (2013) results from specific features in the test construction. The items developed to measure PCK include the necessary content-related information. CK is not necessary to solve the PCK items, thus a relatively low correlation is not surprising. Another relevant aspect to consider when examining the relationship between CK and PCK is the track (non-academic track vs. academic track) the teachers are certified for. The assumption is that teachers who had a higher amount of content-related training during pre-service teacher education (i.e., the teachers certified for the academic track; KMK, 2008; see 2.5.2) integrate the domains of content-related professional knowledge, thus a higher correlation between CK and PCK can be found for this subsample. This is supported by the findings of Krauss et al. (2013) who found different results concerning the structure depending on the subsample. Whereas CK and PCK are separable for the whole sample (consisting of academic track teachers and non-academic track teachers [$r = .79$]) and for a subsample of non-academic track teachers ($r = .61$), the structure is not stable for a subsample of academic track teachers (not separable, $r = .96$).

As mentioned before, the relationship between CK and PCK was also examined for pre-service teachers. These results reveal that CK and PCK are empirically separable constructs (Großschedl et al., 2015).

The second focus in research on the structure of teachers' content-related professional knowledge is the separability of teachers' PCK and CuK. Shulman (1986) theoretically described PCK and CuK as unique domains of content-related professional knowledge. Nevertheless, several studies recommend considering CuK as an integral part of PCK (Grossman, 1990; Loughran et al., 2001; Magnusson et al., 1999; Park & Chen, 2012). Magnusson et al. (1999) explain the integration of CuK in PCK by defining CuK as a body of knowledge that is characteristic for teachers and that helps to distinguish teachers from content-specialists. Although Park and Chen (2012) assume CuK to be an integral part of PCK, they found CuK to be only weakly correlated to the other assumed facets of PCK. This at least gives a hint that CuK could represent a unique domain of content-related professional knowledge. Comparing the different studies which deal with the relationship between PCK

and CuK is difficult because the different studies have a different understanding of what CuK comprises in detail (Grossman, 1990; Magnusson et al., 1999; Shulman, 1986).

2.4.2 Structure of Motivational Orientations

The question if teachers' self-efficacy and enthusiasm represent unique domains of teachers' motivational orientations was not in the focus of research. Nevertheless, theoretical considerations help to understand the relationship between self-efficacy and enthusiasm. Self-efficacy is described to be the cognitive domain of teachers' motivational orientations, whereas teacher enthusiasm embodies the affective domain (Baumert & Kunter, 2006; Kunter et al., 2011; see 2.3.2). The considerations made in the expectancy-value theory (Wigfield & Eccles, 2000) are also interesting in this context (see also 2.3.2). Whereas self-efficacy is very closely related to the *expectancy* part in the model (the expectancy how well one will act in meeting a certain demand), teacher enthusiasm is very closely related to the *intrinsic value* one attributes in a certain activity. Accordingly, teacher self-efficacy and teacher enthusiasm are related to different parts of the expectancy-value model. These conceptual distinctions support the assumption that teachers' self-efficacy and enthusiasm are distinguishable domains of teachers' motivational orientations.

Another interesting question concerns the inner structure of teacher enthusiasm. As the definition of Kunter et al. (2011) foreshadows, teacher enthusiasm is assumed to cover two unique facets: (1) subject-specific enthusiasm, and (2) enthusiasm for teaching the subject. Kunter and colleagues (2011) examined if the two assumed facets of teacher enthusiasm are also empirically separable. The results indicate that teacher enthusiasm is comprised of two separable but correlated facets ($r = .36$). This moderate correlation implies that teachers who are enthusiastic about their subject are not necessarily enthusiastic about teaching the subject (and vice versa).

2.4.3 The Relationship Between Content-Related Professional Knowledge and Motivational Orientations

Although both the domains of content-related professional knowledge as well as the domains of motivational orientations are well-discussed in the literature, only little research was conducted on the relationship between these aspects of professional competence. Nevertheless, as I consider effective teaching to require more than professional knowledge

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(namely a bundle of competence aspects), it comes short to consider only one aspect at a time. Teachers' professional competence should rather be regarded as a construct with complex interrelationships. This subchapter gives an overview of the available findings on the relationship between content-related professional knowledge and motivational orientations.

The available research focuses on the relationship between content-related professional knowledge or related constructs and self-efficacy. Riese and Reinhold (2010) examined the relationship between physics teachers' content-related professional knowledge and both their general and teaching-related self-efficacy. They found teaching-related self-efficacy to be related to CK. This result is supported by other studies, which consider knowledge (Raudenbush, 1992) or academic achievement (Pekkanli Egel, 2009). In contrast, Moulding et al. (2014) were not able to find a positive relationship between academic achievement and self-efficacy. Bandura's (1977) considerations support the assumption that content-related professional knowledge is related to teachers' self-efficacy. He defined mastery experiences (performance accomplishments; see 2.3.2) as relevant aspect for the manifestation of self-efficacy. It is likely that the acquisition of content-related professional knowledge enables teachers to have mastery experiences.

Studies which explicitly concern the relationship between content-related professional knowledge and teacher enthusiasm are lacking. Again, theoretical considerations can help to understand the interrelationship between content-related professional knowledge and teacher enthusiasm. Enthusiasm is very closely related to the concept of intrinsic motivation (Kunter et al., 2011; Wigfield & Eccles, 2000). As known from the work of Deci and Ryan (2000), different needs have to be fulfilled in order to enable the manifestation of intrinsic motivation. One of these needs is the experience of competence. As both CK and PCK could help to experience competence, a relationship between these domains and teacher enthusiasm seems plausible. Nevertheless, empirical evidence is lacking.

2.4.4 Research Gaps – Structure of Teachers' Professional Competence

Although the structure of content-related professional knowledge is a widely discussed topic, some research gaps become apparent.

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(1) Despite the initial trinomial definition of content-related professional knowledge made by Shulman (1986), none of the available studies consider these three domains to examine their structure. Either both CK and PCK are in the focus or the relationship between PCK and CuK is discussed. Accordingly, findings concerning the relationship between CK and CuK are missing. Although a separability is expectable because of the different foci (or facets) within the constructs, the relationship between CK and CuK would have interesting implications for the development of CuK (e.g., in terms of teacher education courses that integrate CK- and CuK-related topics).

(2) Concerning the structure of teachers' motivational orientations, the body of research is notably smaller. No study explicitly deals with the structure of teachers' motivational orientations and its domains self-efficacy and enthusiasm. Although a separability of self-efficacy and enthusiasm seems plausible because of their different nature (cognitive vs. affective), it nevertheless would be interesting to examine if these two domains of motivational orientations are also *empirically* separable.

(3) Only little research has been conducted in order to examine the object of teacher enthusiasm. Kunter and colleagues (Kunter et al., 2008, 2011; Kunter, 2013) made an important first step to gather a deeper insight into this issue by distinguishing subject-specific enthusiasm and enthusiasm for teaching the subject. Further research is needed to examine the relationship between these facets of enthusiasm and self-efficacy as well as the inner structure of teacher enthusiasm.

(4) Although both knowledge and motivation of teachers were in the focus of research long before the holistic model of teachers' professional competence was developed, there is a lack of both theoretical and empirical work dealing with the interrelations between content-related professional knowledge and motivational orientations. The available research often deals with proxy variables (Helmke, 2009) like academic achievement or the amount of university courses. As I assume that the respective competence aspects do not operate in an isolated, but rather in an integrated manner, the examination of interrelationships within the model is of crucial importance.

2.5 Opportunities for the Development of Teachers' Professional Competence

The assumption that provides the basis for this research strand is that there are interindividual differences between teachers concerning their effectiveness which lead to differences in the professional practice (Kunter et al., 2013a). The question what in detail causes these differences arises. Here, the review of different research paradigms is again interesting (see 2.2). The early focus on individual characteristics or the aptitude of teachers (Helmke, 2009; Helmke & Klieme, 2008; Kennedy et al., 2008; Kunter, 2011) implied that teachers enter the career with favorable stable characteristics (Kennedy et al., 2008) and that especially the recruitment of teachers is important to ensure the quality of teaching and learning (Kennedy et al., 2008). Hence, the development and education of teachers were not in the focus of research. As the focus shifted to a more profession-centered approach, which assumes an effective teacher to be characterized by different learnable capabilities (Baumert & Kunter, 2006, 2013), particularly teacher education was assumed to be responsible for the interindividual differences (Kennedy et al., 2008). Kennedy et al. (2008) found that differences in teacher education are more predictive for students' performance than differences in personal characteristics are.

2.5.1 Malleability and Stability of Teachers' Professional Competence

Changes in teachers' content-related professional knowledge seem plausible as the knowledge domains are teaching-specific and are thus not determined with the entrance in a teacher education program. Teacher education at university focuses on the acquisition of professional knowledge (e.g., KMK, 2004a; Kunter et al., 2013a).

The concept of competence of Weinert (2001a, b) indicates that teachers' motivational orientations are also not determined with the entry in a teacher education program, but change over the time. Nevertheless, the development or even 'learning' of motivational orientations seems to be not intuitive. Concerning teacher enthusiasm, this issue has been addressed by Kunter (2013). She examined the stability of subject-specific enthusiasm and enthusiasm for teaching the subject. By doing so, she found that both facets of teacher enthusiasm change over time, but that subject-specific enthusiasm is the more stable facet of teacher enthusiasm. Kunter (2013) explained this difference by the fact that enthusiasm

for teaching the subject is more influenced by situations during teaching (e.g., student motivation, disciplinary problems) (Kunter, 2013).

2.5.2 Identification of Opportunities for the Development of Teachers' Professional Competence

Different phases in the professional lives of teachers are defined as important for the development of teachers. Beyond the own school experience, especially (1) (pre- and in-service) teacher education and (2) the time in the occupational life provide opportunities to develop professional competence (Friedrichsen et al., 2009). During these phases, both formal and informal development takes place (Tynjälä, 2008). Formal development proceeds in an institutional context and leads to a certain kind of certification (e.g., teacher education at university, professional development during in-service teacher education), whereas informal learning is not related to an institutional context and proceeds voluntarily (e.g., self-study) or even unconscious (e.g., development through experience).

Excursus: Teacher education

This section provides a brief introduction into teacher education in Germany. Teacher education in Germany is divided into three phases, which build on one another (KMK, 2008; Neumann, Härtig, Harms, & Parchmann, in press).

First phase of teacher education. The first phase of teacher education is regulated by standards for teacher education (KMK, 2004b; KMK, 2008). These standards were introduced to provide a basis for the evaluation of teacher education programs. Moreover, they should enable prospective teachers to continue the first phase of teacher education at another university in another federal state. The introduction of the standards further aimed to enable the mutual recognition of certificates between the different federal states (KMK, 2008).

The first phase of teacher education aims at the acquisition of basic competencies (i.e., especially professional knowledge [KMK, 2008]). On the secondary school level, several school types with differing names (differing between the different federal states) exist (e.g., *Stadtteilschule* [Hamburg], *Gemeinschaftsschule* [Schleswig-Holstein]). What all federal states have in common is the distinction between the academic track, which qualifies the

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students for an academic career and the non-academic track, which qualifies the students for a non-academic career (e.g., for vocational training). According to this distinction, different teacher education programs for the first phase of teacher education at university exist. These teacher education programs certify the prospective teachers either for a teaching career at academic track schools or for a teaching career at non-academic track schools. They take four to five years and are particularly distinguished by different demands concerning the acquisition of CK. Prospective academic track teachers have to master a higher amount of content-related courses when compared to prospective non-academic track teachers (Baumert et al., 2010; Brunner et al., 2006; Krauss et al., 2008a; KMK, 2008). The amount of PCK-related courses is comparable (KMK, 2008). A third type of teacher education program took place at the former German Democratic Republic (*Diplomlehrer*) (Baumert et al., 2010; Führ, 1993; Schmidt, 1986). This type of teacher program also qualified for teaching two school-subjects, but there was no distinction between the academic track and non-academic track on the secondary school level (Schmidt, 1986). This teacher education program includes four to five years of teacher education at university (since 1982/1983 prospective teachers participated five years in a teacher education program) with an integrated practical phase (Führ, 1993; Schmidt, 1986). This type of teacher education program was not completed with a separate trainee program (*Referendariat*) (Führ, 1993; Schmidt, 1986) that ends with a separate certification (i.e., a second state examination) (Führ, 1993).

There is a further type of teacher education program that qualifies the prospective teachers exclusively for a teaching career in primary schools. This certification type is not further considered in this dissertation.

The first phase of teacher education ends with the first state examination that allows prospective teachers to enter the second phase of teacher education.

Second phase of teacher education. In contrast to the acquisition of basic competencies during the first phase of teacher education, the second phase of teacher education aims at the acquisition of competencies which are more related to the demands of the teaching profession (KMK, 2008). After completing the teacher education program at the university, the second more practical phase follows (*Referendariat*). It usually takes between one and a half year and two years to complete, depending on the federal state (Cortina & Thames,

2013). During the second phase of teacher education, prospective teachers are supported by experienced colleagues (*Mentoren*) and visit further teacher education courses (Cortina & Thames, 2013). This second phase of teacher education is completed with the second state examination. The previously described third type of teacher education program that took place in the former German Democratic Republic did not include an explicit trainee period (Führ, 1993; Schmidt, 1986).

Third phase of teacher education. The third phase of teacher education concerns the further development during the occupational life of teachers, i.e., in-service teacher education (KMK, 2008). This third phase is noticeably less structured than the first two phases. During this phase, both formal learning (professional development courses) as well as informal learning (e.g., reading journals) takes place. The participation in formally organized professional development programs is mandatory for teachers (e.g., Bavaria: BayLBG, 2016; Berlin: LBiG, 2014; Hamburg: HmbSG, 2016; Schleswig-Holstein: LehrBG, 2014). Nevertheless, the amount of mandatory attendances in professional development courses strongly varies (e.g., Hamburg: 30 h per year [Landesinstitut für Lehrerbildung und Schulentwicklung, 2011], Bavaria: 60 h in four years [Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst, 2002]) or is not strictly regulated (Berlin: LBiG, 2014; Schleswig-Holstein: LehrBG, 2014).

Opportunities for the development of professional competence in a formal context

Research reveals that also content-related professional knowledge as well as motivational orientations develop within a formal context.

Teacher education at university. Kunter et al. (2011) characterize *teacher education at university* as the most impacting phase for the development of professional competence and thus for the quality of teaching and learning. There is consensus in the literature supporting the relevance of teacher education at university, especially for the development of professional knowledge (Kleickmann & Anders, 2013; Schmidt et al., 2007; Tatto & Senk, 2011). This relevance seems plausible as teacher education programs at university primarily focus on the acquisition of professional knowledge (KMK, 2008; Kunter et al., 2013a). Empirical findings concerning the development of teachers' motivational orientations during the first phase of teacher education are lacking, but theoretical assumptions give hints that

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teacher education at university also provides opportunities for self-efficacy and teacher enthusiasm. Teacher education at university equips prospective teachers with a broad body of knowledge, which enables them to meet the demands of the profession. This knowledge base enables the teachers to have mastery experiences as well as the experience of competence during teaching. From the work of Bandura (1977) we know that mastery experiences are the most important aspect for the manifestation of self-efficacy. Moreover, the experience of competence is considered as important in terms of intrinsic motivation by Deci and Ryan (2000).

Professional development. An important opportunity to develop professional competence in the context of in-service teacher education (or the third phase of teacher education) is the attendance in lectures and workshops (i.e., professional development). Professional development is identified as relevant for the development of both content-related professional knowledge (Brunner et al., 2006; Clermont, Krajcik, & Borko, 1993) as well as motivational orientations (Bettencourt et al., 1983; Campbell, 1996; Collins, 1978; Roness, 2011). As described before, in terms of teacher education at university, professional development also helps the teacher to acquire professional knowledge and skills that are important to meet the demands of the profession. This knowledge and skills enable the teacher to have mastery experiences and to experience the own competence. This also explains the relevance of professional development for teachers' motivational orientations.

Opportunities for the development of professional competence in an informal context

Also, informal opportunities to develop professional competence are important both for teachers' content-related professional knowledge as well as for their motivational orientations.

Teaching experience. Teaching experience is described to provide the opportunity to further develop the knowledge acquired in teacher education (van Driel, De Jong, and Verloop, 2002) and to integrate the different domains of knowledge (Berliner, 2001; Krauss et al., 2008a). Moreover, teachers make different experiences (both success and failure) during their time in the profession, which have an important impact on their motivational orientations (e.g., mastery experiences are considered as an important source for self-efficacy [Bandura, 1977]). The empirical evidence for teaching experience is mixed; some

studies report a positive effect on the development of professional competence (*content-related professional knowledge*: Clermont et al., 1994; Grossman, 1990; Lederman, Gess-Newsome, & Latz, 1994; Schmelzing et al., 2013; *motivational orientations*: Carleton et al., 2008; Kunter et al., 2011), whereas other studies report teaching experience to not be important (*content-related professional knowledge*: Brunner et al., 2006; Friedrichsen et al., 2009; Kleickmann et al., 2013; *motivational orientations*: Schmitz, 1998).

Self-study. I assume another important aspect that impacts on the development of professional competence: self-study (e.g., reading journals). This aspect of informal learning has not yet been in the focus of a study.

2.5.3 Research Gaps – Opportunities for the Development of Teachers’ Professional Competence

Research concerning opportunities for the development of teachers’ professional competence features four considerable gaps.

(1) A consideration of teachers’ CuK when identifying opportunities for the development of teachers’ professional competence is completely missing. As I assume that CuK is a relevant domain of teachers’ content-related professional knowledge (e.g., due to the relevance of national standards in Germany and many other countries; see 2.3.2), its consideration in this field of research is definitely needed.

(2) The second research gap concerns the development of teachers’ motivational orientations during teacher education at university. As we know that teachers’ motivational orientations are not determined with the entry in a teacher education program at university, this phase seems to have impact on the development of their motivational orientations. Furthermore, there are some theoretical assumptions that suggest that teacher education at university could be fruitful for the development of motivational orientations (e.g., Bandura, 1977; Deci & Ryan, 2000). Nevertheless, research that focuses on this issue is missing.

(3) The focus on knowledge acquisition in teacher education programs at university leads to another important point, which has been neglected in research so far. The relationship between content-related professional knowledge and motivational orientations

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has to be further investigated in order to clarify the meaning of content-related courses for the development of motivational orientations.

(4) The fourth aspect missing in available research is the deeper examination of the development of professional competence in an informal context. This research gap concerns both the development of teachers' content-related professional knowledge as well as the development of their motivational orientations. The findings concerning the impact of teaching experience are inconsistent, accordingly further research is definitely needed. Another aspect which has been entirely neglected in research is the meaning of self-study.

2.6 Significance of Teachers' Professional Competence for Students' Performance

Students' performance is one of the most important indicators when thinking about an effective teacher. Although it is widely accepted in the literature that the teacher acts as an important determining factor for successful learning (e.g., Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000b; Hattie, 2009; Rivkin, Hanushek, & Kain, 2005), there is no consensus to date which characteristics in detail are important to improve students' performance. This subchapter provides an overview of the current state of research related to the significance of teachers' content-related professional knowledge and teachers' motivational orientations for students' performance.

2.6.1 Content-Related Professional Knowledge

A broad body of research deals with the meaning of content-related professional knowledge for students' performance. Theoretical considerations concerning CK and PCK relate these two domains of content-related professional knowledge to several aspects of instructional quality (e.g., cognitive activation, dealing with prior knowledge, learning gains, and learning difficulties) (CK: Baumert & Kunter, 2006; Cochran & Jones, 1998; Darling Hammond, 2000; Hashweh, 1987; Leinhardt & Smith, 1998; Rowan et al., 1997; Shulman, 1986; PCK: Ball, Lubienski, & Mewborn, 2001; Kunter et al., 2013b; Magnusson et al., 1999). Although these theoretical assumptions seem to draw a unified picture of the relevance of both CK and PCK for students' performance, empirical findings do not. Whereas there is clear empirical

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evidence for the significance of PCK for students' performance (Baumert et al., 2010; Fennema et al., 1996; Lange et al., 2015; Sadler et al., 2013), the role of CK seems to be not entirely clarified. Some studies also empirically support the relevance of CK (Baumert et al., 2010; Hill et al., 2005; Ohle et al., 2011; Rowan et al., 1997; Sadler et al., 2013), whereas other studies were not able to find a relationship (Carlisle, Correnti, Phelps, & Zeng, 2009; Lange et al., 2015). It is important to mention that in the studies which found CK to impact on students' performance, some methodological issues arise: Teachers' CK was highly related to teachers' PCK (Baumert et al., 2010), CK was measured using only one item (Rowan et al., 1997) or the study focused on a construct which considers CK and PCK in an integrated manner (*mathematical knowledge for teaching*: Hill et al., 2005, 2007).

To my knowledge, findings on the significance of CuK for students' performance are entirely lacking. Nevertheless, due to the impact of the German national educational standards on the planning and conduction of lessons (KMK, 2004a), CuK may contribute to the relevance of teachers for students' performance.

2.6.2 Motivational Orientations

Concerning teachers' motivational orientations, both the significance of teachers' self-efficacy as well as of teachers' enthusiasm for students' performance base on a broad body of research. The positive role of self-efficacy for students' performance is clearly supported (Abernathy-Dyer, Ortlieb, & Cheek, 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Ross, 1992). On the contrary, the findings on teacher enthusiasm are more heterogeneous. Most of the research that was conducted to examine the significance of teacher enthusiasm for students' performance can be assigned to the process-product-paradigm (i.e., the focus on teacher behaviors that have an impact on favorable student outcomes). Research in the tradition of the process-product paradigm considers teacher enthusiasm as instructional behavior rather than as a personality trait. Studies in this context were often based on the training of teachers (e.g., Bettencourt et al., 1983). For these studies, teachers are trained to show a certain (artificial) level of enthusiasm during teaching (e.g., a high level of enthusiasm vs. a normal level of enthusiasm vs. lethargic behavior). The empirical evidence concerning the meaning of teacher enthusiasm is mixed. Especially older research supports the

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significance of teacher enthusiasm for students' performance to a large extent (for reviews see: Brophy & Good, 1984 and Rosenshine, 1970; Brigham et al., 1992; Williams & Ware, 1977; Wood, 1989). However, there are also studies which found no effect of teacher enthusiasm on students' performance (Bettencourt et al., 1983; Mc Kinney et al., 1983). Mc Kinney et al. (1983) even observed that a high level of expressed enthusiasm could lead to disciplinary problems in younger classes. These disciplinary problems in turn could lead to a loss in students' performance. Different mechanisms are described in terms of how teacher enthusiasm (conceptualized as instructional behavior) impacts on students' performance. Emotional contagion is one example for such a mechanism. It concerns the "infection" of students with the the teacher's enthusiasm (Hatfield, Cacioppo, & Rapson, 1994). See study 4 for a detailed description of the underlying mechanisms.

Only little research was conducted concerning teacher enthusiasm as personality trait and its significance for students' learning (Kunter et al., 2008; Kunter, 2013). In the working group of Kunter and colleagues, a differentiated look was taken on the meaning of the two facets of teacher enthusiasm (subject-specific enthusiasm and enthusiasm for teaching the subject). Especially enthusiasm for teaching the subject was identified to be an important determining factor for students' performance as well as for instructional quality (a factor that is important for students' performance [Kunter et al., 2013b]).

2.6.3 Research Gaps – Significance of Teachers' Professional Competence for Students' Performance

Considerable gaps become apparent when reviewing the literature related to the impact of teachers' professional competence on students' performance. This concerns both content-related professional knowledge and motivational orientations.

(1) Although teachers' CK had been the subject of several studies examining the meaning for students' performance (Baumert et al., 2010; Carlisle et al., 2009; Hill et al., 2005; Lange et al., 2015; Ohle, Fischer, & Kauertz, 2011; Rowan et al., 1997; Sadler et al., 2013), the findings concerning the role of CK for students' performance remains unclear. Further research is needed to clarify the role of teachers' CK.

(2) No research on the significance of teachers' CuK for students' performance (or related constructs) has been conducted. This is not surprising as the body of research

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focusing on teachers' CuK is relatively small (see also the findings on structure and development: 2.4.4, 2.5.3) and most of the studies understand CuK as an integral part of PCK (Grossman, 1990; Magnusson et al., 1998; Park & Chen, 2012). Further research considering CuK as a unique domain of content-related professional knowledge is needed, especially when thinking about the meaning of national educational standards for the German educational system.

(3) A further and very important research gap concerns the research on teacher enthusiasm. As already stated, most of the available research refers to another conceptualization as I do in this dissertation, i.e., teacher enthusiasm is understood as instructional behavior. Beyond the problem that the displayed enthusiasm can be biased, a further problem is related to the research design of most of these studies. The teachers 'learn' to show a certain level of enthusiasm in preceding trainings. Often, even an artificially lethargic level is considered. Most of these studies were able to find an effect of enthusiastic behavior on students' performance. Nevertheless, as the teacher displayed artificial levels of enthusiasm, the results give no information about their natural level of enthusiasm and its significance for students' performance.

(4) A study which considers both the cognitive and the affective domain of teachers' motivational orientations has, to my knowledge, not yet been conducted. Even though there are studies which take a look at the single domains, a look on what is the driving force in this context would give a deeper insight into how motivational orientations impact on students' performance.

All research gaps which were identified for the three research foci are addressed in this dissertation. The following chapter gives an overview of the respective research questions and hypotheses.

3 RESEARCH QUESTIONS AND HYPOTHESES

Although a broad body of research has been conducted in terms of teachers' professional competence, several research gaps become apparent. My dissertation aims to clarify these issues by focusing on three aspects (1) the structure of teachers' professional competence, (2) the identification of opportunities for the development of teachers' professional competence, and (3) the significance of teachers' professional competence for students' performance. According to these three research foci, I address three superordinate research questions. This section provides an overview of the overarching research questions and hypotheses. For detailed research questions and hypotheses see study 1 to 4.

Research question 1 – Structure:

How are the domains of teachers' professional competence related to each other?

This research question concerns two aspects: (1) the empirical separability of the domains of teachers' professional competence (content-related professional knowledge and motivational orientations) and (2) the interrelationships between these domains.

Hypotheses. I hypothesize that teachers' content-related professional knowledge comprises three empirically separable domains: (1) CK, (2) PCK, and (3) CuK. This hypothesis is supported by theoretical considerations (Baumert & Kunter, 2006; Shulman, 1986, 1987) as well as empirical findings (Baumert et al., 2010; Großschedl et al., 2013; Großschedl et al., 2015; Krauss et al., 2008a; Jüttner et al., 2013; Phelps & Schilling, 2004; Schmidt et al., 2007).

Concerning the empirical structure of teachers' motivational orientations, I assume three unique domains, namely (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching the subject. This hypothesis results from the fact that self-efficacy and teacher enthusiasm are described as cognitive (self-efficacy) and affective (teacher enthusiasm) domains of teachers' motivational orientations, respectively (Baumert &

Kunter, 2006; Kunter et al., 2011). Moreover, the findings of Kunter and colleagues (Kunter et al., 2008; Kunter et al., 2011, Kunter, 2013) indicate that teacher enthusiasm is composed of two facets, namely (1) subject-specific enthusiasm, and (2) enthusiasm for teaching the subject.

Beyond their separability I hypothesize that the domains of teachers' professional competence are related. I assume that significantly positive relationships may occur both within the competence aspects (Krauss et al., 2013; Kunter et al., 2011; Jüttner et al., 2013) and between the domains of different competence aspects (Pekkanli Egel, 2009; Raudenbush, 1992; Riese and Reinhold, 2010).

See study 1 (content-related professional knowledge) and study 2 (motivational orientations) for the detailed consideration of this research question and the empirical examination of the hypotheses.

Research question 2 – Opportunities for the development of teachers' professional competence: How are formal and informal opportunities for the development of teachers' professional competence related to the respective domains of teachers' professional competence?

I consider different opportunities for the development of teachers' professional competence. More detailed, I consider (1) teacher education at university as well as (2) the attendance in professional development courses as opportunities in a formal context and (3) teaching experience as well as (4) the conduction of self-study as opportunities in an informal context.

Hypotheses. According to the definition of the competence concept by Weinert (2001 a, b), I hypothesize that both teachers' content-related professional knowledge as well as teachers' motivational orientations are malleable and learnable.

Moreover, considering theoretical ideas in the literature as well as the state of empirical research, I hypothesize that the uptake of both formal (*content-related professional knowledge*: Brunner et al., 2006; Clermont et al., 1993; Kleickmann & Anders, 2013; KMK, 2008; Kunter et al., 2013a; Schmidt et al., 2007; Tatto & Senk, 2011; *teachers' motivational orientations*: Bettencourt et al., 1983; Campbell, 1996; Collins, 1978;

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Roness, 2011) and informal (*content-related professional knowledge*: Clermont et al., 1994; Grossman, 1990; Krauss et al., 2008a; Lederman et al., 1994; Schmelzing et al., 2013; van Driel et al., 2002; *teachers' motivational orientations*: Bandura, 1977; Carleton et al., 2008; Kunter et al. 2011) opportunities is significantly positively related to the domains of professional competence.

See study 1 (content-related professional knowledge) and study 2 (motivational orientations) for the detailed consideration of this research question and the empirical examination of the hypotheses.

Research question 3 – Significance of teachers' professional competence for students' performance: How is teachers' professional competence related to students' performance?

Addressing this research question aims to elucidate the significance of teachers' professional competence for students' performance. Both teachers' content-related professional knowledge and teachers' motivational orientations are considered with their respective domains.

Hypothesis. According to theoretical considerations in the literature as well as the findings of different empirical studies, I hypothesize that both teachers' content-related professional knowledge (Ball et al., 2001; Baumert & Kunter, 2006; Baumert et al., 2010; Cochran & Jones, 1998; Darling Hammond, 2000; Hill et al., 2005; Fennema et al., 1996; Hashweh, 1987; Kunter et al., 2013b; Lange et al., 2015; Leinhardt & Smith, 1998; Magnusson et al., 1999; Ohle et al., 2011; Rowan et al., 1997; Sadler et al., 2013; Shulman, 1986) as well as their motivational orientations are significantly positively related to students' performance (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Brigham et al., 1992; Brophy & Good, 1984 ; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Rosenshine, 1970; Ross, 1992; Williams and Ware, 1977; Wood, 1989).

See study 3 (content-related professional knowledge) and study 4 (teachers' motivational orientations) for the detailed research questions and the empirical examination of the hypotheses.

An expanded model of teachers' professional competence (see Fig. 3-1) provides an overview of my research questions and hypotheses. I refer to a model which was originally developed by Kunter et al. (2013a) to illustrate the development of teachers' professional competence.

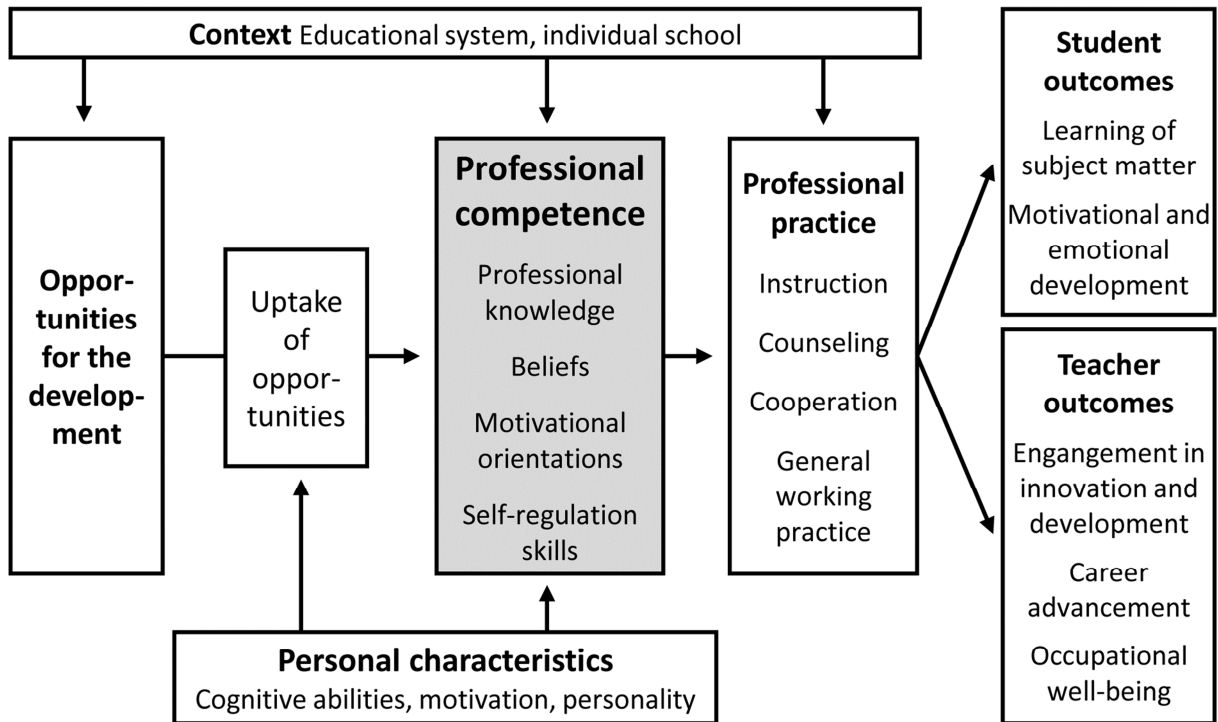
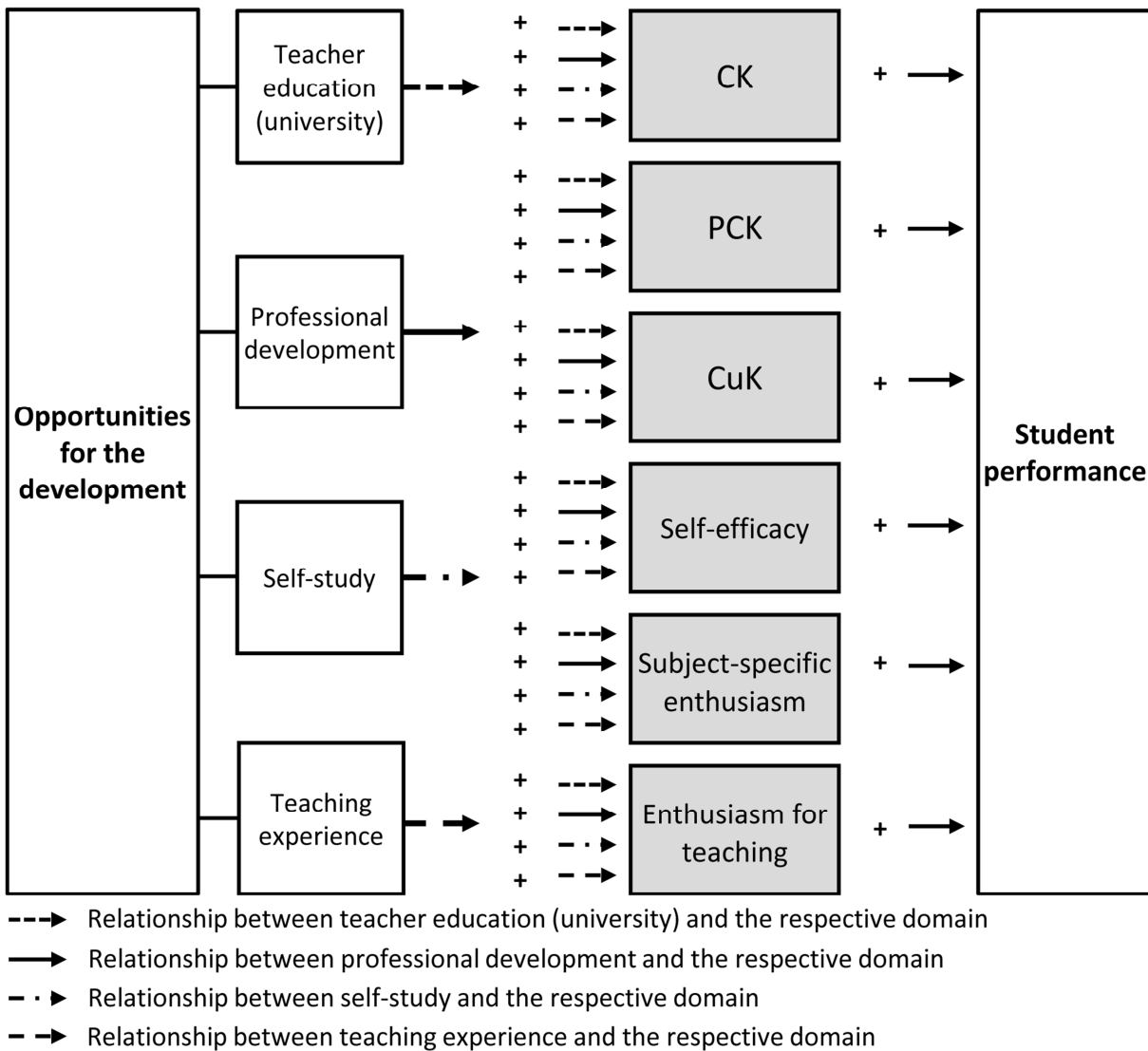


Figure 3-1. Model of the Determinants and Consequences of Teachers' Professional Competence (cf. Kunter et al. 2013a).

I adapted and reduced this model according to the aims of my dissertation (see Fig. 3-2).

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Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge; + = positive relationship.

Figure 3-2. Overview of the Hypotheses.

The 'core' of the model is teachers' professional competence. As already mentioned, different aspects and domains are considered for teachers' professional competence (RQ 1). The left part of the model refers to the development of teachers' professional competence considering different opportunities for the development of professional competence (RQ 2). The right part of the model comprises the significance teachers' professional competence has on students' performance (RQ 3).

4 METHOD

This chapter provides a detailed description of the overarching procedure as well as an overview of the applied measures. For the detailed consideration of the applied research methods see study 1 to 4 (chapter 5 - 8).

4.1 Sample

Teachers. The total sample consists of 134 biology teachers from German secondary schools (75.4% female). At the time the study was conducted, the teachers were 43.7 years old on average ($SD = 10.2$) and had an average teaching experience of 16.4 years ($SD = 11.7$, range: 7 months to 42 years). The participating teachers held different certifications. 54.4% were certified for a teaching career at academic track schools, 17.1% were certified for a teaching career at non-academic track schools, 26.9% held a degree of a teacher education program in the former GDR (*Diplomlehrer*), and 1.4% were certified for a career outside the teaching profession (e.g., a Master's degree in biology). The participants were recruited from different types of schools (*Hauptschule*: 1.5%, *Realschule*: 1.5%, *Gymnasium*: 63.4%, *Gesamtschule*: 32.8%, other: 0.7%) in different federal states (Schleswig-Holstein: 32.8%, Mecklenburg-Western Pomerania: 35.8%, Lower Saxony: 16.4%; Bremen: 7.5%, Hamburg: 3.7%, Bavaria: 3.0%, Rhineland-Palatinate: 0.7%).

Only a subsample of these teachers participated together with their students ($N = 48$; 75.0% female). On average, the teachers of this subsample were 40.91 years old ($SD = 11.02$) and had 11.58 years of teaching experience ($SD = 10.46$). 58.3% of the participants were certified to teach at academic track schools, 39.6% held a certificate for non-academic track schools, and 2.1% were certified for a career outside the teaching profession. In this subsample, none of the teachers held a certification from a teacher education program in

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the former GDR (*Diplomlehrer*). The teachers of this subsample were recruited from different school types (*Hauptschule*: 4.2%, *Realschule*: 4.2%, *Gymnasium*: 54.2%, *Gesamtschule*: 37.5%) in Schleswig-Holstein (89.6%) and Hamburg (10.4%). See chapter 2.5.2 for more information about the different tracks and the respective teacher education programs.

Students. A total of 1036 students from secondary schools (50.6% female) participated in this study. These students were related to the previously mentioned subsample of teachers. At the time the study was conducted, the students were in the seventh (20.1%) and eighth grade (79.9%) and were 13.5 years old on average. Analogous to their teachers, the participants were both from academic track schools (54.2%) as well as from non-academic track schools (45.8%). These schools (*Hauptschule*: 4.2%, *Realschule*: 4.2%, *Gymnasium*: 54.2%, *Gesamtschule*: 37.5%) were located in Schleswig-Holstein (89.6%) and Hamburg (10.4%).

Study 1 and 2 exclusively focus on the teachers. All of the 134 biology teachers from the total sample participated in these studies. For study 3 and 4, the teacher subsample ($N = 48$) participated together with their students.

4.2 Research Design and Procedure

This section provides an overview of the conducted research design as well as information about the data collection procedure.

As the research questions concern the teacher level (research question 1 and 2) as well as the student level (research question 3), data had been collected on both levels.

The participating teachers were recruited in 2011 by telephone and mail. The whole teacher sample completed paper and pencil tests which measured their (1) CK, (2) PCK, (3) CuK, (4) self-efficacy, (5) subject-specific enthusiasm, and (6) enthusiasm for teaching the subject. Moreover, the teachers provided demographic information (e.g., teaching experience) as well as information about their pre- and inservice teacher education (e.g., type of teacher education program, amount of professional development courses). Afterwards, a subsample ($N = 48$) was asked to develop and to conduct a short teaching unit

(4 h). These four lessons referred to the topic 'ecosystem Wadden Sea' with a focus on *Mytilus edulis* (Blue Mussel). More detailed, the unit focused on nutrition, respiration, living conditions, development, predators, mussel fishing, and mussel breeding (cf. Fraune, 2014). The teachers were given information about the content as well as the necessary materials (e.g., Blue Mussels, aquaria). As incentive, the teachers were allowed to keep the aquaria with the mussels. Beyond the planning and conduction of the four lessons, the teachers were asked to complete a grid that provided information about the lessons and the applied materials (e.g., work sheets). The conduction and documentation of the lessons had two functions. First, they allow an insight into how teachers' professional competence is reflected in the lessons. Second, this procedure allows considering students' prior knowledge in the analyses.

Students' performance was measured before and after the four lessons using paper and pencil tests as well as concept maps. Moreover, their verbal and non-verbal cognitive abilities were assessed.

Conceptualization of students' performance

As an example for students' performance, I consider students' performance in biology. More detailed, students' performance is conceptualized as the ability to deal with complex biological systems, i.e., *system thinking*. System thinking is a very important aspect of biology education. This is due to the fact that open and living systems are of crucial importance for biology as science. These systems exchange matter, energy, and information with their environment (Verhoeff, 2003). Dealing with these open systems is very demanding, nevertheless, only a systemic view of relationships and processes enables a meaningful understanding of science (e.g., Brandstädter, Großschedl, & Harms, 2012; Hannon & Ruth, 2000).

Several researchers engaged in the question which abilities are necessary in order to be able to deal with systems (e.g., Evagorou et al., 2009; Riess & Mischo, 2010; Sommer & Lücken, 2010). To identify these abilities, it is important to consider that systems are usually described by two main characteristics: (1) structure and (2) function (Bertalanffy, 1968; Bossel, 1987). In order to operationalize system thinking, these main characteristics have to be translated into abilities (Sommer & Lücken, 2010). In order to deal with a system's

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structure, the students have to be able to understand the organizational framework of a system (Assaraf & Orion, 2005, 2010; Evagorou et al., 2009; Riess & Mischo, 2010; Sommer & Lücken, 2010; Verhoeff, 2003). In order to understand the function of a system, students have to be able to deal with dynamic and cyclic relationships within a system (Assaraf & Orion, 2005, 2010; Evagorou et al., 2009; Riess & Mischo, 2010; Sommer & Lücken, 2010; Verhoeff, 2003). Sommer and Lücken (2010) pick up this two-dimensionality and describe system thinking as composed of two domains. The first domain, *structural system thinking* (Brandstädter et al., 2012; Sommer & Lücken, 2010), covers the ability to identify and connect the elements of a system, to organize the elements of the system in a reference framework, and to identify and draw system borders (Sommer & Lücken, 2010). The second domain, *procedural system thinking* (Brandstädter et al., 2012; Sommer & Lücken, 2010), includes the ability to distinguish the characteristics of the system from the characteristics of its elements as well as the ability to identify dynamic relationships and to understand and predict consequences of changes. Procedural system thinking furthermore comprises the understanding and evaluation of effects and reactions within a system. The *National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2004a) consider *system* as a basic concept. Moreover, the relevance to consider system thinking is supported for science education (ACARA, 2009; DfE, 2013; EDK, 2011; NGSS, 2013) and for geography education (Rempfler & Uphues, 2012). Beyond its relevance for biology, science and geography education, system thinking covers abilities which are also very important for the understanding of complex systems in the students' everyday life (Anderson & Johnson, 1997).

The biological system to which I refer to is the *ecosystem Wadden Sea*. This ecosystem was chosen because of its relevance for Northern Germany, where the participating schools were located. See study 3 and 4 for more information concerning the assessment of students' system thinking in the framework of this dissertation.

Figure 4-1 gives an overview of the overall research design and the assignment of the respective studies.

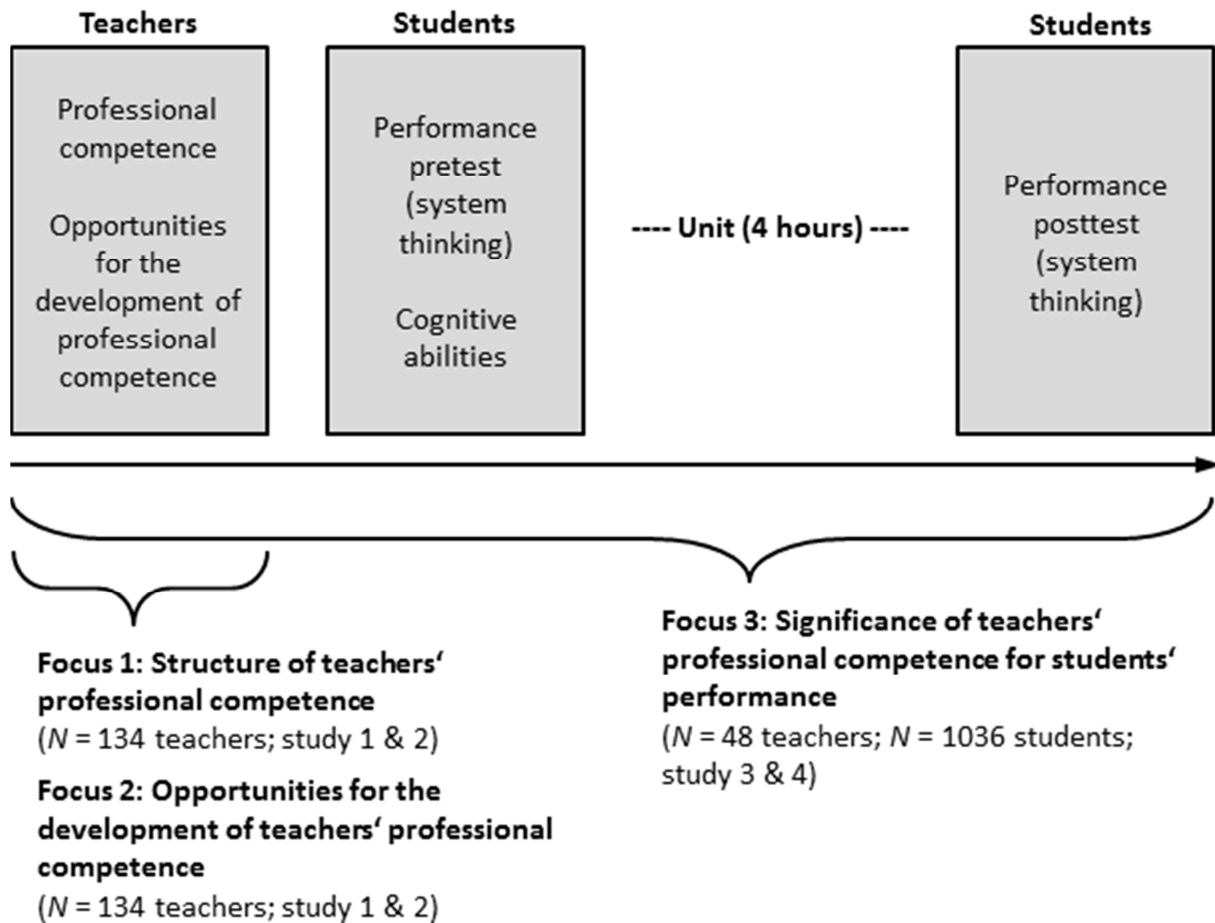


Figure 4-1. Research Design.

Table 4-1 provides information about all the applied instruments.

Table 4-1
Measures – Overview of the Applied Measures

Measure	N of items	Scoring	M	SD	min	max	Reliability ¹	Facets of knowledge	Reference
<i>Teachers' content-related professional knowledge</i>									
CK	19 (closed)	dichotomous: N = 10; polytomous: N = 9	19.60	3.21	0	2	.68	(a) knowledge about <i>Mytilus edulis</i> (N=11); (b) knowledge about the ecosystem Wadden Sea (N=4); (c) a general understanding of systems (N=4)	Großschedl et al. (2014)
PCK	9 (open)	dichotomous: N = 0; polytomous: N = 4	8.90	4.10	0	2	.79	(a) knowledge about instructional strategies for teaching (N=5); (b) knowledge about students' understanding (N=4)	Großschedl et al. (2014)
CuK	4 (open)	dichotomous: N = 1; polytomous: N = 3	2.92	2.01	0	2	.78	knowledge about the German national educational standards for the intermediate school leaving certificate in biology	Großschedl et al. (2014)

(continued)

Table 4-1 (continued)

Measure	N of items	Scoring	M	SD	min	max	Reliability ¹	Facets of knowledge	Reference
<i>Teachers' motivational orientations</i>									
self-efficacy	10 (closed)	Likert type	20.51	3.30	1	4	.68	-	Schmitz & Schwarzer (2000)
subject-specific enthusiasm	3 (closed)	Likert type	8.35	1.01	1	4	.73	-	Baumert et al. (2009)
enthusiasm for teaching the subject	2 (closed)	Likert type	5.27	0.93	1	4	.77	-	Baumert et al. (2009)

(continued)

Table 4-1 (continued)

Measure	N of items	Scoring	M	SD	min	max	Reliability ¹	Facets of knowledge	Reference
<i>Opportunities for the development of teachers' professional competence</i>									
type of teacher education program	1 (closed)	polytomous ²	2.11	0.67	1	3	-	-	Großschedl et al. (2014)
perceived quality of teacher education	1 (closed)	polytomous ³	3.06	1.04	1	6	-	-	Mahler, Großschedl, & Harms (submitted)
professional development	1 (closed)	polytomous ⁴	2.10	1.11	0	3	-	-	Großschedl et al. (2014)
self-study	1 (closed)	Polytomous ⁴	2.51	0.82	0	3	-	-	Großschedl et al. (2014)
teaching experience (years)	1 (closed)	polytomous	16.38	11.71	0	42	-	-	Großschedl et al. (2014)

(continued)

Table 4-1 (continued)

Measure	N of items	Scoring	M	SD	min	max	Reliability ¹	Facets of knowledge	Reference
<i>Students' system thinking performance</i>									
System thinking	26 (22 closed and 4 open items)	dichotomous: N = 9; polytomous: N = 17	19.04 (pre); 25.50 (post)	4.71 (pre); 5.60 (post)	0	2	.79 (pre); .81 (post)	(a) structural system thinking (N=18); (b) procedural system thinking (N=8)	Brandstädter et al. (2012)
<i>Students' cognitive abilities</i>									
Cognitive abilities - verbal	20 (closed)	dichotomous: N = 20; polytomous: N = 0	11.19	4.25	0	20	.76 (A); .81 (B)	relationships between words	Heller & Perleth (2000)
Cognitive abilities - non-verbal	25 (closed)	dichotomous: N = 25; polytomous: N = 0	16.78	5.90	0	25	.87 (A); .90 (B)	figural relationships	Heller & Perleth (2000)

Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge; dichotomous scoring: 0 = wrong, 1 = correct; polytomous scoring: 0 = wrong, 1 = half correct (partial credit), 2 = correct; ¹ = cronbach's α , N = 134; ² 1 = non-academic track, 2 = academic track, 3 = teacher education program in the former GDR; ³ 1 = very good, 2 = good, 3 = satisfactory, 4 = sufficient, 5 = poor, 6 = deficient; ⁴ 0 = never, 1 = once, 2 = once a year, 3 = more than once a year.

5 STUDY 1: Content-Related Knowledge of Biology Teachers from Secondary Schools: Structure and Learning Opportunities¹

Abstract

Teachers' content-related knowledge is a key factor influencing the learning progress of students. Different models of content-related knowledge have been proposed by educational researchers; most of them take into account three categories: content knowledge, pedagogical content knowledge, and curricular knowledge. As there is no consensus about the empirical separability (i.e., empirical structure) of content-related knowledge yet, a total of 134 biology teachers from secondary schools completed three tests which were to capture each of the three categories of content-related knowledge. The empirical structure of content-related knowledge was analyzed by Rasch analysis, which suggests content-related knowledge to be composed of (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge. Pedagogical content knowledge and curricular knowledge are highly related ($r_{\text{latent}} = .70$). The latent correlations between content knowledge and pedagogical content knowledge ($r_{\text{latent}} = .48$) and curricular knowledge, respectively ($r_{\text{latent}} = .35$) are moderate to low (all $ps < .001$). Beyond the empirical structure of content-related knowledge, different learning opportunities for teachers were investigated with regard to their relationship to content knowledge, pedagogical content knowledge, and curricular knowledge acquisition. Our results show that an in-depth training in teacher education, professional development, and teacher self-study are positively related to particular categories of content-related knowledge. Furthermore,

¹ Großschedl, J., Mahler, D., Kleickmann, T. & Harms, U. (2014). Content-Related Knowledge of Biology Teachers from Secondary Schools: Structure and Learning Opportunities. *International Journal of Science Education*, 36(14), 2335-2366.

our results indicate that teaching experience is negatively related to curricular knowledge, compared to no significant relationship with content knowledge and pedagogical content knowledge.

Keywords: *Content-related knowledge; Pedagogical content knowledge; Curricular knowledge; Learning opportunities; Multi-dimensional Rasch analysis*

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5.1 Introduction

A central challenge for school teachers is to support students in their development of subject matter knowledge (in biology, e.g., knowledge about ecosystems). This challenge is influenced by various factors, such as students' prior knowledge (Blurton, 1985; Hegarty-Hazel, & Prosser, 1991), intelligence (e.g., Hattie & Hansford, 1982), and motivation (Hattie, 2009). Also, it is influenced by the professional knowledge of the individual teacher, which is the knowledge relevant to his or her professional practice (Baumert et al., 2010). In the literature, two main categories of professional knowledge are described (e.g., Shulman, 1986): non-content-related knowledge and content-related knowledge. Non-content-related knowledge (e.g., knowledge about classroom management) goes beyond the subject matter and is not considered in more detail in this article. In recent years, particular interest has been directed toward content-related knowledge (e.g., Jüttner, Boone, Park, & Neuhaus, 2013; Krauss, Baumert, & Blum, 2008), its components (e.g., Lee & Luft, 2008; Park & Oliver, 2008), and its influence on the learning progress of students (Baumert et al., 2010; Hill, Rowan, & Ball, 2005). Shulman (1987) distinguishes between three categories of content-related knowledge: (1) (subject matter) *content knowledge*, (2) *pedagogical content knowledge*, and (3) *curricular knowledge*. Since Shulman's trinomial model of content-related knowledge has inspired many responses among educational scholars (resulting in modified models; cf. Fernandez-Balboa & Stiehl, 1995; Magnusson, Krajcik, & Borko, 1999; Marks, 1990), the first aim of our study is to investigate the empirical structure of these types of knowledge.

Friedrichsen et al. (2009) distinguish between three different sources of content-related knowledge: (1) teachers' own K-12 learning experience, (2) teacher education and

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professional development programs, and (3) teaching experience. In a cross-sectional study, Kleickmann et al. (2013) investigated the development of pre- and in-service mathematics teachers' content knowledge and pedagogical content knowledge with regard to the second and third sources of content-related knowledge. They found out that university teacher education plays an important role in the acquisition of content knowledge and pedagogical content knowledge. Similar results were reported by Kleickmann and Anders (2013), Schmidt et al. (2007), as well as Tatto and Senk (2011) for mathematics, too. In contrast, teaching experience plays a subordinate role for content knowledge and pedagogical content knowledge development of mathematics teachers (Brunner et al., 2006; Kleickmann et al., 2013). However, other scholars identified teaching experience as a major source from which pedagogical content knowledge is developed (Grossman, 1990; Lederman, Gess-Newsome, & Latz, 1994; Schmelzing et al., 2013).

The studies conducted so far mainly concentrate on mathematics education; they neglect the development of curricular knowledge as the third category of content-related knowledge. Since only little is known about the factors which affect the development of science teachers' content knowledge, pedagogical content knowledge, and curricular knowledge, the second aim of our study is to investigate the relations between formal ([a] type of teacher education program, [b] professional development in workshops and lectures) and informal¹ ([c] teaching experience, [d] self-study) learning opportunities and science teachers' knowledge in the three respective categories.

5.2 Background

5.2.1 Conceptualization of Content-Related Knowledge

Content knowledge constitutes the knowledge of the concepts and principles of a domain (e.g., ecology) in which relevant facts are organized. It also includes the knowledge how validity or invalidity is established within the domain (Shulman, 1986). It represents a deep understanding of a domain, which does not only imply understanding that something is so, but also to understand why it is so (Shulman, 1986). Content knowledge is a prerequisite to teaching students in a particular domain. This is confirmed by studies which provide evidence for a positive relationship between teachers' content knowledge and students'

learning progress (Abell, 2007; Baumert et al., 2010; Gess-Newsome & Lederman, 1995; Hashweh, 2005; Lee, 1995; Rowan, Chiang, & Miller, 1997).

Going beyond content knowledge, Shulman (1987) describes teachers' pedagogical content knowledge as a second type of content-related knowledge, forming an 'amalgam of content and pedagogy' (p. 8). This knowledge is assumed to make the subject matter comprehensible (Shulman, 1986), for example, by providing appropriate teaching situations (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001). Shulman (1986) addresses two issues which arise from pedagogical content knowledge in more detail: 'the ways of representing and formulating the subject that make it comprehensible to others' and the knowledge about students' 'conceptions and preconceptions' (p. 9). According to Grossman (1990), the first issue concerns the knowledge of instructional strategies that integrate the representation of subject matter and responses to specific learning difficulties (here: knowledge of instructional strategies for teaching). The second issue concerns the knowledge of students' conceptions and preconceptions (here: knowledge of students' understanding). Many educational scholars have further concretized pedagogical content knowledge by integrating additional subcomponents to their definition. Such subcomponents are, for example, the knowledge of goals for teaching a subject matter (Grossman, 1990; Hashweh, 2005; Loughran et al., 2001; Magnusson et al., 1999), the knowledge of methods to assess student learning (Hashweh, 2005; Magnusson et al., 1999), and the knowledge of resources (e.g., multimedia, science magazines) which can be used for teaching (Lee & Luft, 2008). Some subcomponents included in the category of pedagogical content knowledge by particular scholars contradict the trinomial model of content-related knowledge, which consists of (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge; they treat content knowledge (or knowledge of subject matter; Fernandez-Balboa & Stiehl, 1995) and curricular knowledge (or knowledge of science curriculum; Grossman, 1990; Loughran et al., 2001; Magnusson et al., 1999) as subcomponents of pedagogical content knowledge. As there is a broad consensus between educational scholars that (1) knowledge of instructional strategies for teaching and (2) knowledge of students' understanding are the most important subcomponents of pedagogical content knowledge (cf. van Driel, Verloop, & De Vos, 1998; Lee & Luft, 2008; Park & Oliver, 2008; Schmelzing et al., 2013), our study addresses these two.

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The initial definition of curricular knowledge is proposed by Shulman (1986), who states that it is ‘knowledge, with particular grasp of the materials and programs that serve as “tools of the trade” for teachers’ (p. 8). Grossman (1990) expands this definition by adding the knowledge of the goals and objectives of a subject, including knowledge about national- or state-level documents (Magnusson et al., 1999). In our study, we refer to knowledge of standards and objectives in particular when using the term ‘curricular knowledge’.

Although (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge are well established components of content-related knowledge, there has been no consensus on the relationship between these components up until now. Most scholars regard content and pedagogical content knowledge as unique components of content-related knowledge (e.g., Grossman, 1990; Jüttner et al., 2013; Magnusson et al., 1999; Shulman, 1986). Conversely, some scholars argue that content knowledge should be regarded as a part of pedagogical content knowledge (e.g., Fernandez-Balboa & Stiehl, 1995; Marks, 1990). Empirical research provides evidence for both positions. Jüttner et al. (2013) found a low correlation ($r = .22$, $p < .01$) between content knowledge and pedagogical content knowledge for in-service biology teachers from secondary schools. However, subject matter information was included in the items assessing pedagogical content knowledge to ensure that the items were independent of teachers’ content knowledge (Jüttner & Neuhaus, 2012). Without including subject matter information, Großschedl, Harms, & Glowinski (2013) found a stronger correlation, $r = .64$, $p < .001$, between content knowledge and pedagogical content knowledge in a sample of preservice biology teachers aspiring to teach at secondary schools. Both studies provide evidence that content knowledge and pedagogical content knowledge are correlated, but separable and unique constructs. In contrast, a study in the field of mathematics (Krauss, Baumert, et al., 2008) suggests that the correlation between both constructs might vary between different teacher populations. Results indicate that teachers who have mastered higher demands in matters of content knowledge during teacher education integrate both constructs more strongly than teachers who have mastered less subject matter training. Comparable to the integration of content knowledge within pedagogical content knowledge by some scholars (Shulman, 1987), many scholars have classified curricular knowledge as a subcomponent within pedagogical content knowledge (e.g., Grossman, 1990; Loughran et al., 2001;

Magnusson et al., 1999; Park & Chen, 2012). Very well accepted is the model of Magnusson et al. (1999), who argue that curricular knowledge has to be a part of pedagogical content knowledge because it represents knowledge which distinguishes the content specialist—in our case the biologist—from the educator—in our case the biology teacher. This knowledge is relevant for teaching a specific topic and choosing the adequate instructions. However, a study by Park and Chen (2012) shows that curricular knowledge is only very weakly connected to the other subcomponents of pedagogical content knowledge.

5.2.2 Development of Content-Related Knowledge

Given the importance of teachers' content-related knowledge for the learning progress of their students, the question of how teachers develop this knowledge arises. Therefore, a special focus of research is directed toward pre- and in-service teachers' learning opportunities for the development of content-related knowledge (e.g., Kleickmann et al., 2013). According to Tynjälä (2008), learning opportunities can be classified into two categories: formal and informal. 'Formal' refers to learning opportunities in the context of educational institutions, for example, universities. These learning opportunities usually lead to particular qualifications (e.g., a Masters' degree in teaching). As different teacher education programs are implemented in Germany, Germany provides promising conditions for an investigation of how the type of a teacher education program is associated to content-related knowledge.

On the secondary level of the German school system, there is a clear distinction between schools qualifying their students for an academic career (grades 5–12 [or 13]; academic track) and schools qualifying their students for a non-academic career (grades 5–9 [or 10]; non-academic track). In both cases, secondary teacher education is split into two phases, with a four- to five-year period of university studies and a two-year period of traineeship. Although both groups acquire a teacher certificate for two subjects (e.g., biology and mathematics), pre-service teachers, who aspire to a teaching profession in the academic track (certification type A) have to master higher demands (approximately one-third more) in matters of content knowledge than their colleagues qualifying for the non-academic tracks (certification type B; cf. Baumert et al., 2010; Krauss, Brunner, et al., 2008). Referring to pedagogical content knowledge, demands are comparable. A further teacher education

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program was implemented in the former German Democratic Republic (certification type C; cf. Baumert et al., 2010). There was a single type of secondary schools (grades 5–12) and no distinction between teachers for an academic or non-academic track. In a similar fashion to current teacher education in reunified Germany, preservice teachers completed a five-year period of university studies, also acquiring a teacher certificate for two subjects. In contrast to certification types A and B teachers, however, there is a main difference concerning traineeship, which was already implemented in university studies in the former German Democratic Republic.

The influence of formal learning opportunities was examined by COACTIV, a study which investigated mathematics teachers' content-related knowledge (Baumert et al., 2010; Brunner et al., 2006; Kleickmann et al., 2013). This study shows that German mathematics teachers with a teaching profession in the academic track (certification type A) outperform their colleagues in the non-academic tracks (certification type B) with regard to content knowledge and pedagogical content knowledge. Baumert et al. (2010) discuss this result with reference to the requirements of German teacher education. Whereas 'certification type A' teachers receive an in-depth training concerning content knowledge, 'certification type B' teachers receive less training in content knowledge (Baumert et al., 2010; Krauss, Brunner, et al., 2008). Concerning pedagogical content knowledge, in contrast, the requirements are similar in both tracks. Since content knowledge is regarded as a prerequisite for pedagogical content knowledge development (e.g., Ball, Hill, & Bass, 2005; Ma, 1999), however, Baumert et al. (2010) argue that a better pedagogical content knowledge performance is to be expected for the teachers of the academic track as well. After the completion of the initial teacher education, continuing professional development of teachers is rare (Dunn & Shriner, 1999), even if teachers have the opportunity to attend formal learning opportunities (e.g., workshops or lectures). The amount of time teachers devote to these learning opportunities is low. For example, Brunner et al. (2006) report about 10 hours per teacher a year. Despite the shortage of these formal learning opportunities, they still have positive effects on mathematics teachers' content knowledge and pedagogical content knowledge, even though these effects are not statistically significant. Similar results are reported by Clermont, Krajcik, and Borko (1993) with respect to chemistry teachers' pedagogical content knowledge.

In contrast to formal learning opportunities, informal learning opportunities are not intentionally organized. They take place incidentally (e.g., by teaching activity) or are not organized by educational institutions (e.g., self-study; Tynjälä, 2008). According to van Driel, De Jong, and Verloop (2002), it seems reasonable that teaching experience forms potential opportunities for pedagogical content knowledge acquisition. This is because student answers, questions, and behavior patterns provide insight both into students' conceptions of the respective subject matter and into the efficiency of a particular instructional strategy. Friedrichsen et al. (2009) compare individuals with teaching experience who aspire to a biology teaching certification for secondary schools to those lacking teaching experience. They found no difference between both groups with regard to pedagogical content knowledge. However, only four participants attended the study; therefore, the results should be generalized with caution. Brunner et al. (2006) also investigated the relationship between teaching experience as well as mathematics teachers' content knowledge and pedagogical content knowledge, respectively. They found that teaching experience is not related to content knowledge and pedagogical content knowledge. In contrast, Clermont, Borko, and Krajcik (1994) show that experienced teachers show a greater repertoire of pedagogical content knowledge of instructional strategies for teaching than inexperienced ones. Beyond teaching experience as an informal learning opportunity, self-study (e.g., reading journals) can be regarded as a further informal learning opportunity which has not been investigated yet.

5.2.3 Assessment of Content-Related Knowledge

Both qualitative and quantitative approaches are applied to assess teachers' professional knowledge in previous research. Qualitative approaches (for a review see Depaepe, Verschaffel, & Kelchtermans, 2013) are supposed to provide deep insight into teachers' professional knowledge, for example, by using interviews (e.g., Jüttner & Neuhaus, 2013; Peng, 2007), observing lessons (through field notes, video- or audiotaping; e.g., Ball, Thames, & Phelps, 2008; van Driel et al., 2002; Park & Oliver, 2008), and performing document analyses (of lesson preparations or portfolios; e.g. Davis, 2009; Friedrichsen et al., 2009; van der Valk & Broekman, 1999). Although these methods have been successfully applied especially in studies with small sample sizes (e.g., Davis, 2009; Peng, 2007), they seem inapplicable when dealing with larger sample sizes as intended in this study.

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In contrast, quantitative approaches such as paper-pencil tests (e.g., Baumert et al., 2010; Großschedl, Harms, & Glowinski, 2013; Hill, Schilling, & Ball, 2004; Jüttner et al., 2013; Schmidt et al., 2007) have been proved successful when teachers' professional knowledge is assessed in larger samples. Researchers usually distinguish between open-ended items (e.g., essay exams) and closed-ended items (e.g., multiple-choice items). In general, open-ended items are supposed to provide better insight into the thinking processes of the test subjects than closed-ended items, because responses reflect the individual logic and knowledge of the test subjects (in contrast to prefabricated responses in closed-ended items; Großschedl & Harms, 2013; Schoenfeld, 2007). However, open-ended items have an ever-present disadvantage: they require a high level of effort from test subjects and raters (e.g., Lipton & Huxham, 1970; Walstad & Becker, 1994). Closed-ended items, such as multiple-choice items, provide an alternative to open-ended items for some reasons. First, they have the advantage that subjectivity is minimized when rating test subjects' responses (Lipton & Huxham, 1970; Walstad & Becker, 1994). Second, the scoring of closed-ended items needs less time and, therefore, facilitates the assessment of large samples (Bacon, 2003; Lipton & Huxham, 1970). Third, closed-ended items permit to capture a wider range of content by giving more questions in the testing period (Lipton & Huxham, 1970; Walstad & Becker, 1994).

Although some researchers emphasize the superior validity of open-ended items (Baumert et al., 2010; Schoenfeld, 2007), others observed no difference between open-ended and closed-ended items (Bridgeman & Lewis, 1994). Especially noteworthy seems the result that there is little difference between the knowledge, skills, or abilities measured by closed-ended and open-ended questions (e.g., Bennett, Rock, & Wang, 1991; Wainer & Thissen, 1993; Walstad & Becker, 1994). For our study, we developed paper-pencil tests to assess biology teachers' content-related professional knowledge (i.e., content knowledge, pedagogical content knowledge, and curricular knowledge). In order to assess a wide range of content knowledge in the given test time, we captured content knowledge by closed-ended questions. In contrast, pedagogical content knowledge and curricular knowledge were captured by open-ended items to avoid restrictions concerning teachers' didactical creativity (Baxter & Lederman, 1999) and to provide information about teachers' individual logic.

5.3 Research Questions

As shown in the section above, the evidence for the empirical separability of teachers' content-related knowledge is mixed. Few studies so far have found evidence for the separation of in-service teachers' content knowledge and pedagogical content knowledge of mathematics (Baumert et al., 2010; Krauss, Baumert, et al., 2008; Schmidt et al., 2007), biology (Großschedl, Harms, & Glowinski, 2013; Jüttner et al., 2013), and reading (Phelps & Schilling, 2004). Other studies suggest that content-related knowledge may be merged into one body of knowledge (Hill et al., 2004), which does not seem surprising as pedagogical content knowledge is regarded as an 'amalgam of content and pedagogy' (Shulman, 1987, p. 8). However, since separability is a prerequisite for the analysis of unique effects of biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge on students' knowledge acquisition in further studies, we aim to investigate if our measures can really capture different constructs of teachers' professional knowledge. Beyond that, our study aims to identify learning opportunities which are related to biology teachers' content-related knowledge by focusing on (1) type of teacher education program (leading to different certification types), (2) professional development (attendance at workshops and lectures), (3) teaching experience, and (4) self-study (reading journals).

Hence, the following questions are addressed:

(1) Are biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge empirically separable?

(2) If so, how are biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge related?

(3) How are formal learning opportunities ([a] type of teacher education program, [b] professional development) related to biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge?

(4) How are informal learning opportunities ([a] teaching experience, [b] self-study) related to biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge?

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5.4 Method

5.4.1 Measures

Teachers' content-related knowledge. Three questionnaires were developed to capture biology teachers' content-related knowledge – that is teachers' content knowledge, pedagogical content knowledge (operationalized as pedagogical content knowledge of instructional strategies for teaching and pedagogical content knowledge of students' understanding), and curricular knowledge. (1) Teachers' content knowledge was assessed using 19 multiple choice items. Ten items are dichotomously scored (0 = wrong answer vs. 1 = correct answer) and nine items are polytomously scored (0 = wrong answer; 1 = half-correct answer [partial credit]; 2 = correct answer). These items address teachers' knowledge of a particular ecosystem (the Wadden Sea), focusing on the species *Mytilus edulis* (blue mussel; see Appendix 1). The topic was selected because it represents a typical content of biology education in secondary schools of Northern Germany, where the study was conducted. It is implemented in the school curriculum and tangent to the environment of students in Northern Germany. The items focus on three categories: (a) knowledge about *Mytilus edulis*, (b) knowledge of the Wadden Sea ecosystem, and (c) general understanding of a system, which is relevant for understanding ecology. (2) Teachers' pedagogical content knowledge was captured with the help of nine open-ended items (polytomously scored [0–1–2]) addressing both knowledge of instructional strategies for teaching and knowledge of students' understanding (see Appendix 2). Comparable to the content knowledge items, the items addressing pedagogical content knowledge refer to *Mytilus edulis* in the context of the Wadden Sea ecosystem. (3) Finally, teachers' curricular knowledge was assessed with four items in an open-ended format as well (one item dichotomously scored, three items polytomously scored [0–1–2]; see Appendix 3). These items focus on the national educational standards for the intermediate school leaving certificate in biology (Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs in the Federal Republic of Germany [KMK], 2010). In accordance with Wirtz and Caspar (2002), about 10% of the test booklets were randomly selected; the respective open-ended items were separately coded by the same two researchers to estimate intercoder reliability (Wirtz & Caspar, 2002). The intraclass correlation coefficient = .97 on average, which indicates satisfactory intercoder reliability. Our questionnaires are based on a pilot study, in

which an original set of 53 items (33 items for content knowledge, 15 items for pedagogical content knowledge, and 5 items for curricular knowledge) was administered to a sample of $N = 86$ biology teachers. Our item selection was based upon an item analysis, in which items with an item difficulty outside the range of .20 and .80 as well as items with discrimination indices less than .20 for content knowledge ($\alpha = .71$, $n = 19$ items) and less than .40 for pedagogical content knowledge ($\alpha = .80$, $n = 9$ items) and curricular knowledge ($\alpha = .83$, $n = 4$ items) were removed. Due to the small sample size, correlation analyses with sum scores were performed to gain information about the discriminant validity of the questionnaires. The correlations were low to moderate, indicating the discriminant validity of the questionnaires (content knowledge and pedagogical content knowledge: $r = .21$, $p = .06$; content knowledge and curricular knowledge: $r = .11$, $p = .34$; pedagogical content knowledge and curricular knowledge: $r = .51$, $p < .001$).

Learning opportunities. Four learning opportunities were distinguished: (1) type of teacher education program (leading to certification types A, B, and C), (2) professional development (attendance to workshops and lectures), (3) teaching experience, and (4) self-study (reading journals).

(1) Concerning the certification type, a single multiple-choice item was used ('Which type of teacher education program did you attend?'). Consistent with the German tracking system implemented after grade 4, this item distinguishes between three certification types (A = qualifying for the academic track; B = qualifying for the non-academic tracks; C = qualifying for secondary schools in the former German Democratic Republic).

(2) Concerning the attendance to workshops and lectures, a single multiple-choice item was used as well ('How often did you attend workshops and lectures for the purpose of professional development concerning your subject "biology" in the past two years?'). Four answer alternatives were provided: *never*, *once*, *once a year*, *more than once a year*.

(3) Concerning teaching experience, teachers were asked how many years they had taught students ('I have been engaged in school teaching for ___ years.').

(4) Concerning self-study, we asked how often teachers undertook further trainings individually ('How often do you engage in self-study [e.g., reading journals]?'). The following answer alternatives were provided: *never*, *once a year*, *once every six months*, *once a month*.

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5.4.2 Sample and Data Collection Procedure

A total of 134 biology teachers (75.4% female) from secondary schools participated in our study. 54.5% of them were certified for the academic track (certification type A), 18.6% for the non-academic track (certification type B), and 26.9% attended a teacher education program in the former German Democratic Republic (certification type C). On average, the teachers were 43.7 years old ($SD = 10.2$), and their teaching experience ranged from 7 months to 42 years ($M = 16.4$ years, $SD = 11.7$). Participants were recruited in Northern Germany (e.g., Mecklenburg-West Pomerania, Schleswig-Holstein) by telephone or mail. Teachers who were willing to participate in our study had to plan and conduct four lessons about the Wadden Sea ecosystem focusing on the species *Mytilus edulis* in grade seven or eight. They were instructed to consider the morphology and life (respiration, development, nutrition, predators) of *Mytilus edulis*. In order to support the preparation of the lessons, teachers were equipped with an aquarium and instructions to hold *Mytilus edulis* and to experiment with *Mytilus edulis* (e.g., for visualizing respiratory flow with Uranin as a non-toxic colorant). However, no applicable teaching material was provided, so as to avoid that their content-related knowledge was considerably influenced by such material. After conducting the four lessons, teachers received the questionnaires for assessing their content-related knowledge by mail; they were instructed not to use external devices such as textbooks or the internet. No time limit was set for processing. As an incentive for participation teachers received the fully equipped aquarium as a gift.

5.4.3 Statistical Analysis

Rasch analysis. The construct validity of the content-related knowledge measures (content knowledge, pedagogical content knowledge, and curricular knowledge) was investigated using the Rasch analysis. The Rasch analysis is based on a mathematical model within the Item Response Theory which provides the means for dealing with ordinal data (Bond & Fox, 2001; Wright & Mok, 2000) as well as missing values (Smith, 2000; Wright & Mok, 2000). It converts ordinal data into interval measures, which allow for calculating parametric descriptive and inferential statistics (Bond & Fox, 2001; Smith, 2000; Wright & Mok, 2000). Furthermore, the Rasch analysis predicts the probability with which a participant would answer a particular item (Smith, 2000), which allows to

address problems arising with missing data by reflecting item difficulty when calculating person ability scores. Imagine two individuals (A and B) answered a biology questionnaire consisting of five simple and five difficult dichotomous items. Person A omitted all the difficult items, whereas person B omitted the simple items only because they seemed not challenging. Taken that both correctly answered each of the five items, a True-Score-Model would assign five credits to person A and five credits to person B, although B obviously is more knowledgeable than A. Person ability scores obtained by the Rasch analysis consider item difficulty. Therefore, a higher person ability estimate could be expected for person B than A. This is possible because person ability scores and item difficulty values are located on an interval scale with a common metric (Smith, 2000).

Dealing with ordinal data as well as missing data is based on the assumption that the statistical model fits the set of observed data. The discrepancy between the model and the data is expressed in a descriptive measure: the weighted mean square (WMNSQ). WMNSQ is a residual-based fit index with an expected value of 1, ranging from 0 to infinity. WMNSQ values greater than 1 indicate that an item is less predictable than the model expects (i.e., underfit), whereas values smaller than 1 indicate the item is more predictable (i.e., overfit; Wright & Linacre, 1994). Although Wright and Linacre (1994) do not provide a hard-and-fast rule for WMNSQ values, they state that the WMNSQ should at least be located within the range of 0.5 to 1.5 for a productive measurement. However, using a tighter range is recommended by the authors, ranging from 0.7 to 1.3 for multiple-choice items. Besides using descriptive WMNSQ values for item selection, we used *t*-values to identify WMNSQ values significantly deviating from 1. Items fitting the model have *t*-values beyond the range of 22.0 to 2.0. Neither WMNSQ values nor *t*-values indicate misfitting items within our questionnaires.

The ACER ConQuest software (version 1.0.0.1; see Wu, Adams, Wilson, & Haldane, 2007) was used to analyze data. Since a mixture of dichotomously and polytomously scored items appears in the measures, person ability and item difficulty were estimated with Masters' (1982) partial credit model (PCM), which is an extension of the simple logistic model. This model allows for the analysis of cognitive items which are scored into more than two ordered categories, assumes different measurement scales for different items, and estimates threshold parameters for each item, assuming that thresholds vary between items

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(Wright & Mok, 2000; Wu et al., 2007). Person ability was estimated with the WLE method (Weighted Maximum Likelihood Estimate), which is less biased than a maximum likelihood estimation and provides best point estimates of individual ability (Warm, 1989). The accuracy of measurement was provided by expected A posteriori/plausible value (EAP/PV) reliability (see Wu et al., 2007).

Analyzing dimensionality. As we suggest that different attributes (or ‘traits’) can be captured by our measures, a multidimensional Rasch analysis was applied to analyze the construct validity of our measures. Since three measures were developed to capture teachers’ content-related knowledge, first of all a three-dimensional model was fitted to the data. The three-dimensional model assumes (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge as separate dimensions — an empirical structure whose theory is derived from the study of Park and Chen (2012). Afterwards we compared the model fit to the corresponding fit values of a one-, and a two-dimensional model as alternative models. The one-dimensional model assumes a single latent trait behind teachers’ responses. This model is consistent with the findings of Hill et al. (2004), who state that elementary teachers’ content knowledge and pedagogical content knowledge in mathematics are merged into a single body of knowledge. The two-dimensional model includes one dimension for content knowledge as well as one dimension for pedagogical content knowledge and curricular knowledge together. For example, this model is consistent with the models of Grossman (1990), Magnusson et al. (1999), or Park and Oliver (2008).

In order to decide which model fits best, the factor of final deviance is taken into account. Final deviance indicates the likelihood of the observed data to fit the assumptions of the estimated model. The smaller the corresponding value, the better the model fits. A χ^2 test can be performed to explore whether two models significantly differ in fitting the data. The χ^2 value is obtained from the difference of the respective deviance values, whereas the degrees of freedom are determined by the difference in the number of parameters which are estimated (Bentler, 1990).

In addition to the χ^2 statistics, information-based criteria such as Akaike’s (1981) information criterion (AIC = deviance + $2 n_p$) and Bayes’ information criterion (BIC = deviance + $[\ln N] 2 n_p$; Wilson, De Boeck, & Carstensen, 2008) were employed to compare models characterized by different dimensionalities. Although these criteria do not allow for a

significance test between different models, they take the parsimony of the model into account. When comparing information-based criteria of different models, it is a general rule that the lower the coefficient, the better the model fits the data (Schermelleh-Engel, Moosbrugger, & Müller, 2003; Wilson et al., 2008). The AIC is to be preferred in short tests with many response patterns, whereas the BIC has its strengths in long tests with little response patterns (Rost, 2004).

5.5 Results

Are biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge empirically separable?

To find an answer to our first research question, we investigated the empirical separability of our measures. Concordantly, we fitted a three-dimensional PCM to the data, each dimension representing a particular measure ([1] content knowledge, [2] pedagogical content knowledge, and [3] curricular knowledge). In order to explore the empirical separability of these measures, we also fitted the one- and two-dimensional models to the data.

The Rasch analysis supports the finding that the three-dimensional model fits the data better than the other models. Table 5-1 shows that the information-based criteria (AIC, BIC) are lower for this model than for the one- and two-dimensional models, respectively. A χ^2 test was performed to decide whether the three-dimensional model significantly outperforms the other models. The χ^2 test shows that the three-dimensional model indeed significantly outperforms the one-dimensional model, $\chi^2 [2] = 210.88, p < .001$, and the two-dimensional model, $\chi^2 [2] = 57.12, p < .001$; in other words, biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge are empirically separable constructs.

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Table 5-1

Final Deviance and Information-Based Criteria for Different PCMs of Content-Related Knowledge (n of items = 32)

	Component of content-related knowledge	One-dimensional model	Two-dimensional model	Three-dimensional model
Allocation to dimension	Content Knowledge	A	A	A
	Pedagogical content knowledge	A	B	B
	Curricular knowledge	A	B	C
Deviance (no. of free parameters)		6713.86 (54)	6560.09 (56)	6502.98 (59)
AIC		6821.86	6672.09	6620.98
BIC		6978.34	6834.37	6791.95

Note. A = indicator(s) of dimension 1; B = indicator(s) of dimension 2; C = indicator of dimension 3.

The items forming the measures for content knowledge, pedagogical content knowledge, and curricular knowledge had acceptable item fit, ranging from 0.86 to 1.20 for WMNSQ and 21.50 to 1.70 for *t*-values. As evident from their item-total correlations (see Table 5-2, Columns 2–3), the items discriminated adequately. Item difficulties varied between easy and difficult (content knowledge range: .31–.88; pedagogical content knowledge range: .42–.54; curricular knowledge range: .26–.51). EAP/PV reliability of the content knowledge scale was weak (.71), whereas it was acceptable for pedagogical content knowledge (.86) and curricular knowledge (.81). Using a test version of ACER ConQuest 3, we further analyzed whether participants fit the model, too. Analysis shows that one participant had person fit outside the range of -2.0-2.0 for *t*-values. As Rost (2004) recommends keeping unexpected response patterns (outliers) when they occur so rarely, we keep this participant in our analysis to avoid that the sample size decreases. However, we reanalyzed dimensionality of our test without this person showing that the three-dimensional model still outperforms the one- and two-dimensional model.

Table 5-2
Description of the Scales and Item Fit Values

Scale	Discrimination ^a		WMNSQ ^a		<i>t</i> ^a		<i>n</i> of items	Reliability ^a EAP/PV
	Min.	Max.	Min.	Max.	Min.	Max.		
Content knowledge	.20	.50	.93	1.09	-1.50	.80	19	.71
Pedagogical content knowledge	.54	.70	.86	1.09	-1.40	.70	9	.86
Curricular knowledge	.60	.87	.86	1.20	-1.10	1.70	4	.81

Note. WMNSQ, weighted mean square; *t*, *t*-values; EAP/PV, expected A posteriori/plausible value reliability; ^aReduced set of items.

How are biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge related?

Since the three-dimensional model ([1] content knowledge, [2] pedagogical content knowledge, and [3] curricular knowledge) fits the data better than the one- and two-dimensional models, we calculated latent correlations between the latent constructs for the three-dimensional model (cf. research question 2). Our analyses show that there is a large correlation between pedagogical content knowledge and curricular knowledge, $r = .70$, $p < .001$, a medium correlation between content knowledge and pedagogical content knowledge, $r = .48$, $p < .001$, and also a medium correlation between content knowledge and curricular knowledge, $r = .35$, $p < .001$.

How are formal learning opportunities related to biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge?

Our third research question concerned the analysis of the relationship between formal learning opportunities and biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge. Latent regressions were performed to explore these relationships. With regard to the type of teacher education program, we differentiated teachers of the academic track (type A), teachers of the non-academic track (type B), and teachers qualified for a teaching profession in the former German Democratic Republic (type C). We entered the type of teacher education program into the regression analysis as two dummy-coded variables (types B and C). In Table 5-3, the constant represents the mean of

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type A teachers (reference group) in logit units. The regression coefficients for the type B teachers indicate the difference between types A and B teachers in logit units. The regression coefficient for the type C teachers represents the respective difference between types A and C teachers. Because type C teachers have more teaching experience on average ($M = 28.83$ years, $SD = 5.32$) than type A ($M = 11.63$ years, $SD = 9.63$) and B teachers ($M = 12.39$ years, $SD = 11.09$), results are adjusted for teaching experience by including teaching experience as a covariate into the regression. The analysis shows that certification type A outperforms certification type C concerning content knowledge, $B = -.35$, $SE = .16$, $p = .02$, and curricular knowledge, $B = -.99$, $SE = .39$, $p = .01$. No statistically significant differences are observed between certification types A and B, which indicates that the teacher education program in reunified Germany is not related to content knowledge, pedagogical content knowledge, or curricular knowledge with regard to the particular topic of the measures.

Taking into account professional development as a further formal learning opportunity, we investigated the relationship between professional development on the one side and content knowledge, pedagogical content knowledge, as well as curricular knowledge on the other. Since the type of teacher education program is related to teachers' content-related knowledge, the certification type was partialled out in these regressions. Latent regressions show that the number of workshops and lectures teachers attended in the past two years is positively related to content knowledge, $B = .10$, $SE = .05$, $p = .05$, and pedagogical content knowledge, $B = .24$, $SE = .10$, $p = .02$. No significant relation was obtained for curricular knowledge, $B = .18$, $SE = .13$, $p = .17$.

Table 5-3

Regression Models Predicting Content Knowledge, Pedagogical Content Knowledge, and Curricular Knowledge

Scale	Content knowledge			Pedagogical content knowledge			Curricular knowledge		
	Estimate	SE	<i>p</i>	Estimate	SE	<i>p</i>	Estimate	SE	<i>p</i>
Constant	0.74	.10	<.001	-0.22	.17	.19	-1.23	.24	<.001
Type B teachers	0.18	.14	.20	0.42	.25	.24	0.53	.37	.15
Type C teachers	-0.35	.16	.02	-0.37	.27	.17	-0.99	.39	.01

Note. Constant is related to the mean performance of certification type A. Adding *B* coefficients (estimate) of certification type B or C to the constant yields mean performance of these certification types. B = qualified for a teaching profession in the non-academic track; C = qualified for a teaching profession in the former German Democratic Republic.

How are informal learning opportunities related to biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge?

Our final research question addressed the analysis of the relationship between informal learning opportunities and biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge. Hence, we focused on teaching experience and self-study (e.g., reading journals) as informal learning opportunities. Concerning teaching experience, we estimated latent regressions between the predictor 'teaching experience' and the outcome variables content knowledge, pedagogical content knowledge, and curricular knowledge, respectively (see Table 5-4). Our analyses show that teaching experience is negatively related to curricular knowledge, $B = -.03$, $SE = .01$, $p = .003$, which indicates that teachers with more teaching experience are less familiar with the current curriculum. No significant relationship was observed between teaching experience and content knowledge, $B = .01$, $SE = .01$, $p = .32$, or between teaching experience and pedagogical content knowledge, $B = -.01$, $SE = .01$, $p = .32$. Concerning self-study as a further learning opportunity, we found positive relationships toward pedagogical content knowledge, $B = .31$, $SE = .11$, $p = .005$, and curricular knowledge, $B = .36$, $SE = .17$, $p = .03$. No significant relationship was observed between self-study and content knowledge, $B = .11$, $SE = .06$, $p = .09$.

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Table 5-4

Regression Coefficients and Standard Errors for Teaching Experience and Self-Study

Component of content-related knowledge	<i>B</i>	<i>SE</i>	<i>p</i>
<i>Teaching experience</i>			
Content knowledge	.01	.01	.32
Pedagogical content knowledge	-.01	.01	.32
Curricular knowledge	-.03	.01	.003
<i>Self-study</i>			
Content knowledge	.11	.06	.09
Pedagogical content knowledge	.31	.11	.005
Curricular knowledge	.36	.17	.03

5.6 Discussion

Although teachers' content-related knowledge is regarded as an important factor influencing students' learning progress (e.g., Baumert et al., 2010), no consensus has been reached about the empirical structure of this type of knowledge yet. In fact, various models have been proposed by educational researchers (cf. Chapter 5.2.1). Hence, it remains an open question, which model represents teachers' content-related knowledge best. It might even be possible that some of the models merely exist in the researchers' minds (e.g., Hiebert, Gallimore, & Stigler, 2002). In addition, little is known to date specifically about the development of biology teachers' content-related knowledge. Therefore, our research was guided by two aims. First, we sought to explore the empirical structure of biology teachers' content-related knowledge. Second, we pursued to investigate the relations between learning opportunities and biology teachers' content-related knowledge in order to draw conclusions on its development.

5.6.1 Empirical Structure of Biology Teachers' Content-Related Knowledge

Most models of teachers' content-related knowledge consider content knowledge, pedagogical content knowledge, and curricular knowledge as inherent components (e.g., Grossman, 1990; Magnusson et al., 1999; Shulman, 1986). As stated in our first aim, we analyzed the empirical structure of content-related knowledge (first research question) as well as the relationship between the components of content-related knowledge (second

research question). Our analyses indicate that biology teachers' content-related knowledge consists of three unique and separable, but correlated types of knowledge: (1) content knowledge, (2) pedagogical content knowledge, and (3) curricular knowledge. This taxonomy is consistent with Shulman's (1987) original conceptualization of content-related knowledge.

Researchers differ notably concerning both the relation of content knowledge and pedagogical content knowledge as well as the relation of pedagogical content knowledge and curricular knowledge. As outlined above, some of them assume content knowledge and pedagogical content knowledge to be merged into a single body of knowledge (e.g., Fernandez-Balboa & Stiehl, 1995; Hill et al., 2004; Marks, 1990), whereas others regard them to be unique types of knowledge (e.g., Grossman, 1990; Jüttner et al., 2013). Our results strongly support the two-type assumption. Multiple factors may account for the empirical separability of content knowledge and pedagogical content knowledge. Krauss, Brunner, et al. (2008) conclude that separability depends on teachers' expertise; they assume that teachers who have undergone an in-depth training integrate content knowledge and pedagogical content knowledge more tightly than teachers who have received less subject matter training. Furthermore, Lederman et al. (1994) observe pedagogical content knowledge to be developed by integrating content knowledge and pedagogical content knowledge. Since this process depends on teaching experience, content knowledge and pedagogical content knowledge become more similar with increasing teaching experience.

In a similar fashion to the question of whether content knowledge and pedagogical content knowledge are two separate types of knowledge, it is controversial whether curricular knowledge is a sub-component of pedagogical content knowledge (Grossman, 1990; Park & Chen, 2012) or a unique type of content-related knowledge (Shulman, 1986, 1987). In line with Shulman's (1986, 1987) theoretical conceptualization of content-related knowledge, our study shows curricular knowledge as a unique type of knowledge with a moderate correlation between curricular knowledge and pedagogical content knowledge. Similarly, curricular knowledge was weakly connected to other subcomponents of pedagogical content knowledge in the study of Park and Chen (2012). However, it is difficult to generalize this result, because different conceptualizations of curricular knowledge exist (cf. 5.2.1), ranging from 'knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers' (Shulman, 1986, p. 8) to

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knowledge about the articulation of topics during a school year (Grossman, 1990) or knowledge of the goals and objectives of a subject including knowledge about national- or state-level documents (Grossman, 1990; Magnusson et al., 1999). Since neither nation-wide authoritative materials and programs for teaching are available in Germany nor consistent curricula exist between the federal states of Germany from which the participants were recruited, our measure focuses on knowledge of the goals and objectives which is represented by the national educational standards for the intermediate school leaving certificate in biology (KMK, 2010).

5.6.2 Learning Opportunities

As stated above, it is the second aim of our study to investigate the relations between learning opportunities and biology teachers' content-related knowledge in order to draw conclusions on its development. Although the development of teachers' content-related knowledge is the main subject of several studies, more research in this direction – especially for the other science subjects as chemistry and physics – is definitely needed. On the one hand, findings are contradictory between the individual studies. For example, Clermont et al. (1994) find teaching experience positively related to pedagogical content knowledge of chemistry teachers, whereas Brunner et al. (2006) and Kleickmann et al. (2013) state that there are no such relations in a sample of mathematics teachers. On the other hand, only a few studies investigate the differential effects of these learning opportunities by discriminating between different types of content-related knowledge (e.g., Kleickmann et al., 2013). Correspondingly, we investigated how biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge are related to formal (research question 3) and informal learning opportunities (research question 4).

Type of teacher education program. In order to explore how teacher education is related to content-related knowledge, we compared teachers with certification type A (qualified for a teaching profession in the academic track) to teachers with certification type B (qualified for a teaching profession in the non-academic track) and teachers with certification type C (qualified for a teaching profession in the former German Democratic Republic) with regard to content knowledge, pedagogical content knowledge, and curricular knowledge. Our findings are inconsistent with the ones of COACTIV (Baumert et al., 2010;

Brunner et al., 2006; Krauss, Brunner, et al., 2008), as we obtained no significant difference between certification types A and B concerning content knowledge and pedagogical content knowledge. With respect to content knowledge, this result seems surprising, because certification type A teachers have to attend considerably more subject matter courses during their university studies than their counterparts. It might be the case that the particular ecosystem (the Wadden Sea) focusing on the species *Mytilus edulis* does not represent a relevant topic of biology teacher education in university studies. Therefore, in-depth training (certification type A) does not present an advantage over less-extensive training (certification type B). Furthermore, the difference between the different certification types could be blurred because of opportunities to prepare the respective lessons. As certification type A teachers have a comparable amount of learning opportunities for pedagogical content knowledge in university studies, the absent difference between certification types A and B seems plausible. Concerning curricular knowledge, no comparable studies are available yet.

When comparing certification types A and C teachers, it is noticeable that an in-depth training (certification type A) is positively related with content knowledge and curricular knowledge. These findings are in line with COACTIV with regard to content knowledge (Baumert et al., 2010; Brunner et al., 2006; Krauss, Brunner, et al., 2008). Despite several structural differences between the German teacher education after the German reunification and teacher education in the former German Democratic Republic, there is a clear difference in implementing traineeship. Whereas a two-year traineeship has been separated from university studies after the German reunification, it was implemented in university studies in the former German Democratic Republic. Both traineeship after university studies and traineeship implemented into university studies are supposed to be important learning opportunities for pedagogical content knowledge (Kleickmann et al., 2013); hence, it is plausible that there is no difference concerning pedagogical content knowledge. However, certification types A and C are hardly comparable to each other. Therefore, this conclusion should be treated with caution.

Professional development. We were also interested in possible relations between formal learning opportunities in the in-service phase and biology teachers' content knowledge, pedagogical content knowledge, and curricular knowledge. Therefore, we asked biology teachers how often they had attended workshops and lectures concerning their

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subject biology in the past two years. The results suggest that participation in professional development programs is positively related to biology teachers' content-related knowledge. Although we cannot exclude that this is a consequence of the particular selectivity of these learning opportunities (maybe mainly extremely dedicated teachers assemble), this finding is in line with other studies, which found positive effects of in-service workshops on novice chemistry teachers' pedagogical content knowledge (Clermont et al., 1993) and primary science teachers' content knowledge (Smith & Neale, 1989). No significant, but nevertheless descriptively positive effects on content knowledge and pedagogical content knowledge were found by Brunner et al. (2006).

Teaching experience. As stated in our fourth research question, we were interested in informal learning opportunities such as teaching experience and self-study. Our findings about the relation of teaching experience to content knowledge, pedagogical content knowledge, and curricular knowledge are mixed. On the one hand, teaching experience is theoretically identified as a central learning opportunity for pedagogical content knowledge (Clermont et al., 1994; Friedrichsen et al., 2009). On the other hand, large-scale studies did not find teaching experience to be correlated with pedagogical content knowledge scores (Brunner et al., 2006; Schmidt et al., 2007). Concerning content knowledge, COACTIV shows that content knowledge scores of mathematics teachers stagnate across their professional life (Kleickmann et al., 2013). In a similar fashion, we found that teaching experience is not related to the development of content knowledge and pedagogical content knowledge. It is possible that teachers do not sufficiently renew their knowledge during their professional lives. Another possible reason could be that the questionnaires which are used in quantitative studies do not capture the kinds of content knowledge and pedagogical content knowledge which are really relevant for their professional lives. Further, we found teaching experience to be negatively related with curricular knowledge. One reason could be that teachers with little teaching experience were instructed in this kind of knowledge during teacher education, whereas teachers acquiring a teacher certificate before the national educational standards for the intermediate school leaving certificate in biology (KMK, 2010) were released in 2010 do not possess this knowledge. Because the development of curricular knowledge has not been investigated yet, our results cannot be compared with other findings. We assume that teaching experience negatively affects curricular knowledge

because of experienced teachers' intuitive use of curricular knowledge. Another plausible reason could be that experienced teachers are less willing to familiarize themselves with current reforms of curricular guidelines.

Self-study. Self-study (e.g., reading journals) was investigated as a second informal learning opportunity. In contrast to teaching experience, self-study seems to be positively related to biology teachers' pedagogical content knowledge and curricular knowledge, which could be explained by a suitable matching with regard to individual demands of particular teachers. We found no relationship between self-study and content knowledge due to the specific underlying topic in the test. Since we do not know much about the manner of self-study and its efficiency, further research is needed to investigate self-study.

5.6.3 Limitations of the Study

One limitation of our study is the very specialized topic chosen for the investigation, that is, 'the Wadden Sea ecosystem'. Even though it is a typical content for biology education in secondary schools of Northern Germany – where the study was conducted – it might be that it was not considered in detail in university teacher education. Further limitations concern the operationalization of curricular knowledge: On the one hand, curricular knowledge was not adjusted to the same content as content knowledge and pedagogical content knowledge, and on the other hand we applied a narrow definition of curricular knowledge. Our definition included knowledge of standards and objectives only. Whether our results generalize to broader definitions of curricular knowledge (cf. Grossman, 1990; Shulman, 1986) should be investigated in further studies. Furthermore, our study had a cross-sectional design, which inhibits causal conclusions about the effect of particular learning opportunities on the development of content-related knowledge. Moreover, self-study was captured only in general terms. Distinguishing between different kinds of self-study activities would provide more information about the relation of self-study and content-related knowledge. Finally, the use of external devices such as textbooks or the internet to answer the questionnaires by individual teachers cannot be excluded, although they were specifically instructed not to do so.

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5.6.4 Implications

Implications for further research. The aim of our study was to cast light on the empirical structure of biology teachers' content-related knowledge and to investigate its relations to formal and informal learning opportunities. Our literature review shows that there are different models of content-related knowledge available; they vary in the structure and the components included. A particular strength of our study lies in the fact that it investigates the empirical structure of content knowledge and pedagogical content knowledge within the same biological content, namely the Wadden Sea ecosystem focusing on the species *Mytilus edulis*. This provides more evidence that a low correlation between two components of knowledge really is a consequence of unique knowledge components and not only results from different biological contents. However, curricular knowledge is only weakly related to this particular biological content. Therefore, further research is necessary to explore how curricular knowledge is related to content knowledge and pedagogical content knowledge when curricular knowledge refers to the same topic.

Krauss, Baumert, et al. (2008) conclude that the structure of content-related knowledge may differ across teacher populations. In order to investigate this assumption with respect to biology teachers, the German educational system provides a quasi-experimental design because of its different standardized teacher education programs. However, the sample size of our study did not allow for investigating the latent structure of content-related knowledge within these groups of teachers with different certification types. Further research is also needed concerning the relevance of formal and informal learning opportunities. Because of the cross-sectional design of our study, our results can only provide hints about the relevance of the particular learning opportunities. In order to draw causal conclusions, longitudinal studies are needed. Finally, it is important to keep in mind that content-related knowledge indeed is an important, but not the only component of teachers' professional competence. Therefore, research should include further components (e.g., pedagogical knowledge, self-efficacy, interest) which form an 'expert' teacher. Beyond that, we have neglected to investigate which of these variables really effect students' achievement.

In teacher education, it is important to look at how professional knowledge is developed. Although causal conclusions cannot be drawn from our study because of its cross-sectional

design, we are confident that our study provides a number of hints related to professional knowledge development. Nevertheless, further research should use longitudinal studies to investigate which type of teacher education program (e.g., traineeship implemented in university studies [yes vs. no]) and which type of professional development program (e.g., subject matter related lectures [yes vs. no]) is positively related to teachers' professional knowledge. Furthermore, it should be investigated how teachers can be motivated to improve their professional knowledge during their professional life.

Implications for teacher education. In consideration of a stagnating to decreasing knowledge base during teachers' professional life, there is an apparent need for continuing education of teachers. Therefore, school authorities should provide incentives to attend professional development programs continuously. Also, school authorities could state a minimum number of workshops or lectures which a teacher has to attend each school year. Since self-study also seems to be a successful device for professional knowledge development, facilitating teachers to cooperate within college may motivate them to improve their professional knowledge. These implications are relevant in view of previous research, which has shown that teachers are a key factor for the learning progress of students (e.g., Hattie, 2009; National Research Council, 2001).

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Note

1. In line with research on workplace learning, informal learning opportunities refer to that type of learning that is not intentionally organized (Tynjälä, 2008). Informal learning is characterized by the absence of a teacher and a formal curriculum and occurs as a part of everyday work processes and activities (Eraut, 2004; Hein, 1998; Tynjälä, 2008). In science education, the term is often used for the learning at the museum which is not in the focus of this article (e.g., Rennie, 2007).

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5.8 Appendix

Appendix 1

Content Knowledge Measure Items

Please answer the following questions by marking the right answer with a cross. In this part of the questionnaire, only one answer per question is correct. If you want to correct your choice, please strike out the wrong answer.

Item 1. **The nervous system of a mussel is...**

- a metameric nervous system.
- a nervous system with three pairs of ganglions.
- a central nervous system with an encephalon.
- an autonomic nervous system.

Item 2. **What is the difference between blue mussels and other domestic mussels?**

- Blue mussels filter seawater.
- Blue mussels have a foot for moving.
- Blue mussels live on the surface of the seabed.
- Blue mussels produce levitating larvae.

Item 3. **Blue mussels produce a gluey substance, which is interesting for industrial use because of its elasticity and stability. Mark the right substance.**

- pseudofaeces
- hormones
- secretions
- protein filaments

Item 4. **Because of their way of life, blue mussels are of great interest for biologists and toxicologists. Which of the statements below are correct?**

- Blue mussels filter large quantities of saltwater in a short time. Biologists and toxicologists profit from this benefit; they use blue mussels to clean up lakes and ponds.
- Blue mussels produce mud while filtrating. This mud is used by biologists and toxicologists to analyze seawater.
- Blue mussels absorb harmful substances and toxins into their bodies. Biologists and toxicologists analyze the blue mussels to make conclusions about water pollution.
- Biologists and toxicologists make conclusions about water quality by analyzing the color of the lime shell.

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Item 5. **For an experiment, two beaker glasses (capacity 1 liter) are filled with mud water. 5-10 blue mussels are placed into one of the two beaker glasses. Compare the two beaker glasses after 20 minutes. Which conclusion can you make?**

- There is no difference between the two beakers.
- The turbidity of the water has decreased in the beaker with the blue mussels.
- The turbidity of the water has increased in the beaker with the blue mussels.
- The blue mussels have not survived the experiment.

Item 6. **The Wadden Sea is one of the habitats of the blue mussel. What happens to the mussels during low tide?**

- The blue mussels are washed away by the water, because they would dry up without it. The flood takes them back.
- The blue mussels delve into the tidal flat soil for a few hours to survive.
- The blue mussels close their shells and survive with a little supply of water.
- Blue mussels only live in sublittoral zones (constantly under water), so there is no problem during low tide.

Item 7. **Why do mussel fishermen have such a big influence on the population of Eider ducks?**

- Mussel fishermen harvest the young blue mussels on offshore mussel beds, taking away the Eider duck's food source in the Wadden Sea.
- Mussel fishermen shoot Eider ducks to protect their mussels.
- Mussel breeding provides Eider ducks with an ever-growing food source.
- Mussel fishermen place nets near their mussel beds, in which Eider ducks are caught and die.

Item 8. **Which of the following examples is no system by definition?**

- sunflower
- bicycle
- pile of sand
- cell

Item 9. **Which of the following statements is the correct definition for the term "successions"? Successions are...**

- short-term changes within an ecosystem which have no long-term effect on the biocenosis.
- long-term development processes within ecosystems which start with an initial stage and blend into a climax community via numerous intermediate stages.
- long-term developments in which ecosystems revert back to their initial stage after passing through some intermediate phases.
- a series of simultaneous transformation processes which cause a spontaneous change in the ecosystem.

In the following part of the questionnaire, more than one answer may be correct. Please answer the following questions by marking the right answers with a cross.

Item 10. Which characteristics distinguish homoeothermals from poikilothermals?

- The need for nutrition and energy is very low.
- The activities of the animals are more or less unaffected by the outer air temperature.
- They regulate their body temperature via suitable behavior.
- They can populate nearly all living environments of the earth.

Item 11. Which of the following abiotic factors define the life conditions in the sea?

- salt concentration
- temperature
- lighting conditions
- wind conditions

Item 12. Mussel beds are important for blue mussels. Do they have another function for the sea ecosystem?

- Yes, mussel beds are settlement areas for numerous animal and plant species.
- No, mussel beds are only important for blue mussels and their procreation.
- Yes, mussel beds are a food source for a great number of species.
- Yes, blue mussels stabilize the ocean bed.

Item 13. Aristotle (384-322 BC) is one of the first taxonomists. He said: "The whole is more than the sum of its parts." What does this statement mean?

- To understand a system, it is not sufficient to only know the elements of the system and their characteristics.
- The characteristics of the elements of the system together make up the characteristics of the whole system.
- To understand a system, one has to know and understand the correlations between the elements of the system.
- A system can be understood by knowing the isolated elements of the system.

Item 14. The elements of a system have a cause and effect relationship. What does this mean?

- The effect does not only produce a reaction, but also affects other elements.
- The output has a direct connection to the input.
- An input triggers a certain consequence.
- A consequence retroacts on the initial element.

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Item 15. **What is the difference between a natural mussel bed and a farmed mussel bed?**

- In contrast to natural ones, farmed mussel beds have a much longer life expectancy.
- In contrast to natural ones, farmed mussel beds are impoverished in species.
- In contrast to natural ones, farmed mussel beds are located in a protected area, so that there are fewer external hazards.
- In contrast to natural ones, farmed mussel beds offer a diverse habitat for flora and fauna.

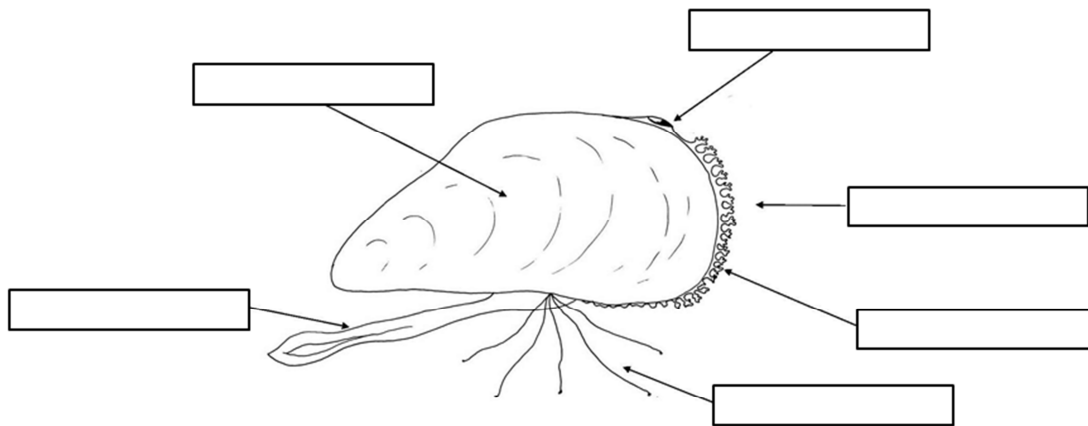
Item 16. **Which of the following statements relating to the shell-structure of mollusks are correct?**

- The shells of mollusks are structured in three layers.
- The shells of mollusks consist of a dense epithelial layer.
- The shells of mollusks consist of an organic lipid layer and an inner nacre layer.
- The shells of mollusks contain an organic glycoprotein layer, an outer prism layer, and an inner nacre layer.

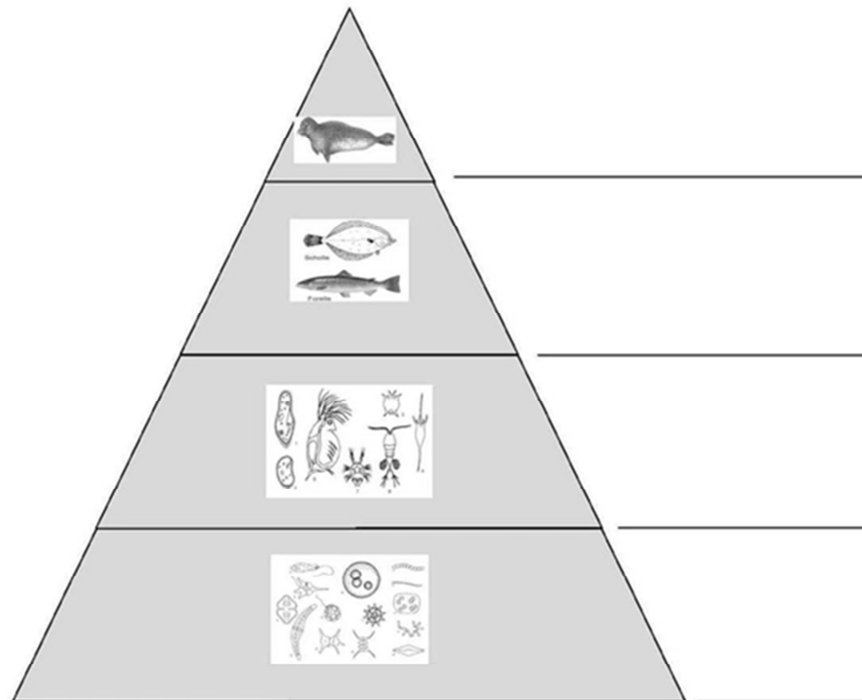
Item 17. **Which of the following statements about the "radula" are correct?**

- The radula enables movement.
- The radula serves to rasp nutrition.
- Mussels do not have radula.
- The radula covers the sperm before copulation.

Item 18. **Please label the following image of a mussel.**



Item 19. The following image shows a nutrition food pyramid. Please name the levels of the pyramid. Use technical terms!



Appendix 2

Pedagogical Content Knowledge Measure Items

Please answer the following questions concerning pedagogical content knowledge. If you want to correct your response, please strike out the wrong sentence.

Item 1. **A trainee teacher has completed a teaching unit concerning the topic "snails" with 8th grade students. The students are supposed to list the specifics of all other mollusk species in a comparative overview.**

Outline the structure of the lesson: What should the trainee teacher do to allow them to integrate their own interest in the topic into the completion of the task?

Item 2. **A trainee teacher has conducted an experiment with an 8th grade class to test the filtration capacity of blue mussels. After the lesson, you note that it would have been useful to let the students write a log during the experiment.**

Explain why experiment logs are important for students.

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Item 3. **In the lesson before, 8th grade students have learned that blue mussels need water to be able to breathe.**

Please create a short outline for a problem-oriented beginning of a lesson with the topic "survival of the blue mussels during low tide."

Item 4. **You are supposed to teach "The Nutrition of Blue Mussels" to your students in the 8th grade.**

Outline three ways of presenting the following text in a student-comprehensible way.

"The blue mussel opens its shell in order to ventilate. A curled mantle edge borders the gap through which water can enter the mantle cavity. The curled appendages of the mantle edge control the intake of water. In the mantle cavity, cilia around the gills and mouth lobes do not only control the strength and direction of the water flow, but also sort particles which enter with the water. The water flooding through the inflow opening to the lamellae of gills, and then to the frontal gills, is filtered to remove any unwanted particles. The water then flows into the inner, then into the outer gill chamber, from which the water reaches the outflow opening and leaves the mussel. If the filtered particles are identified as nutrition, they reach the mouth. Other particles reach the mantle cavity, where the mantle edges press these particles to form a slimy substance. Sometimes mussels excrete the filtered particles in the form of compact clots – so-called 'pseudofaeces' – released from the upper corner of the inflow opening."

Item 5. **The national educational standards for the intermediate school-leaving certificate in biology (KMK, 2010) contain the following declaration: "The students [...] describe and evaluate the impact of human intervention on ecosystems" (B5).**

Illustrate how you can implement this standard into your 8th grade unit topic "blue mussels."

Item 6. **5th grade students are supposed to work on an experiment on their own, including its planning and execution.**

Please mention some issues the students may have with the planning, interpretation, and evaluation of experiments.

Item 7. **A trainee teacher wants to capture his students' conceptions of "the role of human beings in nature." He asks for your help.**

Present two methods which the trainee teacher could use to capture the students' conceptions.

Item 8. **Students in the 5th grade are supposed to categorize creatures into classes which they think are appropriate ones.**

Please give four examples of incorrect classes into which the students might categorize the creatures.

Item 9. **In an 8th grade class, a trainee teacher starts a unit with writing the classes "snails/slugs," "mollusks," and "cephalopods" on the blackboard. One student asks why they did not included "jellyfish".**

Describe how the trainee teacher could reorganize the lesson to take the students' conceptions into account.

Appendix 3

Curricular Knowledge Measure Items

Please answer the following questions concerning pedagogical content knowledge. If you want to correct your response, please strike out the wrong sentence.

Item 1. **In the national educational standards for the intermediate school-leaving certificate in biology (KMK, 2010), three basic concepts indicate the substance dimension of the competences.**

Please name the three basic concepts.

Item 2. **The national educational standard for biology at the end of the lower secondary level wants the students to have competences in substance dimension (expert knowledge) and in operational dimension (KMK, 2010).**

Please comment on the meaning of "operational dimension."

Item 3. **The national educational standard for biology at the end of the lower secondary level (KMK, 2010) differentiates between three requirement levels into which exercises are divided. They describe the level of difficulties of one sphere of competence.**

Define which claims these three requirement levels present.

Requirement level I:

Requirement level II:

Requirement level III:

Item 4. **Please mention the four areas of competence demonstrated in the national educational standards for the intermediate school-leaving certificate in biology (KMK, 2010).**

6 STUDY 2:

Teachers' Self-efficacy and Enthusiasm: Opportunities for Teachers to Develop Motivational Orientations²

Selbstwirksamkeitserwartungen und Enthusiasmus: Gelegenheiten für die Entwicklung motivationaler Orientierungen bei Lehrkräften

Abstract

Effective teaching depends on manifold characteristics of the teacher. Besides professional knowledge, self-efficacy and enthusiasm of teachers are central to successful operation in the classroom. Yet, how are self-efficacy and enthusiasm of teachers developed during their professional training and later in their professional life? With this question in mind, we considered different situations both during teacher education as well as at different points in teaching careers which provide opportunities for the development of self-efficacy and enthusiasm. Additionally, we investigated the relationships between these two motivational orientations and teachers' professional knowledge. 134 biology teachers provided information about their self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching as well as about their content knowledge and their pedagogical content knowledge (CK and PCK). We assumed that a high quality university-level teacher education, professional development, self-study, and teaching experience present opportunities for teachers to (further) develop self-efficacy and enthusiasm. Significant relationships were observed between both self-efficacy and enthusiasm for teaching and the quality of university-level teacher education, the amount of professional development, and the frequency of self-

² Mahler, D., Großschedl, J., & Harms, U. (submitted). Teachers' Self-efficacy and Enthusiasm: Opportunities for Teachers to Develop Motivational Orientations. *Journal for Educational Research Online*.

study. Our correlation analysis showed self-efficacy and subject-specific enthusiasm to be positively related to PCK.

Keywords: *Self-Efficacy; Teacher enthusiasm; Teacher education; Professional knowledge*

Zusammenfassung

Eine erfolgreiche Lehrkraft zeichnet sich durch vielfältige Aspekte professioneller Kompetenz aus. Neben dem Professionswissen werden die Selbstwirksamkeitserwartungen sowie der Enthusiasmus der Lehrkraft als relevant für erfolgreiches Unterrichten beschrieben. Welche Gelegenheiten aber bieten die Lehramtsausbildung bzw. die Zeit im Lehrerberuf für die (weitere) Entwicklung von Selbstwirksamkeitserwartungen und Enthusiasmus? Neben dieser Frage wurde in der vorliegenden Studie zusätzlich der Zusammenhang zwischen den Selbstwirksamkeitserwartungen und dem Enthusiasmus der Lehrkraft einerseits und ihrem Professionswissen andererseits untersucht. Selbstwirksamkeitserwartungen, fachbezogener Enthusiasmus, Enthusiasmus für das Unterrichten sowie Fachwissen und fachdidaktisches Wissen (CK und PCK) von 134 Biologielehrkräften wurden mit Fragebögen erhoben. Die Qualität der universitären Lehramtsausbildung, die Teilnahme an Fortbildungen, die Häufigkeit des Selbststudiums sowie die Berufserfahrung wurden als relevant für die Selbstwirksamkeitserwartungen und den Enthusiasmus von Lehrkräften angenommen. Die Ergebnisse zeigen signifikante Zusammenhänge zwischen den Selbstwirksamkeitserwartungen sowie dem Enthusiasmus für das Unterrichten und der Qualität der universitären Lehramtsausbildung, der Teilnahme an Fortbildungen sowie der Häufigkeit des Selbststudiums. Sowohl die Selbstwirksamkeitserwartungen als auch der fachbezogene Enthusiasmus korrelieren signifikant positiv mit dem PCK.

Stichworte: *Selbstwirksamkeitserwartungen; Enthusiasmus; Lehramtsausbildung; Professionswissen*

STUDY 2

6.1 Introduction

Teachers significantly impact on students' learning outcomes (e.g., Hattie, 2009; Coe, Aloisi, Higgins & Major, 2014; Kleickmann et al., 2013). These imply students' motivation as well as performance (e.g., Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000b; Hattie, 2009). On the teacher side, a wide range of abilities is needed. Baumert and Kunter (2013) map these abilities in their model of professional competence. They define four aspects: (1) professional knowledge, (2) motivational orientations, (3) self-regulation, as well as (4) beliefs, values, and goals. Currently, the aspect of professional knowledge is an emphasized object of research (e.g., Fennema et al., 1996; Gess-Newsome & Lederman, 1995; Großschedl, Mahler, Kleickmann, & Harms, 2014; Großschedl, Harms, Kleickmann, & Glowinski, 2015; Hill, Rowan, & Ball, 2005; Jüttner, Boone, Park, & Neuhaus, 2013; Jüttner & Neuhaus, 2012; Jüttner & Neuhaus, 2013; Kleickmann et al., 2013; Kleickmann et al., 2015; Krauss et al., 2008; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013). However, being an effective teacher takes more than just having professional knowledge.

Teachers face numerous demands and challenges, for example due to high student diversity in and between their classes, complex curricular requirements, and demanding communicative situations with students, parents, or colleagues. Effectiveness in teaching is impermanent (Baumert & Kunter, 2013). Even a thorough lesson preparation does not guarantee effective teaching, because no planning can anticipate all the situations or conflicts which may possibly occur in the classroom. A challenge - particularly for novice teachers - is the gap between theoretical knowledge acquired in teacher education programs and the reality of teaching in schools (Brouwer & Korthagen, 2005; Korthagen, 2009). Due to these circumstances, teachers suffer from high levels of job stress, which can lead to disaffection or even burnout (Stoeber & Rennert, 2008). With respect to this big strain on teachers, several studies have highlighted the relevance of competence aspects which go beyond professional knowledge, such as motivational orientations (e.g., Baumert & Kunter, 2013; Kunter et al., 2013; Lee, Cawton, & Dawson, 2013).

Motivational orientations are relevant characteristics of psychological functioning. They are related to the "psychological dynamics of behavior, the maintenance of intentions, and the monitoring and regulation of occupational behavior" (Baumert & Kunter, 2013, p. 38). Motivational orientations cover different domains, namely (1) self-efficacy, (2) control

beliefs, and (3) enthusiasm (Baumert & Kunter, 2013). In the study at hand, we address both cognitive as well as affective domains of motivational orientations by taking teachers' self-efficacy and enthusiasm into consideration. Self-efficacy is a cognitive domain of teachers' motivational orientations (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011) and has already been in the focus of several studies (e.g., Ashton, 1984; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). Here, we are enhancing this focus by adding the aspect of teacher enthusiasm as an affective domain of motivational orientations (e.g., Kunter et al., 2011; Kunter, 2013; Long & Hoy, 2006). In the following, two facets – namely subject-related enthusiasm and enthusiasm for teaching (Kunter et al., 2011) – will receive special attention.

The necessity of taking teachers' self-efficacy and enthusiasm into account when characterizing a successful and healthy teacher leads to the question of whether current teacher education as well as teachers' professional lives offer adequate opportunities which support these two domains of motivational orientations. Conclusively, the first aim of this study is to investigate whether different situations during pre-service and in-service teacher education as well as teachers' careers are related to their self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching.

Pre-service and in-service teacher education predominantly aims at the acquisition of professional knowledge (cf. for Germany KMK, 2008). Thus, in a second step, we seek to explore the question of how self-efficacy as well as enthusiasm and professional knowledge interact. In this context, we will focus on teachers' content knowledge (CK) and pedagogical content knowledge (PCK).

6.2 Background

6.2.1 Teachers' Self-Efficacy and Enthusiasm

Self-efficacy

Self-efficacy denotes an individual's belief that she or he is capable to produce a successful outcome (Bandura, 1977). In contrast to more general constructs such as for example self-esteem, it is linked to a specific context or task (Moulding, Stewart, Dunmeyer, 2014). In the context of teacher education, self-efficacy can accordingly be described as a teacher's

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confidence to effectively organize and perform specific actions related to a particular teaching task (Tschannen-Moran et al., 1998).

Research has shown that the self-efficacy of teachers is interrelated to different areas of their professional lives. In particular, three areas are described in the literature: (1) beliefs about the relationship between teachers and students (e.g., teachers' personal responsibility for students' learning; Ashton, 1984; Schriver & Czerniak, 1999), (2) teachers' professional practice (e.g., classroom management; Allinder, 1994; Schriver & Czerniak, 1999; Tschannen-Moran et al., 1998), and (3) emotional aspects (e.g., emotional exhaustion or job satisfaction; Allinder, 1994; Ashton, 1984; Klusmann, Kunter, Trautwein, & Baumert, 2006, Moè et al., 2001). Furthermore, the self-efficacy of teachers is associated with their students' performance (Caprara, Barbaranelli, Steca, & Malone, 2006; Guo, Piasta, Justice, & Kaderavek, 2010; Tschannen-Moran & Woolfolk Hoy, 2001; Webb & Ashton, 1986; Woolfolk-Hoy & Burke-Spero, 2005) and motivation (Midgley, Feldlaufer, & Eccles, 1989).

Enthusiasm

Kunter et al. (2011) define teacher enthusiasm as an affective teacher orientation which includes enjoyment, excitement, and pleasure for teaching in general and for a specific school subject. This definition uses internal indicators to describe enthusiasm; it treats enthusiasm as a personality trait, which is in line with other approaches applied in teacher enthusiasm research (Keller, Goetz, Becker, Morger, & Hensley, 2014; Kunter et al., 2008). This definition foreshadows that teacher enthusiasm contains at least two facets, namely (1) subject-specific enthusiasm and (2) enthusiasm for teaching (Kunter et al., 2011). *Subject-specific enthusiasm* describes a topic-related affective orientation (Kunter et al., 2011). It is close to the construct of individual interest which is defined as a fairly stable positive person-object relation (Krapp, 2002), here a teacher-subject relation. It is relatively resistant to the circumstances in the classroom because the source of enthusiasm – namely the subject – is constantly present (Kunter et al., 2011). *Enthusiasm for teaching* can be described as the enjoyment of the activity of teaching (Kunter et al., 2011). In this case, the object in the person-object relationship is the interaction with students. In contrast to subject-specific enthusiasm, enthusiasm for teaching is not immune to influences such as organizational structures in schools or students' motivational characteristics (Kunter et al., 2011). Both

constructs are not independent of each other, but moderately correlated ($r = .36$) (Kunter, 2013). Teacher enthusiasm is an important determining factor for teachers' job satisfaction (Moè, Pazzaglia, & Ronconi, 2001) as well as students' performance (Kunter et al., 2013).

6.2.2 Opportunities to Develop Self-Efficacy and Enthusiasm

Friedrichsen et al. (2009) identified three sources with respect to the development of professional knowledge: (1) the teacher's own school experience, (2) pre-service and in-service teacher education, and (3) teaching experience. Especially pre-service and in-service teacher education (Großschedl et al., 2014; Kleickmann & Anders, 2013; Schmidt et al., 2007; Tatto & Senk, 2011) and teaching experience (Grossman, 1990; Lederman, Gess-Newsome, & Latz, 1994; Schmelzing et al., 2013) have been empirically proven to support the development of professional knowledge. Accordingly, we assume pre-service and in-service teacher education as well as teaching experience to also provide opportunities which foster teachers' self-efficacy and enthusiasm. Several scholars support our assumption. The findings of Andrew & Schwab (1995), for example, indicate that pre-service teacher education is important for the development of teachers' self-efficacy because it creates confidence in teaching and influences the intention to stay in the profession. Professional development as defined in our study is part of in-service teacher education and includes lectures or workshops which are related to the teachers' subjects. It is described to have a positive impact on both the development of self-efficacy (Campbell, 1996; Roness, 2011) and teacher enthusiasm (Collins, 1978). Findings from recent research indicate that the relationship between self-efficacy and teaching experience is not entirely clarified. Carleton, Fitch, and Krockover (2008) found that professional experiences help to increase the extent of teachers' self-efficacy. This is in line with Bandura (1986), who stated that mastery experiences are a relevant source of teachers' self-efficacy (Bandura, 1986). In contrast, Schmitz (1998) found that teaching experience has no influence on teachers' self-efficacy. Teaching experience also seems to be a relevant factor in the development of teacher enthusiasm. Kunter et al. (2011) found a positive relationship between enthusiasm for teaching and teaching experience. In our study at hand, we define self-study as individually conducted training (e.g., reading of journals). With regard to the impact of self-study on teachers' motivational orientations, information is still lacking.

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6.2.3 Teachers' Self-Efficacy and Enthusiasm and the Relation to Professional Knowledge

Teacher education mainly focuses on the acquisition of professional knowledge. Accordingly, to gain an understanding of how teachers' self-efficacy and enthusiasm develop, we need to consider professional knowledge and its relation to these domains. Professional knowledge covers the knowledge which is important for the professional life of a teacher (Baumert et al., 2010). In most cases, two categories are distinguished in the literature: (1) non content-related professional knowledge (e.g., pedagogical knowledge) and (2) content-related professional knowledge (Baumert & Kunter, 2013; Shulman, 1986). The study at hand focuses on content-related professional knowledge which is composed of CK and PCK (e.g., Grossman, 1990). CK covers the knowledge of the facts and concepts of a specific subject and its structure (Shulman, 1986). PCK is described as the knowledge which is needed to make the subject matter comprehensible to students (Shulman, 1986). Several studies have described PCK in different facets (e.g., Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986, 1987). Two facets of PCK, however, are constantly included in these models (1) knowledge of instructional strategies for teaching, and (2) knowledge of students' understanding (e.g., Großschedl et al., 2015; Grossman, 1990; Shulman, 1987).

Although CK and PCK as well as self-efficacy and enthusiasm are well-established domains of teachers' professional competence (e.g., Baumert & Kunter, 2013), empirical evidence about their relationship and interplay is relatively limited. Raudenbush et al. (1992) stressed the important interaction between knowledge and self-efficacy. Pekkanli Egel (2009) looked into different aspects with regard to the self-efficacy of prospective English teachers. One of her findings was that high-achieving prospective English teachers scored higher concerning self-efficacy. Bandura (1986) supports these findings. He identified mastery experiences as a source of self-efficacy. Professional knowledge allows for these mastery experiences during teaching. Thus, a relationship between professional knowledge and self-efficacy seems plausible. However, Moulding, Stewart, and Dunmeyer (2014) found no correlation between academic achievement and teachers' self-efficacy, which indicates that academic success during teacher preparation does not automatically lead to self-efficacy. Riese and Reinhold (2010) focused on the relationship between physics teachers' CK and PCK and their general as well as teaching-related self-efficacy. They found a significant positive correlation between teaching-related self-efficacy and CK.

6.3 Research Questions and Hypotheses

This study aims to investigate whether selected situations during teacher education and teachers' careers offer opportunities which support self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching. We consider the following situations to be relevant: (1) university-level teacher education (here: the perceived quality of university-level teacher education), (2) professional development (here: participation in workshops and lectures), (3) teaching experience, and (4) self-study (e.g., reading journals). Accordingly, our first research question is:

1. How are (a) self-efficacy, (b) subject-specific enthusiasm, and (c) enthusiasm for teaching related to the identified situations (1) to (4) during teacher education and teachers' careers? With regard to the findings currently available (Andrew & Schwab, 1995; Campbell, 1996; Carleton et al., 2008; Collins, 1978; Großschedl et al., 2014; Kunter et al., 2011; Roness, 2011), we assume a positive relation of the considered situations to teachers' self-efficacy and both facets of enthusiasm.

It is beyond dispute that the acquisition of professional knowledge is the first aim of both university-level teacher education and in-service teacher training programs. As outlined above, however, becoming and being a professional and healthy teacher takes more than just having professional knowledge. Here, motivational orientations such as self-efficacy and enthusiasm come into play. We assume that professional knowledge and motivational orientations interact in a specific fashion. To gain a first insight into these hypothesized interrelations, our second research question is:

2. How are (a) self-efficacy, (b) subject-specific enthusiasm, and (c) enthusiasm for teaching related to CK and PCK? With reference to current findings (Raudenbush et al., 1992; Riese & Reinhold, 2010), we assume a relationship between teachers' self-efficacy and their content-related professional knowledge. Furthermore, as CK and PCK are very closely related to a specific subject, we assume a positive relationship between subject-specific enthusiasm and both CK and PCK.

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6.4 Method

6.4.1 Measures

Teachers' self-efficacy and enthusiasm

The measure of teachers' self-efficacy ($M = 20.51$, $SD = 3.30$) is a widely-used instrument developed by Schmitz and Schwarzer (2000) which consists of ten Likert-type items (4 = fully applies; 3 = largely applies; 2 = does rather not apply; 1 = does not apply at all). The instrument assesses different skills which are relevant for the teaching profession. It addresses (1) the relationship with students and parents (e.g., dealing with difficult students), (2) emotional aspects (e.g., resignation), as well as (3) aspects related to professional practice (e.g., creative ideas for the improvement of lessons; *"I know that I will be able to clarify individual problems of students even better in the future."*).

Both subject-specific enthusiasm ($M = 8.35$, $SD = 1.01$; three items; e.g., *"I am enthusiastic about the subject biology."*) and enthusiasm for teaching ($M = 5.27$, $SD = 0.93$; two items; e.g., *"I teach biology with great enthusiasm."*) were measured using instruments developed by Baumert et al. (2009). As our sample consists of biology teachers while the original instruments address mathematics teachers, we replaced 'mathematics' with 'biology' in the items. The same Likert-scale which was used for self-efficacy was applied to the items. The reliability of the scales is described by the factor ρ coefficient which overcomes the shortcomings of Cronbach's alpha coefficient outlined by Raykov (2004). The factor ρ coefficients for teachers' self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching were .71, .73, and .79 respectively, which indicates that the scales had good reliability and confirm convergent validity among indicators of these factors (Kline, 2011).

Situations during teacher education and teachers' careers

We assume four situations to provide opportunities for the development of self-efficacy and the two facets of enthusiasm: (1) the perceived quality of university-level teacher education, (2) professional development (participation in workshops and lectures), (3) teaching experience, and (4) self-study (reading journals).

1. Three Likert-type items were applied to measure the perceived quality of university-level teacher education ($M = 3.06$, $SD = 1.04$). As we have a sample of in-service teachers,

the quality of university-level teacher education was graded retrospectively. Each item focused on a particular area of teacher education at German universities which is composed of (a) biology courses (acquisition of CK), (b) biology education courses (acquisition of PCK), and (c) courses in general pedagogy (acquisition of pedagogical knowledge). Each item started with a request (*"Please grade the quality of the teacher education program you attended with regard to your job as a biology teacher."*). The following answer alternatives were provided for each item: 1 = very good, 2 = good, 3 = satisfying, 4 = sufficient, 5 = inadequate, 6 = unsatisfactory or not part of teacher education program. The areas of teacher education (a) to (c) were summarized to provide a score which describes the general quality of teacher education. We decided to assess the *perceived* quality of teacher education, as we assume that the individual rating of quality is more predictive for motivational orientations.

2. To measure the amount of professional development, we asked the teachers about their participation in workshops and lectures related to their subject biology in the last two years. We used a single item ($M = 2.10$, $SD = 1.11$; *"How often did you participate in workshops and lectures for the purpose of professional development in your subject biology during the past two years?"*). Four answer alternatives were provided: 0 = never, 1 = once, 2 = once a year, 3 = more than once a year.

3. To measure their teaching experience, teachers were asked about the number of years they had been teaching ($M = 16.38$, $SD = 11.71$) *"I have been teaching in schools for ___ years."*

4. For self-study, teachers were asked how often they undertook further training individually beyond organized workshops or lectures ($M = 2.51$, $SD = 0.82$; *"How often do you engage in self-study [e.g., reading journals]?"*). The following four answer alternatives were provided: 0 = never, 1 = once, 2 = once a year, 3 = more than once a year.

Teachers' content-related professional knowledge

Two questionnaires (cf. Großschedl et al., 2014) were used to capture biology teachers' content-related professional knowledge - that is their CK and PCK. The latter was operationalized as PCK of instructional strategies for teaching and PCK of students' understanding. Teachers' CK was assessed using 19 multiple choice items ($M = 17.95$, $SD = 3.95$; e.g.,

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"Mussel beds are important for blue mussels. Do they have another function in the sea ecosystem?"). Ten items were dichotomously scored (0 = wrong answer vs. 1 = correct answer), and nine items were polytomously scored (0 = wrong answer; 1 = half-correct answer [partial credit]; 2 = correct answer). The items addressed teachers' knowledge of a particular ecosystem (the Wadden Sea), with a special focus on the species *Mytilus edulis* (Blue Mussel). The topic was chosen because it represents a typical content of biology education in secondary schools of Northern Germany, where the study was conducted. It is implemented in the school curriculum and is tangent to the environment of students in Northern Germany (Brandstädter, Harms, & Großschedl, 2012). The items focused on three categories: (a) knowledge about *Mytilus edulis* (11 items), (b) knowledge about the ecosystem Wadden Sea (four items), and (c) general understanding of a system – what is relevant for understanding ecology (four items). Teachers' PCK ($M = 8.69$, $SD = 3.56$; e.g., "In the lesson before, 8th grade students have learned that blue mussels need water to be able to breathe. Please create a short outline for a problem-oriented beginning of a lesson with the topic 'survival of the blue mussels during low tide'.") was measured with the help of nine polytomously scored open-ended items which addressed both knowledge of instructional strategies for teaching (five items) and knowledge of students' understanding (four items). The items addressing PCK referred to *Mytilus edulis* in the context of the Wadden Sea ecosystem as well. WLE person separation reliability for CK and PCK was .69 and .78 respectively, indicating that both scales had acceptable internal consistency.

6.4.2 Sample and Data Collection Procedure

A total of 134 secondary biology teachers (75.4% female) participated in our study. At the German secondary school level, there is a clear distinction between schools which qualify their students for an academic career (grade 5-12 [or 13]; academic track) and schools which qualify their students for a non-academic career (grade 5-9 [or 10]; non-academic tracks). A further type of teacher education program was implemented in the former German Democratic Republic (cf. Baumert et al., 2010). There, the system consisted of a single type of secondary school (grade 5-12) only; no distinction was made between teachers certified for an academic or non-academic track. In our sample, a proportion of 54.5% of the participants was certified for the academic track, 17.1% for the non-academic tracks, and 26.9% attended a teacher education program in the former German Democratic Republic.

On average, the teachers were 43.7 years old ($SD = 10.2$), and their teaching experience ranged from seven months to 42 years ($M = 16.4$, $SD = 11.7$). Participants were recruited in Northern Germany (e.g., Mecklenburg-West Pomerania, Schleswig-Holstein) by telephone or mail. Teachers received the questionnaires by mail; they were instructed not to use external sources of information such as textbooks or the internet. No time limit was set for answering the questionnaires.

6.5 Results

6.5.1 Validity Check: Are Teachers' Self-Efficacy, Subject-Specific Enthusiasm, and Enthusiasm for Teaching Empirically Separable?

We analyzed the discriminant validity of our measures with confirmatory factor analysis (CFA) using the structural equation software MPlus 5.21 (Muthén & Muthén, 2007). The three-factor model assumes different latent factors for (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching. This model was compared to a one- and two-factor model. The one-factor model assumes a single latent factor behind teachers' responses. The two-factor model distinguishes between self-efficacy and enthusiasm (both subject-specific enthusiasm and enthusiasm for teaching) as separate factors. Maximum likelihood estimation with robust standard errors was applied to the data. The results show that the three-factor model outperforms both the one- and the two-factor model. To test whether the three-factor model fits the data significantly better than the one- and two-factor models, we computed the scaled χ^2 -statistic according to Satorra and Bentler (2001). This test indeed showed that the three-factor model fits significantly better than both the one- (TRd = 63.89, $\Delta df = 3$; $p < .001$) and the two-factor model (TRd = 15.10, $\Delta df = 2$; $p < .001$). No post-hoc modifications were indicated by the analysis; the goodness-of-fit indices for the three-factor model and the residual analysis did not indicate any problems. The latent correlations between the respective constructs are not excessively high (i.e., $< .90$), which confirms the discriminant validity of the measures (cf. Kline, 2011). Analyses show that there is a large latent correlation between subject-specific enthusiasm and enthusiasm for teaching, $r = .57$, $p < .001$, a medium correlation between self-efficacy and subject-specific enthusiasm, $r = .43$, $p < .001$, and also a medium correlation between self-efficacy and enthusiasm for teaching, $r = .49$, $p < .001$. See Table 6-1 for detailed results.

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The three-factor structure which we found in this analysis was considered in the following regression analysis.

Table 6-1

Goodness-of-Fit Indices for Three Models (N = 134)

	df	χ^2	χ^2/df	CFI	TLI	RMSEA	AIC	BIC
Single factor	77	144.98	1.88	.73	.68	.08	2797.54	2918.94
Two factor	76	114.70	1.51	.85	.82	.06	2753.90	2878.19
Three factor	74	79.57	1.08	.98	.97	.02	2722.49	2852.56

Note. χ^2/df = relative chi-square; CFI = comparative fit index; TLI = Tucker-Lewis fit index; RMSEA = root-mean-square error of approximation; AIC = Akaike Information Criterion; BIC = Bayes' Information Criterion.

6.5.2 How are the Considered Situations During Teacher Education and Teachers' Careers Related to Teachers' Self-Efficacy, Subject-Specific Enthusiasm, and Enthusiasm for Teaching?

In an analogous fashion to our first research question, we analyzed the relationship between the considered situations during teacher education as well as teachers' careers and teachers' self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching with the structural equation software Mplus (Muthén & Muthén, 2007). As we found that these three domains of motivational orientations are empirically separable (see 6.5.1), they are represented as separate latent factors in a regression analysis. In contrast, the perceived quality of university-level teacher education, professional development, teaching experience, and self-study represent manifest variables. The latent factors were regressed on the manifest covariates (MIMIC-model, Muthén & Muthén, 2007). We conducted separate analyses for the three dependent variables. Detailed results are provided in Table 6-2.

Self-efficacy

Our analysis shows that there is a significant relationship between the perceived quality of university-level teacher education and self-efficacy, which indicates that self-efficacy improves with increasing perceived quality. Moreover, the results show a significant positive relationship between the frequency of participation in professional development courses and self-efficacy as well as between the frequency of self-study and self-efficacy. In contrast, no significant relationship was found for teaching experience and self-efficacy.

Subject-specific enthusiasm

Our study shows that subject-specific enthusiasm is not significantly related to either the perceived quality of university-level teacher education, professional development, teaching experience, or self-study.

Enthusiasm for teaching

Enthusiasm for teaching and the perceived quality of university-level teacher education are significantly related, which indicates that the enthusiasm for teaching improves with an increasing perceived quality of teacher education. We found a marginally significant positive relationship between the frequency of participation in professional development courses and enthusiasm for teaching. Moreover, the frequency of self-study is significantly positively related to enthusiasm for teaching. No significant relations occur between enthusiasm for teaching and teaching experience.

Table 6-2

Unstandardized Regression Coefficients for Teachers' Self-Efficacy as well as Enthusiasm and the Considered Situations During Teacher Education and the Career of Teachers

	Self- efficacy	Subject- specific enthusiasm	Enthusiasm for teaching
Quality	-.22 (.11)*	.08 (.19)	-.23 (.11)*
Frequency of professional development	.14 (.06)*	-.01 (.04)	.08 (.05)†
Teaching experience	.05 (.11)	-.10 (.13)	<.001 (.003)
Frequency of self-study	.23 (.08)**	.02 (.04)	.12 (.05)*

Note. Quality = Perceived quality of university-level teacher education (1 = very good – 6 = unsatisfactory or not part of teacher education program): a negative regression coefficient indicates that the respective motivational orientation increases with increasing quality. The continuous variables (quality, teaching experience) were standardized before the analysis. † $p < .10$, * $p < .05$, ** $p < .01$.

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6.5.3 How are CK and PCK Related to Biology Teachers' Self-Efficacy, Subject-Specific Enthusiasm, and Enthusiasm for Teaching?

With reference to our second research question, we analyzed how CK and PCK are related to self-efficacy and the two enthusiasm facets. In order to investigate this relationship we computed bivariate correlations using Mplus (Muthén & Muthén, 2007). Both motivational orientations (self-efficacy, subject-specific enthusiasm, enthusiasm for teaching) and content-related professional knowledge (CK, PCK) are represented by latent factors. The results show that CK is not correlated to either self-efficacy ($r = -.01, p = .95$), subject-specific enthusiasm ($r = .12, p = .30$), or enthusiasm for teaching ($r = .08, p = .55$).

For PCK, we found a marginally significant positive correlation with self-efficacy ($r = .17, p = .07$), and a significant positive correlation with subject-specific enthusiasm ($r = .22, p = .04$). In contrast, no relationship occurs between PCK and enthusiasm for teaching ($r = .06, p = .74$). An overview of the bivariate correlations is provided in Table 6-3.

Table 6-3

Correlation Matrix for Self-Efficacy as well as Enthusiasm and Content-Related Professional Knowledge

	Content knowledge	Pedagogical content knowledge	Self-efficacy	Subject-specific enthusiasm	Enthusiasm for teaching
Content knowledge	-	.48***	.01	.12	.08
Pedagogical content knowledge		-	-.17†	.22*	.06
Self-efficacy			-	.43***	.49***
Subject-specific enthusiasm				-	.57***
Enthusiasm for teaching					-

Note. † $p < .10$, * $p < .05$, *** $p < .001$.

6.6 Discussion and Conclusions

6.6.1 The Meaning of Selected Situations During Teacher Education and Teachers' Careers for Self-Efficacy and Enthusiasm

We hypothesized that teachers' self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching are positively related to the considered situations during teacher education and teachers' careers.

Our results show that teachers' self-efficacy increases with the perceived quality of teacher education. Bandura's (1986) studies help to understand the importance of a high-quality teacher education. He identified enactive attainment as an important source of self-efficacy. Enactive attainment describes the success which an individual has in a specific situation or in attending a specific task (Woolfolk Hoy, 2000); it is strongly related to the capabilities of teachers (Bandura, 1997; Brouwers & Tomic, 2000). High-quality teacher education fosters these capabilities (e.g., Großschedl et al., 2014). As a consequence, it enables teachers to achieve success in teaching. Accordingly, high-quality teacher education supports teachers' self-efficacy. In addition, teacher education enables confidence in teaching and supports the intention to stay in the profession - two further aspects which are related to self-efficacy (Andrew & Schwab, 1995). Additionally, professional development and self-study are also related to self-efficacy. Again, the sources of self-efficacy identified by Bandura (1986) are helpful to interpret our findings. Both professional development and self-study can support teachers with having success in their teaching routine, i.e., having enactive attainment. Besides enactive attainment, vicarious experience is described as a further source of self-efficacy (Bandura, 1986). Specifically, professional development training provides the opportunity to profit from vicarious experience, e.g., by reflecting on the teaching experiences of colleagues. Contrary to our expectation, we found no relation between teaching experience and self-efficacy. In the literature, the findings concerning the relevance of teaching experience are mixed (Carleton et al., 2008; Schmitz, 1998). An explanation for our result could be that teaching experience (as it is measured in our study) does not provide any information about the personal success in teaching. More information about the time spent in the profession is necessary to explore how self-efficacy is related to teaching experience.

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Contrary to our assumption, we found no relation between subject-specific enthusiasm and the aspects of teacher education or teaching experience. One possible explanation could be that subject-specific enthusiasm is closely related to the construct of subject interest (Krapp, 2002), which is a rather stable trait and less influenced by contextual factors (Kunter et al., 2011). In contrast, enthusiasm for teaching is related to the perceived quality of university-level teacher education as well as to the frequency of professional development and self-study. Enthusiasm for teaching is more strongly influenced by the daily teaching routine (Kunter et al., 2011) than subject-specific enthusiasm. A high-quality teacher education as well as professional development and self-study support teachers to master demands and conflicts in their teaching routines. Contrary to our expectation and the findings of Kunter et al. (2011), our findings show that neither of the two dimensions of enthusiasm is related to teaching experience. As stated above, capturing the time span of teaching experience only cannot give any further information about this time span.

6.6.2 The Relationship Between Self-Efficacy as well as Enthusiasm and Content-Related Professional Knowledge

To gain a deeper understanding of how teacher education supports self-efficacy and enthusiasm, we investigated how these domains are related to CK and PCK. As teacher education particularly focuses on the acquisition of professional knowledge, it is important to consider this relationship. We hypothesized a positive relationship between self-efficacy as well as subject-specific enthusiasm and the domains of content-related professional knowledge.

Contrary to our expectation, we did not find any correlation between biology teachers' CK and their self-efficacy. In contrast, Riese and Reinhold (2010) did find a significant positive correlation between physics teachers' CK and their self-efficacy. An explanation for this contrasting result could be that Riese and Reinhold (2010) captured self-efficacy related to teaching physics, whereas self-efficacy in this study is not related to a specific subject, but to teaching in general. No relationship occurs between CK and subject-specific enthusiasm. The instrument which was developed to measure CK refers to a very specific knowledge area (the ecosystem Wadden sea), whereas a more general instrument was developed to measure subject-specific enthusiasm. This could be an explanation for the lacking relationship.

We nevertheless found teachers' PCK to be related to self-efficacy and subject-specific enthusiasm. In contrast, no relations appear to enthusiasm for teaching. Self-efficacy is defined as a cognitive domain of teachers' motivational orientations (Kunter et al., 2011). Moreover, PCK is inseparably related to the content and thus, a specific subject. Accordingly, the findings match our expectations. We assume that enthusiasm for teaching is more closely related to the non-content related domains of professional knowledge (i.e., pedagogical knowledge).

6.6.3 Limitations of the Study

Our main concern is related to the cross-sectional design of our study. Due to the limitations of a cross-sectional design, it is not possible to infer about causality. A longitudinal design would help to gain causal information about the effect of the selected opportunities during teacher education on the development of teachers' self-efficacy and enthusiasm.

Our sample consisted of biology teachers only. This may potentially cause concerns about generalizability. Here, further research which considers a more diversified teacher sample is needed.

We measured the quality of teacher education by using retrospective self-reports. There are very experienced teachers in our sample, which causes concerns of validity. It would have been useful to use an additional measure of quality which is more objective (e.g., a ranking). Nevertheless, as we are interested in the meaning of teacher education quality on motivational orientations (not on professional knowledge), the individually perceived quality is an aspect of great importance.

Teachers received the questionnaires by mail. Although they were instructed to complete the questionnaires on their own, we were not able to control this. This is particularly relevant for the instruments used to capture content-related professional knowledge. However, the items were not appropriately solvable using the internet or other external devices.

6.6.4 Implications for Further Research

Professional development and self-study are related to teachers' self-efficacy and the two facets of enthusiasm. Further research could help to elaborate a deeper understanding of

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the meaning of professional development and self-study on teachers' motivational orientations. On the one hand, it would be interesting to know whether it is the content of workshops, lectures, and journals or the motivation to participate in self-study and professional development courses which is the determining factor for a beneficial use of these. On the other hand, it would be fruitful to know more about what is effective in professional development courses. Is content-related training (e.g., new findings in the framework of evolution or cell biology) or training related to teaching methods more effective to foster teachers' self-efficacy and enthusiasm? Are person-related topics such as time management, methods to deal with stress, the identification of sources of inefficacy, or the reflection of teachers' own teaching practice especially fruitful? Lee et al. (2013) found that teachers' self-efficacy differs based on different tasks (e.g., classroom-management), which indicates that teachers' self-efficacy is not a general construct. This supports the assumption that different trainings related to different tasks would have different effects.

With regard to the strong focus on knowledge acquisition in teacher education, it is of additional interest to further investigate the relationship between motivational orientations and content-related professional knowledge. Here a longitudinal design would also help to shed light on this aspect and to make causal statements. One assumption is that content-related professional knowledge enables teachers to face the demands in the teaching profession and thus has a positive influence on teachers' motivational orientations. Reversely, motivated teachers are more willing to actively participate in teacher education courses, which in turn cause higher amounts of knowledge.

Moreover, the relationship between non content-related professional knowledge and self-efficacy as well as enthusiasm are of further interest, as the acquisition of pedagogical knowledge is an additional focus of teacher education programs.

6.6.5 Implications for Teacher Education

Teacher education particularly provides opportunities for the development of self-efficacy and enthusiasm for teaching. Self-efficacy is a very powerful domain of teachers' motivational orientations because it is important not only for the satisfaction in the profession, but also for students' performance (Caprara et al., 2006; Guo et al., 2010; Tschannen-Moran & Woolfolk Hoy, 2001; Webb & Ashton, 1986; Woolfolk-Hoy & Burke-Spero, 2005) and

students' motivation (Midgley et al., 1989). Teacher enthusiasm is an important factor for job satisfaction (Moè et al., 2001) and students' performance (Kunter et al., 2013). Thus, fostering these domains of teachers' motivational orientations should be - beyond fostering professional knowledge - one of the main goals of teacher education.

Both the participation in professional development courses as well as the frequency of self-study is related to self-efficacy and enthusiasm for teaching. In Germany, the guidelines for participation in professional development courses are not very strict. The amount of courses is specified, but there is no additional incentive to attend (e.g., reduction of lessons). Self-study is often neglected because of the high workload in the teaching profession. Thus, it is of great importance to make the teachers aware of the usefulness of professional development courses and self-study. In addition, it is necessary to enable them to do effective self-study, e.g., by conveying strategies of self-study or by informing them about possibilities to get access to journals.

It is important to understand that there is a complex interplay between teachers' professional knowledge and their motivational orientations. Our results indicate that a teacher with a high amount of CK is not necessarily motivated. This is important to keep in mind when thinking about the high amount of content-related courses in teacher education.

6.6.6 Conclusions

Self-efficacy and enthusiasm of teachers increasingly gained attention in recent research on teachers' professional competence. Opportunities for the development of teachers' professional knowledge are already a well-discussed topic in research. Our study took a first step to gain a more in-depth understanding of how teachers' self-efficacy and teacher enthusiasm - two domains of teachers' motivational orientations - could be supported during university-level teacher education and the occupational life of teachers. The key strength of this study is that it focuses on both a cognitive and an affective domain of teachers' motivational orientations. Furthermore, it takes into account the strong focus of teacher education programs on the acquisition of professional knowledge by considering the relationship between self-efficacy as well as enthusiasm and professional knowledge. Our study was able to show that teachers' motivational orientations are indeed related to aspects during pre-service and in-service teacher education. This is a pleasing result, because

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self-efficacy and teacher enthusiasm are important factors throughout a teacher's professional life. Our results indicate that being a motivated teacher is not determined with the beginning of teacher education. Quite the contrary, it develops during university-level teacher education and throughout the occupational life. Additionally, our findings reveal the relevance of considering motivational orientations and professional knowledge as two complex, concurrent aspects of professional competence to gain more insight into their interplay for the sake of teacher education improvement.

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7 STUDY 3: Using Doubly-Latent Multilevel Analysis to Elucidate Relationships Between Science Teachers' Professional Knowledge and Students' Performance³

Abstract

Teachers make a difference for the outcome of their students in science classroom. Hence, science teachers' quality and ways to increase it are of central interest in science education research still today. One focus in this context lies on teachers' professional knowledge. We describe this knowledge according to three domains that appear in the literature, namely (1) content knowledge (CK), (2) pedagogical content knowledge (PCK), and (3) curricular knowledge (CuK). We hypothesize a positive relationship between these three domains of teachers' knowledge and students' performance in science. Students' science performance was conceptualized by *system thinking* performance in the context of biology teaching. In order to test our hypothesis we examined the relationship between the knowledge triplet CK, PCK, and CuK and students' performance. A total of 48 biology teachers and their students ($N = 1036$) participated in this study. Teachers' content-related professional knowledge and students' performance were measured by paper and pencil tests. Moreover, we used concept maps to further assess students' performance. By specifying doubly-latent models we found a significant positive relationship between biology teachers' PCK and students' performance. On the contrary, the results reveal no relationship between CK and CuK on students' performance. These findings are discussed in respect to modeling the interrelationship of teachers' content-related professional knowledge and students' learning

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in science, as well as concerning their relevance for further research and teacher education programs.

Keywords: *Content knowledge; Content-related professional knowledge; Curricular knowledge; Doubly-latent model; Pedagogical content knowledge; System thinking*

7.1 Introduction

The international large-scale study PISA (e.g., OECD, 2013; Schiepe-Tiska, Schöps, Rönnebeck, Köller, & Prenzel, 2013) shows that students' performance in science in many European countries (e.g., Spain, Norway, Hungary, Italy, Luxembourg, Portugal, and Sweden), in the US, and also in other countries outside Europe (e.g., Israel, Mexico, and Chile) still needs improvement. Thus, one of the overarching aims in current science education research is the identification of factors that could foster students' performance in science.

It is well-established that teachers impact on the performance of their students (e.g., Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000b; Hattie, 2003; Rivkin, Hanushek, & Kain, 2005). Existing research indicates that teachers have a greater impact on students' performance ($d = .32$) than class size ($d = .21$) or school finances ($d = .23$) (Hattie, 2009). Therefore, it is important to identify characteristics of teachers (i.e., knowledge, attitudes, beliefs) that are crucial for effective teaching and students' performance. As teaching a particular subject matter is one of the core tasks of a science teacher, content-related professional knowledge should be of great importance when assessing teacher performance (e.g., Hashweh, 1987; Shulman, 1986; Tenorth, 2006). The importance of content-related professional knowledge is also reflected in standards for science teacher education (KMK, 2008 [Germany]; NSTA, 2012 [USA]). Nevertheless, there is not consensus on which domain of content-related professional knowledge most heavily impacts students' science performance (e.g., Lange et al., 2015; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013). This study aims to contribute to the clarification of this problem. We consider three domains of content-related professional knowledge (1) content knowledge (CK), pedagogical content knowledge (PCK), and curricular knowledge (CuK) (Shulman, 1986) and investigate how they

are related to students' science performance. To our knowledge this is the first study to consider CuK as unique domain of teachers' content-related professional knowledge beyond CK and PCK. Moreover, it applies doubly-latent multilevel analysis to elucidate the meaning of content-related professional knowledge for students' performance, thus controlling for the hierarchical data structure, measurement error, and sampling error in the best possible way.

7.2 Background

7.2.1 Conceptualization of Content-Related Professional Knowledge

Teachers' professional knowledge is described as core of professionalism (Baumert & Kunter, 2006). Shulman's (1986) initial description of teachers' professional knowledge was a milestone for research on teacher effectiveness. He subsumed different knowledge domains that form the body of knowledge that is necessary for effective teaching. He originally considered four domains of professional knowledge (a) pedagogical knowledge (PK) (b) CK, (c) PCK, and (d) CuK. PK is understood as the non-content-related domain of professional knowledge whereas CK, PCK, and CuK represent the content-related domains of teachers' professional knowledge. As teaching is a complex interplay between the teacher, the subject, and the student (Hashweh, 1987), this study focuses on content-related professional knowledge.

We engaged in the examination of the empirical structure of teachers' content-related professional knowledge in a previous study (Großschedl, Mahler, Kleickmann, & Harms, 2014) and found that the initial three-dimensional structure with CK, PCK, and CuK as unique domains fits our data best. See the methods section for more information about this analysis. Accordingly, the study at hand refers to (a) CK, (b) PCK, and (c) CuK as unique domains of teachers' content-related professional knowledge.

CK. CK is a domain of knowledge, which is relevant both for teachers and for content-specialists. It covers not only factual knowledge (Ball & Mc Diarmid, 1989), but also a deep understanding of the structure of a specific domain (Shulman, 1986). This understanding includes knowledge about central concepts and principles (Shulman, 1986) as well as an epistemological understanding. This epistemological understanding covers the knowledge of

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how validity and invalidity are established and how to decide for the more warranted opinion, when competitive opinions appear (Cochran & Jones, 1998; Shulman, 1986). Moreover, CK concerns the awareness that a domain can be organized from different points of views. Biology is a good example to illustrate these different theoretical organizations: it can be understood as science of molecules but also as science of ecosystems (Shulman, 1986). This deep conceptual understanding of the content is necessary as the provision of incoherent facts and information does not suffice to foster students in the acquisition of content knowledge (Ball & Mc Diarmid, 1989).

PCK. PCK was initially described to be comprised of two facets. First, it includes the knowledge that allows the teacher to represent and formulate the subject matter in a manner that makes it comprehensible to students (Shulman, 1986). Grossman (1990) further described this first facet as the knowledge of instructional strategies. The second facet of PCK includes knowledge of students' (pre)conceptions (Shulman, 1986). Shulman's initial model was extended by additional facets, but most of the recent models differentiate two common facets (a) knowledge of instructional strategies for teaching and (b) knowledge of students' understanding (cf. Großschedl et al., 2015; Lee & Luft, 2008; Park & Oliver, 2008; Schmelzing et al., 2013; van Driel, Verloop, & De Vos, 1998). We follow this broad body of research and consider PCK to be comprised of these two facets.

The *knowledge of instructional strategies for teaching* includes the knowledge of subject-specific strategies like for instance the triggering of a cognitive conflict. Moreover, it covers the knowledge of topic-specific strategies. An example for such a topic-specific strategy is the support of students' understanding of a specific science concept (Magnusson et al., 1999). The use of representations (e.g., illustrations, models, examples or analogies) is a very important aspect of this knowledge facet as they represent an effective tool to support students' learning (Magnusson et al., 1999; Shulman, 1986). Beyond that, knowledge related to the implementation of subject-related activities (e.g., experiments) is further important for this facet of knowledge (Magnusson et al., 1999).

The *knowledge of students' understanding* as second facet of PCK covers the knowledge of the requirements of learning (e.g., required prior knowledge) as well as of learning difficulties (e.g., knowledge of abstract concepts that could cause misconceptions) (Magnusson et al., 1999).

What is important to keep in mind is that different studies consider different conceptualizations of PCK and thus have a different understanding of this knowledge domain. Although we understand PCK to be separable from CK and CuK other scholars do not. Hill, Ball, Blunk, Goffney, & Rowan (2007) consider mathematical knowledge for teaching, which comprises both CK and PCK within an integrated domain of content-related professional knowledge. Moreover, several studies assume CuK as integrated facet of PCK (Grossman, 1990; Loughran; Milroy, Berry, Gunstone, & Mulhall, 2001; Magnusson et al., 1999; Park & Chen, 2012). These different conceptualizations of PCK have to be considered for the comparison of different studies.

CuK. Beyond CK and PCK, Shulman (1986) defined CuK as a further category of content-related professional knowledge referring to the programs and materials that serve as ‘tools of the trade’ for teachers (Shulman, 1987, p. 8). Grossman (1990) expanded this initial definition of CuK by adding knowledge of the subject’s goals, the articulation of topics, and the knowledge of the vertical curriculum (i.e., the topics that surround the current topic). Furthermore, Magnusson and colleagues (1999) include the knowledge of programs and political regulations such as national educational standards. This short overview of theoretical conceptualizations demonstrates that CuK is understood in a very different manner depending on the different studies. Moreover, CuK is particularly considered as integrated facet of PCK in the available research and there is accordingly a lack of research considering CuK as unique domain. This vague understanding of CuK makes it difficult to identify the core facet of CuK. We follow the latter understanding of CuK (Magnusson et al., 1999) and focus on the knowledge of national educational standards for science education, more detailed on the knowledge related to the *German National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2010). This decision should not negotiate the relevance of the other described facets, but is grounded in the crucial relevance of science standards in the German educational system as well as in educational systems of several countries. The disappointing results in international studies (OECD, 2013; Schiepe-Tiska et al., 2012) as well as a lack of qualified trainees for scientific careers stress the need for the improvement of science education. In order to deal with this problem several countries implemented science standards (e.g., ACARA, 2013 [Australia]; DfE, 2013 [Great Britain]; EDK, 2011 [Switzerland]; KMK, 2004 [Germany]; NGSS, 2013 [USA]).

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According to the findings of recent research in science education, science standards consider mandatory abilities that are necessary for a fundamental understanding of science (e.g., ACARA, 2013; DfE, 2013; EDK, 2011; KMK, 2004; NGSS, 2013). Moreover, science standards harmonize the assessment standards and educational requirements within one country (Cortina & Thames, 2013; EDK, 2011; KMK, 2004).

7.2.2 Content-Related Professional Knowledge and Students' Performance

To improve classroom teaching and science teacher education we necessarily need to know whether science teachers' content-related professional knowledge affects the performance of students, and if so, which domains impact student performance most strongly.

CK is often identified as a construct related to different characteristics of effective teaching. CK enables the effective cognitive activation of (Cochran & Jones, 1998; Darling-Hammond, 2000b; Hashweh, 1987) and interaction with students (Leinhardt & Smith, 1985). Teachers with strong CK show flexible teaching strategies by avoiding textbook-oriented teaching and considering learning difficulties (Hashweh, 1987). Moreover, CK is assumed to be important for the design of well-structured and problem-oriented lessons considering adequate content-related learning environments (Baumert & Kunter, 2006; Darling-Hammond, 2000b; Hashweh, 1987; Rowan, Chiang, & Miller, 1997; Shulman, 1986). Normative official documents (e.g., standards for science teacher education) strongly stress the relevance of CK for teaching (KMK, 2008; NSTA, 2012). Despite this broad theoretical base, empirical studies related to science and different other school subjects show no consensus concerning the relationship between teachers' CK and students' performance. Some scholars did find an effect of CK on students' science performance (Ohle, Fischer, & Kauertz, 2011; Sadler et al., 2013) or mathematics performance (Baumert et al., 2010; Hill, Rowan, & Ball, 2005; Rowan et al., 1997). On the contrary, other studies did not find an effect of CK on students' science performance (Lange et al., 2015) or students reading performance (Carlisle et al., 2009). A closer examination of the respective studies in part reveals methodological issues. In these studies CK is highly correlated with PCK (Baumert et al., 2010), *mathematical knowledge for teaching* (which includes CK and PCK; Hill, et al. 2005, 2007) in spite of pure CK is examined, or only one item was used to measure CK (Rowan et al., 1997).

PCK is likewise theoretically described as important for student outcomes. Teachers with a strong PCK are more likely to individually support their students (Kunter et al., 2013) and to choose adequate tasks, representations, or demonstrations that are related to the students' everyday lives (Ball et al., 2001; Magnusson et al., 1999). Furthermore, PCK is positively related to students' cognitive activation in the classroom (Ball et al., 2001; Kunter et al., 2013; Magnusson et al., 1999). In addition, PCK helps the teacher to decide which specific support is necessary to enable students to deal with a given science concept and to survey prior knowledge, learning gains and learning difficulties (Ball et al., 2001; Magnusson et al., 1999). The impact of teachers' PCK for students' performance is supported by empirical studies related to mathematics (Baumert et al., 2010; Fennema et al., 1996) and physics (Lange et al., 2015; Sadler et al., 2013).

Due to the important role of science standards for lesson planning and teaching (e.g., ACARA, 2009; DfE, 2013; EDK, 2011; KMK, 2010; NGSS, 2013), we believe that CuK also is an important domain to be considered when characterizing an effective teacher. As CuK is often not considered to be a unique domain of content-related professional knowledge, empirical evidence regarding its impact on students' performance is missing from the literature. To our knowledge this study is the first one to address this lacuna.

7.2.3 Students' Science Performance

In our study students' science performance was conceptualized by the construct *system thinking* in biology. The ability to understand systems and to use this knowledge for solving scientific problems – summarized here as *system thinking* – is fundamental for a meaningful understanding of science (e.g., Brandstädter, Harms, & Großschedl, 2012; Hannon & Ruth, 2000).

Biology is the science of living and open systems, which exchange matter, energy, and information with their environment (Verhoeff, 2003). Dealing with biological systems is a challenge for each student (Assaraf & Orion, 2005). Accordingly, one central task of biology teachers is to support students in their system thinking abilities. The importance of system thinking is reflected in different educational standards of many countries by considering *system* as superordinate concept (e.g., ACARA, 2009; DfE, 2013; EDK, 2011; KMK, 2010; NGSS, 2013). Several scholars, especially from geography and biology education, study,

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which abilities are necessary to be able to deal with systems. Current definitions of system thinking (e.g., Assaraf & Orion, 2005, 2010; Evagorou et al., 2009; Riess & Mischo, 2010; Sommer & Lücken, 2010; Verhoeff, 2003) share two fundamental aspects: (1) the ability to organize the system's elements within a system's framework, and (2) the ability to understand the relationships between these elements. Brandstädter and colleagues (2012) expanded this groundwork by describing two domains of system thinking. The first domain - *structural system thinking* - is defined as the ability to identify and connect the elements of a system, to organize these elements in a reference framework, and to identify and draw system borders (Brandstädter et al., 2012; Sommer & Lücken, 2010). The second domain - *procedural system thinking* - concerns the ability to differentiate between the properties of the system and the properties of its elements, as well as the ability to identify dynamic relationships and to understand and predict consequences of changes within a system. In addition, it covers the understanding and evaluation of effects and reactions within a system (Brandstädter et al., 2012; Sommer & Lücken, 2010).

7.3 Research Question

Our aim is to further clarify the relationship between the three domains of biology teachers' content-related professional knowledge and students' science performance. Hence, we address the following research question: How are biology teachers' (a) CK, (b) PCK, and (c) CuK related to students' science performance?

Referring to the state of research (cf. 7.2.2) we assume a positive relationship between CK and students' science performance. Likewise, we assume a positive relationship between PCK and students' science performance. Moreover, we assume that the relationship between PCK and students' science performance is stronger than the relationship between CK and students' science performance (Baumert et al., 2010). As science standards intend the improvement of learning and teaching (e.g., ACARA, 2009; DfE, 2013; EDK, 2011; KMK, 2010; NGSS, 2013), we likewise hypothesize a positive relationship between CuK and students' science performance.

7.4 Methods

7.4.1 Sample and Procedure

Sample. A total of 48 biology teachers (75% female) participated in our study. The teachers were on average 40.91 years old ($SD = 11.02$, min. = 24 years, max. = 64 years) and had on average 11.58 years of teaching experience ($SD = 10.46$). The teachers were recruited from different secondary schools in Northern Germany (Hamburg, Schleswig-Holstein). In Germany there is a distinction on the secondary level between schools qualifying their students for an academic career (*German Gymnasium*; academic track; 54.2% of the participating schools) or for a vocational career (*German Hauptschule, Realschule, Gesamtschule, Gemeinschaftsschule*; non-academic track; 45.8% of the participating schools). Accordingly, prospective secondary school teachers choose their teacher education program qualifying them either for academic track schools or for non-academic track schools. 58.3% of the participating biology teachers were certified for the academic track, 39.6% were certified for the non-academic track, and 2.1% held a degree which is not related to teacher education (e.g., a master's degree in biology). The biology teachers participated together with their 7th (20.1%) and 8th (79.9%) grade students ($N = 1036$, 50.6% female). The students were on average 13.5 years old ($SD = 0.73$).

Procedure. The participating biology teachers were recruited by telephone or mail. To allow for testing the relationship between teachers' professional knowledge and students' science performance a science topic was selected that all participating teachers and students had to deal with in the course of the study: the 'Ecosystem Wadden Sea' and the morphology and life of *Mytilus edulis* (the Blue Mussel; respiration, development, nutrition, predators, mussel farms, fishing industry; for more details see Fraune, 2014). This topic is related to the environment of students from Northern Germany and represents a common content in the local biology education program.

First, the teachers were asked to complete paper and pencil tests measuring their CK, PCK, and CuK. Subsequently, the teachers were requested to plan a short unit (4 lessons) on the above described topic 'Ecosystem Wadden Sea'. Students' performance was measured before and after being taught the unit 'Ecosystem Wadden Sea' by their teachers.

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The integration of the particular teaching unit in our study was a precondition for controlling for students' prior knowledge in the following data analysis. We decided to measure teachers' content-related professional knowledge previous to the unit as we were interested in the initial level of content-related professional knowledge when they start to teach their student concerning the 'Ecosystem Wadden Sea'.

7.4.2 Measures

Teachers' content-related professional knowledge. Biology teachers' content-related professional knowledge was measured using a paper and pencil test with the three subscales (a) CK, (b) PCK, and (c) CuK.

For the assessment of teachers' professional knowledge (especially for PCK) there is no consensus in the literature concerning the adequateness of paper and pencil tests, both qualitative and quantitative methods were used to measure teachers' professional knowledge. Qualitative approaches (e.g., interviews, lesson observations) have the advantage that they provide detailed information (Ball, Thames, & Phelps, 2008; Depaepe, Verschaffel, & Kelchtermans, 2013; Jüttner & Neuhaus, 2013; Park & Oliver, 2008; Peng, 2007; van Driel, de Jong, & Verloop, 2002). A disadvantage is the amount of time for both the assessment as well as the analysis of the qualitative data. Thus qualitative approaches are especially appropriate for studies with a small sample (e.g., Davis, 2009; Peng, 2007). Several studies with larger teacher samples successfully used paper and pencil tests to measure teachers' content-related professional knowledge (e.g., Großschedl & Harms, 2013; Baumert et al., 2010; Hill, Schilling, & Ball, 2004; Jüttner, Boone, Park, & Neuhaus, 2013; Schmidt et al., 2007). The advantage of the application of paper and pencil tests is the adequate amount of time for the assessment as well as for the analysis of the data. In a paper and pencil test both closed and open ended items can be included. Open ended items give a more detailed insight into the mental processes of the teachers during answering the items (Brandstädter et al., 2012; Schoenfeld, 2007). Nevertheless, open-ended items have the disadvantage of a high amount of test time (i.e., applying open-ended items is a demanding procedure for the teachers) as well as a time-consuming rating of the items (e.g., Lipton & Huxham, 1970; Walstad & Becker, 1994). Moreover, the subjectivity of the raters could raise problems (Lipton & Huxham, 1970; Walstad & Becker, 1994). In contrast, closed-

ended items, as for instance multiple choice items, are applicable in an adequate amount of time also in large samples (Bacon, 2003; Lipton & Huxham, 1970) so that more items can be included (i.e., providing a broader overview of teachers' content-related professional knowledge) (Lipton & Huxham, 1970; Walstad & Becker, 1994). Both item formats were found to be adequate (e.g., Bennett, Rock, & Wang, 1991; Wainer & Thissen, 1993; Walstad & Becker, 1994).

As we deal with a larger sample, we used a paper and pencil test to measure teachers' content-related professional knowledge. We decided for a mixture of closed-ended and open-ended items depending on the domain of knowledge. Concerning PCK and CuK we were interested in a more in-depth insight (e.g., into concrete lesson planning considerations) and applied open-ended items, whereas CK was measured with closed-ended items.

The subscales for CK and PCK both referred specifically to the topic 'ecosystem Wadden Sea' focusing on the Blue Mussel. The subscale CuK addressed the entire subject biology. Here we refer to the *German National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2010). See Table 7-2 for further information about the measures and descriptive statistics. Appendix A (see 7.10) provides item examples.

10% of the test booklets were randomly selected and the respective open-ended items were separately coded by two researchers to estimate intercoder reliability (Wirtz & Caspar, 2002). The intraclass correlation coefficient was on average .97, which indicates good intercoder reliability. We used the ACER ConQuest software (version 1.0.0.1, Wu, Adams, Wilson, & Haldane, 2007) to analyze the data from the teachers' paper and pencil test. In order to estimate the person ability we used the Weighted Maximum Likelihood Method (WLE), which is, compared to maximum likelihood estimation, less biased (Warm, 1989). We used the WLE scores for CK, PCK, and CuK for the following analysis.

Students' science performance. In order to assess students' system thinking as an example of science performance, we used a paper and pencil test as well as concept maps.

Students' system thinking is assessed using different methods such as interviews, videotaping, paper and pencil tests (Assaraf & Orion, 2010; Evagorou, Kostas Korfiatis, Nicolaou, & Constantinou, 2009), and concept maps (Assaraf & Orion, 2005; Brandstädter

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et al., 2012; Sommer & Lücken, 2010). According to the large student sample we decided to apply a paper and pencil test with a mixture of closed-ended and open-ended items to measure students' system thinking. Moreover, as system thinking includes a conceptual understanding of a system's structure, concept maps are a promising method to measure students' system thinking (Brandstädter et al., 2012) and are considered as further instrument in the study at hand. Concept maps are used to make internal mental models visible (Yin, Vanides, Ruiz-Primo, Ayla, & Shavelson, 2005), and they allow one to assess these mental models with regard to a conceptual understanding of the given science content (Assaraf & Orion, 2005; Evagorou et al., 2009; Ruiz Primo & Shavelson, 1996). Concept maps consist of terms connected by labeled lines, which represent the relations between the concepts. Different concept mapping techniques are applied in educational research, they are particularly determined by the medium used (paper-pencil vs. computer-based) and the level of directedness (high vs. low) (Brandstädter et al., 2012). In a highly directed setting, the students receive a set of concepts (e.g., blue mussel, star fish) and relations (e.g., protect, feed). Brandstädter and colleagues (2012) identified the computer-based and highly directed method as most valid. Accordingly, we chose this setting for the study at hand.

The paper and pencil test consists of the subscales (a) structural system thinking and (b) procedural system thinking and was validated in a previous study (Brandstädter et al., 2012). The subscales refer to the topic 'ecosystem Wadden Sea' focusing on the Blue Mussel as well. We analyzed the data analogous to the paper and pencil test measuring biology teachers' content-related professional knowledge (Großschedl et al., 2014). See Table 7-2 for further information related to the measures and descriptive statistics. The appendix (see 7.10) provides item examples.

The students' developed their concepts maps using the software MaNET (Eckert, 1998). Ten concepts (e.g., Blue Mussel; see Fig 7-1) and four linking words (e.g., protect; see Fig 7-1) were given to the students.

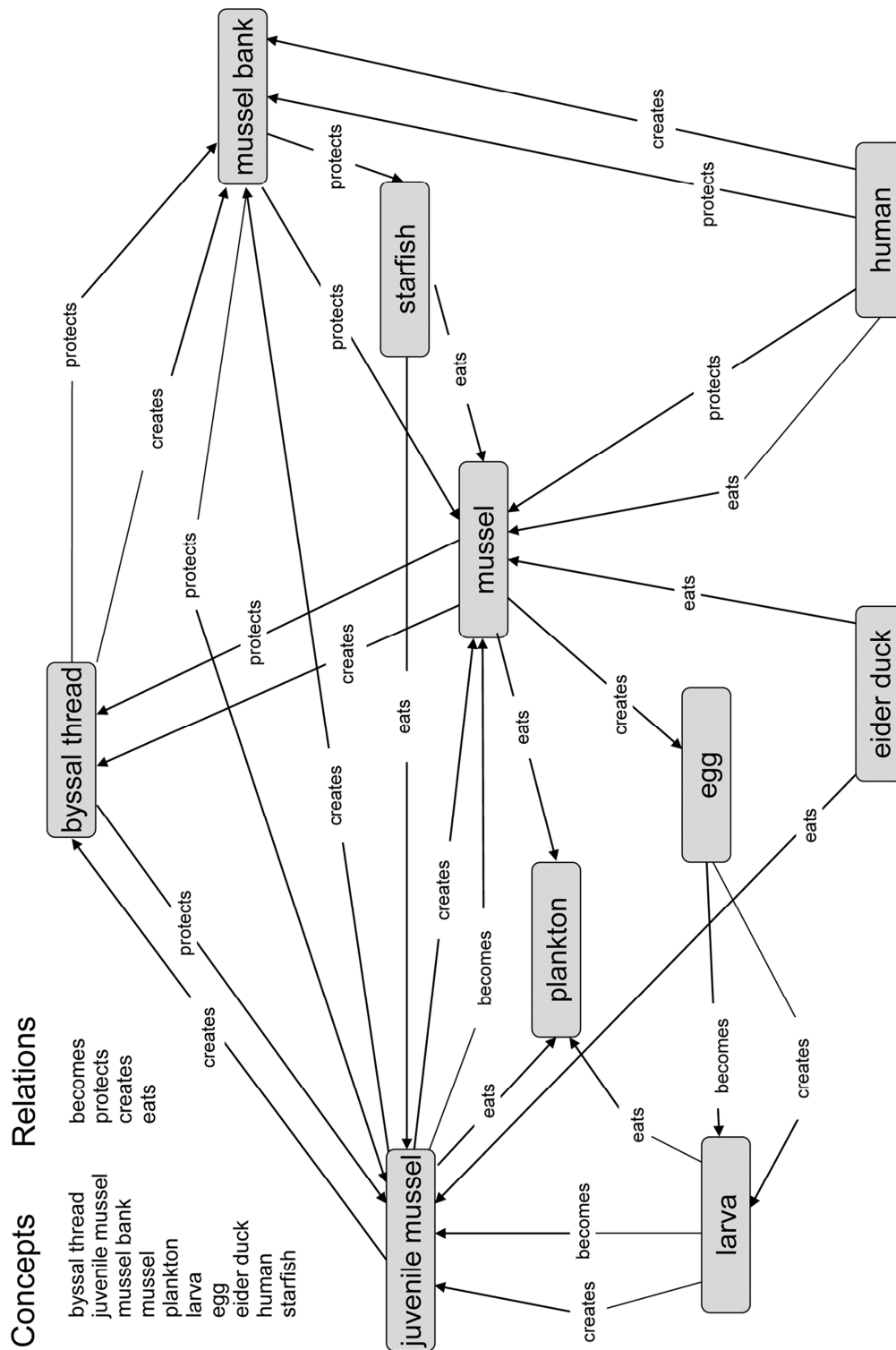


Figure 7-1. Reference Map With Sets of Concepts and Relations.

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The user interface contained the different concepts and the different linking words shown in a pop up window. The software MaNET (Eckert, 1998) was also used to analyze the students' concept maps. The underlying principle of the analysis is the comparison between a student map and a reference map. The reference map (see Fig. 7-1) was developed together with experts (science educators and biologists) as follows: We derived the set of concepts from experts maps related to the topic *Mytilus edulis* in the ecosystem Wadden Sea (e.g., development, enemies, living). We used these concepts to develop a new concept map, which was finally revised by the experts. The correspondence coefficient (C) gives information about the similarity between concept maps (in this case between the reference map and the student map). The underlying principle is provided in Table 7-1.

Table 7-1

Data Base for the Correspondence Coefficient C (translated; Eckert, 1998)

		Map 1		
		0	1	
Map 2	0	p_{00}	p_{01}	p_{0+}
	1	p_{10}	p_{11}	p_{1+}
		p_{+0}	p_{+1}	p

Note. p_{00} = Sum of corresponding concepts, which are not connected in both maps; p_{01} = Sum of corresponding concepts, which are connected in map 2, but not in map 1; p_{10} = Sum of corresponding concepts, which are connected in map 1, but not in map 2; p_{11} = Sum of corresponding concepts, which are connected in both maps; p_{0+} = Sum non-connections in map 1; p_{1+} = Sum of connections in map 1; p_{+0} = Sum non-connections in map 2; p_{+1} = Sum of connections in map 2; p = Sum of all possible connections.

Different levels of strictness can be applied to the data. The least strict level merely considers the presence of a connection between two concepts (yes vs. no). Beyond that, the medium strict level considers the selection of a relation from the given set of relations (right vs. wrong). Finally, the strictest level additionally considers the direction of the relation (right vs. wrong) (Eckert, 1998). We refer to the strictest level in our study. The correspondence coefficient was weighted (C_w) to take account of the fact that a relation in a student map is

more meaningful when the reference map has relatively few relations (Eckert, 1998). Eckert (1998) recommends the weighted correspondence coefficient when concept maps are compared with a reference map. The weighted correspondence coefficient is estimated as follows (Eckert, 1998):

$$C_w = \frac{W_{1CR} + W_{2HIT} - (W_{1FA} + W_{2MISS})}{(W_{1p0} + W_{2p1+})}$$

Note. $W_1 = \frac{(p1+)}{(p0+)}$; $W_2 = \frac{(p0+)}{(p1+)}$ (see also Table 7-1); HIT = correct connection; CR = correct rejection; MISS = missing connection despite connection in reference map; FA = connection despite missing connection in reference map (false alarm) (translated; Eckert, 1998).

We used the weighted correspondence coefficient for the following analysis.

Control variables. We applied two subscales of a cognitive abilities test (verbal, non-verbal; KFT 4-12 R; Heller & Perleth, 2000) to control for cognitive abilities on student level (see Table 7-2). Cognitive abilities are an important predictor for students' performance (Boulanger, 1981; Hattie & Hansford, 1982; Piburn, 1993). The verbal subscale refers to the relationships between words; the non-verbal subscale refers to figural relationships. We used two versions of the test (A and B) to keep the students from copying. Moreover we considered students' prior knowledge (performance in the pretest). See Table 7-2 for further information and descriptive statistics. In addition we considered the school type. We distinguish between academic track schools and non-academic track schools (see paragraph 7.4.1).

Table 7-2
Measures – Descriptive Statistics

Measure	N of items	Scoring	M	SD	min	max	Reliability	Facets of knowledge	Reference
<i>Measures on teacher level</i>									
CK	19 (closed)	dichotomous: N = 10; polytomous: N = 9	19.60	3.21	0	2	.58 ¹	(a) knowledge about <i>Mytilus edulis</i> (N=11); (b) knowledge about the ecosystem Wadden Sea (N=4); (c) a general understanding of systems (N=4)	Großschedl et al. (2014)
PCK	9 (open)	dichotomous: N = 0; polytomous: N = 4	8.90	4.10	0	2	.77 ¹	(a) knowledge about instructional strategies for teaching (N=5); (b) knowledge about students' understanding (N=4)	Großschedl et al. (2014)
CuK	4 (open)	dichotomous: N = 1; polytomous: N = 3	2.92	2.01	0	2	.92 ¹	knowledge about the German national educational standards for the intermediate school leaving certificate in biology	Großschedl et al. (2014)

(continued)

Table 7-2 (continued)

Measure	N of items	Scoring	M	SD	min	max	Reliability ¹	Facets of knowledge	Reference
<i>Measures on student level</i>									
system thinking	26 (22 closed and 4 open items)	dichotomous: N = 9; polytomous: N = 17	19.04 (pre); 25.50 (post)	4.71 (pre); 5.60 (post)	0	2	.79 ¹ (pre); .81 ¹ (post)	(a) structural system thinking (N=18); (b) procedural system thinking (N=8)	Brandstädter et al. (2012)
cognitive abilities - verbal	20 (closed)	dichotomous: N = 20; polytomous: N = 0	11.19	4.25	0	20	.76 ² (A); .81 ² (B)	relationships between words	Heller & Perleth (2000)
cognitive abilities - non-verbal	25 (closed)	dichotomous: N = 25; polytomous: N = 0	16.78	5.90	0	25	.87 ² (A); .90 ² (B)	figural relationships	Heller & Perleth (2000)

Note. CK = content knowledge, PCK = pedagogical content knowledge, CuK = curricular knowledge; KFT = cognitive abilities test; dichotomous scoring: 0 = wrong, 1 = correct, polytomous scoring (content-related professional knowledge, system thinking: 0 = wrong, 1 = half correct (partial credit), 2 = correct; Reliability: ¹ = EAP/PV reliability, ² = cronbach's α).

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Psychometric properties of the measures. This section provides the psychometric properties of the applied measures on teacher and student level. See Großschedl et al., 2014 for a detailed consideration of the psychometric properties for the measures for CK, PCK, and CuK.

The items forming the measures for CK, PCK, and CuK had acceptable item fit (WMNSQ) ranging within 0.86 to 1.20. As displayed in Table 7-3, the items discriminate adequately (range: .20 to .87). Item difficulties vary between easy and difficult and range from .26 to .88. EAP/PV values reveal adequate reliability of the respective scales (range: .71 to .86). The items that were considered to measure students' system thinking have adequate item fit (WMNSQ) ranging within .90 and 1.09 for the pretest and .93 and 1.09 for the posttest. Both easy and difficult items are included in the measure. The item difficulty ranges from .13 to .85 for the pretest and from .29 to .89 for the posttest. As expected, the pretest is more difficult compared with the posttest. The items of the pre- and the posttest discriminated adequately, most of them are in a range between .20 and .80 (pre: $N = 23$, post: $N = 23$). See Table 7-3 for detailed information about the psychometric properties of the measures.

Table 7-3
Psychometric Properties of the Measures

Scale	Item difficulty		Discrimination		WMNSQ		<i>n</i> of items
	Min.	Max.	Min.	Max.	Min.	Max.	
CK	.31	.88	.20	.50	.93	1.09	19
PCK	.42	.54	.54	.70	.86	1.09	9
CuK	.26	.51	.60	.87	.86	1.20	4
system thinking pre	.13	.85	.14	.53	.90	1.09	26
system thinking post	.29	.89	.16	.54	.93	1.09	26

Note. WMNSQ = Weighted Mean Square; EAP/PV = Expected A Posteriori/Plausible Value reliability.

7.4.3 Statistical Analysis

Dimensionality of biology teachers' content-related professional knowledge. As a first step, it is important to ensure that the three assumed domains of biology teachers' content-related professional knowledge (1) CK, (2) PCK, and (3) CuK are also empirically separable. In order to do so, we conducted a Rasch analysis and compared different models. The first model assumes biology teachers' content-related professional knowledge to be one dimensional. Accordingly, CK, PCK, and CuK are allocated to a single dimension. The second model assumes biology teachers' CK to be allocated to one dimension and biology teachers' PCK and CuK to be allocated to a second dimension. Finally, the third model assumes biology teachers' content-related professional knowledge as three-dimensional construct with CK, PCK, and CuK as unique dimensions. Rasch analysis shows that the three-dimensional model (deviance: 6502.98, AIC: 6620.98, BIC: 6791.95) outperforms the one-dimensional model (deviance: 6713.86, AIC: 6821.86, BIC: 6978.34), and the two-dimensional model (deviance: 6560.09, AIC: 6672.09, BIC: 6834.37). A χ^2 -test was performed and reveals that the three-dimensional model significantly outmatches the one-dimensional model, $\chi^2[2] = 210.88$, $p < .05$ and the two-dimensional model, $\chi^2[2] = 57.12$, $p < .05$. Despite their separability, the three domains are correlated. We found a high correlation between PCK and CuK ($r = .70$, $p < .001$) and a medium correlation between CK and PCK, ($r = .48$, $p < .001$) as well as between CK and CuK ($r = .35$, $p < .001$). The detailed results are reported in Großschedl et al. (2014).

Doubly-latent model. To investigate whether biology teachers' CK, PCK, and CuK is predictive for students' science performance, we specified a doubly-latent model (Marsh et al., 2009), which integrates a structural equation model and a multilevel model. In this doubly-latent model the dependent variable (here: students' performance measured in the posttest) is added as latent trait both on the individual and the class level. This model controls for measurement error (sampling of items on both levels) and sampling error (sampling of individuals in the aggregation from the individual to the class level) (Marsh et al., 2009). We chose this method because of the hierarchical structure in our data set. A hierarchical structure occurs when data measured on one level are clustered in another level, for example when individuals are clustered in groups (here: students in classes) (Nezlek, Schröder-Abé, & Schütz, 2006). As a result of the clustering, the observa-

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tions are not independent. For a correct estimation of effects and standard errors, the consideration of the hierarchical structure is necessary (Nezlek et al., 2006). We used the software Mplus for this analysis (Muthén & Muthén, 2007).

In order to check whether specifying a doubly-latent model is necessary for our data, we specified unconditional models to decompose the variance of the dependent variable (students' performance in the posttest) into the proportion of variance lying within classes and the proportion of variance lying between classes. As students' system performance is modeled as latent trait, separate unconditional models were computed for each indicator: (1) structural system thinking, (2) procedural system thinking, and (3) system thinking performance measured with concept maps. The estimation of the intra class correlation (ICC) shows that (1) 27.3%, (2) 22.7%, and (3) 23.9% of the variance is located between the classes. An ICC of .05 or even .01 (5% or 1% variance between the classes; Cohen et al., 2003) requires for the consideration of a multilevel structure.

As mentioned above, the dependent variable is considered as latent trait on both levels. The indicators of the dependent variable appear as latent variables on the class level, because the variance between classes within these indicators (intercept modeled as random effect) is added as latent variable on the class level (see Fig 7-2). To predict performance (post), (a) CK, (b) PCK, and (c) CuK are added as independent variables on the class level.

Control variables. We considered control variables both on the individual and the class level. On the individual level we added students' performance in the pretest which are modeled as latent trait analogous to the performance in the posttest. Moreover, we added students' cognitive abilities (verbal and non-verbal). On the class level we added the track (academic track vs. non-academic track) as a control variable. Figure 7-2 gives an overview of the multilevel model.

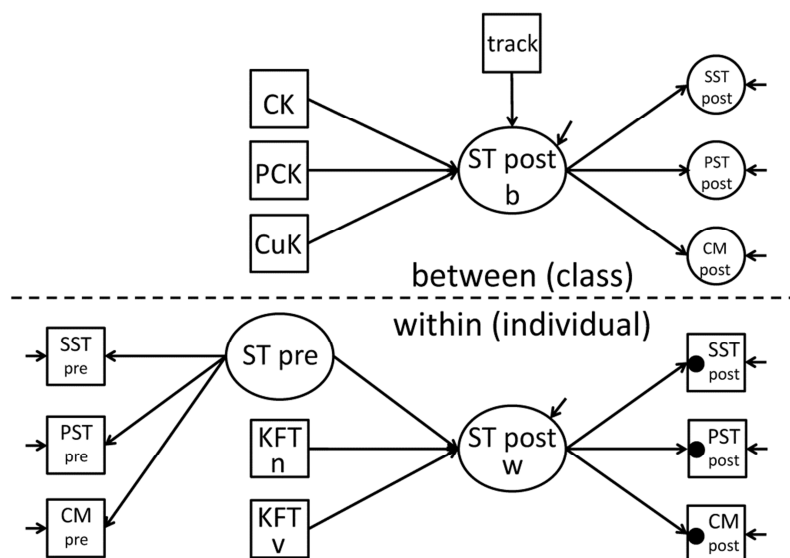


Figure 7-2. Multilevel Model.

Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge; ST = system thinking, SST = structural system thinking; PST = procedural system thinking; CM = concept mapping performance; KFT n = cognitive abilities non-verbal; KFT v = cognitive abilities verbal; pre = pretest; post = posttest; ● = Intercept (DV on indicators) is modeled as random effect; varying between classes.

Missing values. Our data set contains missing values (concept mapping performance pre: 11.7%, concept mapping performance post: 14.6%, cognitive abilities verbal: 0.19%, cognitive abilities non-verbal: 0.78%). Instead of deleting cases with missing values (listwise deletion) which leads to a reduction of sample size and statistical power (Peugh & Enders, 2004) we used multiple imputation to estimate the missing values. Multiple imputation is applicable when values are missing completely at random or missing at random (Rubin, 1976). First, ten imputed data sets are generated, each including plausible values instead of the missing values. Multiple imputation accounts for uncertainty in the imputation of plausible values. The following analysis is computed with each of these ten data sets. Afterwards the estimates are combined to get one result. We used Mplus to generate and analyze the imputed data sets (Muthén & Muthén, 2007).

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7.5 Results

To answer our research question we investigated how the variance of students' performance between classes, controlled for variables on the individual level and the class level, is predicted by biology teachers' content-related professional knowledge. In order to do that, we specified different models.

Model 1 takes the control variables on the individual and the class level into account. The results show that students' performance in the pretest is significantly positive related to their performance in the posttest. Furthermore, there is a significant positive relationship between students' verbal and non-verbal cognitive abilities and their performance in the posttest. *Model 2* considers biology teachers' CK as predictor for students' performance. The results show that there is no relationship between biology teachers' CK and students' performance. Consequently, adding CK to the model does not markedly contribute to the explanation of variance on the class level when compared with model 1. *Model 3* considers biology teachers' PCK as predictor. The results show a significant positive relationship between biology teachers' PCK and students' performance. A comparison of model 1 and model 3 shows that PCK contributes to the explanation of variance on the class level. Biology teachers' CuK is considered as predictor in *model 4*. No significant relationship occurs and no noteworthy additional amount of variance is explained on the class level. The three domains of biology teachers' content-related professional knowledge are considered together in model 5. Analogous to the other models, the positive relationship between PCK and students' performance remains significant whereas no significant relationships occur between CK as well as CuK and students' performance. As expected, this model is able to explain more variance than the models considering a single domain of biology teachers' content-related knowledge. Detailed results are provided in Table 7-4.

Table 7-4

Final Deviance and Information-Based Criteria for Different PCMs of Content-Related Results of the Multilevel Analysis (standard errors in parenthesis)

Parameter	Model 1 (control variables)	Model 2	Model 3	Model 4	Model 5
<i>Individual level</i>					
Pretest	.83*** (.05)	.83*** (.05)	.83*** (.05)	.83*** (.05)	.83*** (.05)
KFT verbal	.14*** (.03)	.14*** (.03)	.14*** (.03)	.14*** (.03)	.14*** (.03)
KFT n-verbal	.19*** (.04)	.19*** (.04)	.19*** (.04)	.19*** (.04)	.19*** (.04)
R ²	.77	.77	.77	.77	.77
<i>Class level</i>					
CK		.19 (.16)			.11 (.15)
PCK			.29* (.13)		.36* (.14)
CuK				-.10 (.16)	-.26 (.15)
Track	.53*** (.15)	.54*** (.15)	.52*** (.15)	.52*** (.15)	.50*** (.15)
R ²	.28	.31	.36	.29	.42

Note. KFT = cognitive abilities test; CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge; * $p < .05$; ** $p < .05$; *** $p < .001$.

7.6 Discussion

The aim of our study was to elucidate the meaning of biology teachers' content-related professional knowledge for students' science performance.

Contrary to our assumption, the results show no direct relationship between biology teachers' CK and students' performance. This finding is in line with other studies focusing on language teachers' (Carlisle et al., 2009) and primary science teachers' CK, respectively (Lange et al., 2015). However, other scholars did find such relationship (Baumert et al., 2010; Hill et al., 2005, 2007; Ohle et al., 2001; Rowan et al., 1997; Sadler et al., 2013). The studies, which were able to find an effect, are related to mathematics and physics. A reason for the incoherent results could be the underlying biological topic of our measure. It focuses on open living biological systems. To deal with open living systems, students have to go beyond the acquisition of factual knowledge. This means that they have to reconstruct knowledge in complex networks as well as to understand interrelationships and effects within a system. Obviously, mere CK does not suffice to support students in the acquisition of system thinking abilities in biology. Open living systems are not in the focus of mathematics and physics

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education. The review of the underlying physical topics that were considered in the study of Sadler et al. (2013) as well as the mathematical items that were applied in the Coactiv study (Baumert et al., 2010) or in the study of Rowan et al. (1997) support this assumption.

However, we do not assume that CK is completely irrelevant for students' performance. As CK is an important prerequisite for the development of PCK (e.g., Ball et al., 2001; Großschedl et al., 2015; Krauss et al., 2008; Ma, 1999; Magnusson, et al., 1999; Riese & Reinhold, 2012), we suppose an indirect effect of CK on system thinking being mediated by PCK. To clarify this further studies are needed.

The positive relationship we found between PCK and students' performance is in line with the results of different studies related to mathematics teachers' PCK (Baumert et al., 2010; Fennema et al., 1996; Kunter et al., 2013), physics teachers' PCK (Sadler et al., 2013), or primary science teachers' PCK (Lange et al., 2015). As the conceptualization of PCK in these different studies is relatively similar to our study (e.g., due to the consideration of students' misconceptions or instructional strategies), a more consistent picture compared with the results related to CK seems plausible.

In addition, PCK is theoretically described as important for students' performance (Ball et al., 2001; Kunter et al., 2013; Magnusson et al., 1999). Unlike CK, PCK seems to be effective in supporting students' ability to face the complex demands described above, when acquiring system thinking abilities.

As science standards intend the improvement of learning and teaching (e.g., ACARA, 2009; DfE, 2013; EDK, 2011; KMK, 2010; NGSS, 2013), we considered a positive relationship between teachers' CuK and students' system thinking performance. Contrary to our expectation, we found no relationship between biology teachers' CuK and students' performance, indicating that CuK does not help students' to acquire system thinking abilities. System is a superordinate issue in these standards. Thus, we do not assume that biology teachers' CuK is completely irrelevant for students' system thinking performance.

Although we consider CuK as unique domain in the study at hand, we do not assume that PCK and CuK are completely independent from each other. In other words, teachers must be knowledgeable concerning the standards they should meet in their lessons. It could be assumed that the knowledge of the *German National Educational Standards for the*

Intermediate School Leaving Certificate in Biology (KMK, 2010) helps the teacher to identify difficult and abstract concepts as well as the relevant knowledge base and necessary skills for the understanding of these concepts. Accordingly, an indirect effect between CuK and students' performance with PCK as mediating variable can be assumed. This interplay between CuK and PCK is supported by the result that CuK and PCK are, despite their separability, correlated.

We hypothesize that an instrument, which is more strongly related to the activity of lesson planning, teaching and assessment (i.e., the implementation of the educational standards in the daily teaching routine), would have given more information about the meaning of CuK for students' performance.

To summarize, our results indicate that PCK seems to be the driving force for the improvement of students' science performance. Moreover, they allow us to carefully assume a relevance of PCK also for other teacher populations. System thinking abilities are described to be likewise relevant for other science subjects beyond biology (Australia: ACARA, 2009; England: DfE, 2013; Switzerland: EDK, 2011; USA: NGSS, 2013) and geography (Rempfler & Uphues, 2012).

7.6.1 Limitations

Concerns are related to the instrument measuring CuK. This instrument basically refers to factual knowledge about the *German National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2010). These standards aimed a massive change in educational requirements and assessment standards (KMK, 2005). To reflect these changes, it is obviously not sufficient to measure only factual knowledge. A measure which focuses more strongly on the implementation of the standards would have been more applicable.

Our study was conducted in a cross-sectional setting. Due to this, it is not possible to draw causal conclusions concerning the relationship between biology teachers' content-related professional knowledge and students' system thinking performance. A longitudinal design would help to solve this methodological issue.

A further remark is related to the application of the measure for teachers' content-related professional knowledge. As mentioned in the methods section we measured

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teachers' CK, PCK, and CuK previous to the four lessons the teachers conducted. We did this in order to measure the initial level of content-related knowledge the teachers referred to. Nevertheless, it would have been fruitful to measure teachers' content-related professional knowledge also after the teaching unit to consider the change in teachers' content-related professional knowledge.

7.7 Implications

7.7.1 Implications for Further Research

The findings concerning CK and its meaning for students' performance are inconsistent in recent research. Although we did not find a relationship in our study as well, we do not assume that CK is irrelevant for students' performance. Further exploration is needed. A topic for further research is to explore whether a certain level of CK is necessary to foster students' performance. This question leads to two assumptions. On the one hand, it could be assumed that CK is only effective until a certain level is reached (Darling-Hammond, 2000b). Apart from that, CK has no additional effect on students' performance. Thinking the other way round, only teachers with a well-developed CK could be effective in influencing their students' performance. Comparing teacher groups with different levels of CK would contribute to the clarification of this issue. A larger teacher sample would have been necessary in order to compare groups in a multilevel design.

CuK as unique category of content-related professional knowledge has been neglected in research so far. Given that many countries have moved to develop and implement educational standards (e.g., ACARA, 2009; DfE, 2013; EDK, 2011; KMK, 2010; NGSS, 2013), further research into the influence of CuK on student performance is warranted. To get an in-depth understanding about the meaning of CuK for students' performance, the development of a more applicable instrument is necessary. This instrument should combine factual knowledge about the official requirements formulated in the standards and the implementation of these standards in teaching and assessment. It should be easily adaptable to the different requirements in the different countries.

Our analysis focused only on direct effects, but it would be fruitful to consider possible indirect effects in the model. As CK is identified as important for the development of PCK

(e.g., Ball et al., 2001; Großschedl et al., 2015; Krauss et al., 2008; Ma, 1999; Magnusson, et al., 1999; Riese & Reinhold, 2012), we assume an indirect effect of CK on students' performance mediated by PCK. A further possible indirect relationship concerns the relationship between CuK and students' performance. As CuK could be assumed to be a precursor for PCK, it would be interesting to consider an indirect relationship between CuK and students' performance including PCK as mediator. This would further clarify the role of CuK for effective teaching. Beyond that, it would be interesting to add the quality of lesson planning as mediator. Several studies give hints that both CK (Baumert & Kunter, 2006; Rowan et al., 1997; Shulman, 1986) and PCK (Ball et al., 2001; Magnusson et al., 1999) are important for effective lesson planning.

The activity of teaching was not observed in our study. More qualitative approaches like lesson observations (e.g., videotaping) could have given a deeper insight in how CK, PCK, and CuK are reflected in the activity of teaching. Doing this could contribute to the clarification of the role of CK and CuK for students' achievement.

It is clearly stated in the literature and supported by our findings that the teacher plays an important role for the performance of students. It would be fruitful to expand the model to further investigate, which aspects besides content-related professional knowledge are important for students' science performance. Non-content-related professional knowledge (e.g., pedagogical knowledge) and motivational orientations (e.g., teacher enthusiasm) are promising predictors to further clarify the teachers' role for students' system thinking performance in biology.

7.7.2 Implications for Teacher Education

The professionalization of teachers is important to ensure quality within educational systems (e.g., Ashton & Crocker, 1987; Baumert & Kunter, 2006; Darling-Hammond, 2000a; Evertson, Hawley, & Zlotnik, 1985; Grossman, 1990; Lipowsky, 2006). As our study confirms that PCK has impact on students' science performance, the acquisition of PCK in pre-service and in-service science teacher education should be strengthened. As teaching experience acquired during practical phases in teacher education is found to be beneficial for the development of PCK (Großschedl et al., 2015), the implementation of more compulsory practical phases and

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more possibilities for voluntary commitment in school could be beneficial for the improvement of teachers' PCK.

Beyond that, communicating the relevance of PCK would be beneficial for the motivational development of teachers. This awareness might encourage teachers to participate in professional development courses related to PCK. The attendance in professional development courses represents an effective learning opportunity for PCK (Großschedl et al., 2014).

7.8 Conclusions

The aim of this study was to investigate the meaning of the different domains of teachers' content-related professional knowledge for students' performance in science. Both the consideration of CuK as unique domain and the conduction of a doubly-latent multilevel analysis are new in this field of research. An additional strength of our study is that we were able to gather a deep insight into students' performance by using concept maps in addition to the paper and pencil test. Our results support the relevance of teachers' PCK and indicate that merely CK is not enough to foster students' performance in science. This supports the special role of the science teacher, in contrast to a scientist, for students' performance. Moreover, our study illustrates the relevance to further consider CuK in research.

Students' science performance is a function of multiple factors, both individual and contextual ones. Contrary to relatively stable factors like the socioeconomic status or cognitive abilities, the 'science teacher factor' is malleable and can be positively influenced particularly by teacher education (e.g., content-related professional knowledge [Großschedl et al., 2014], motivational orientations [Mahler, Großschedl, & Harms, submitted]). This implies that students' science performance could be actively improved by considering science teachers and their education as important parameters.

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7.10 Appendix – Item Examples

Teacher level (Großschedl et al., 2014)

Content knowledge (CK)

Which of the following statements relating to the shell-structure of mollusks are correct?

- The shells of mollusks are structured in three layers.
- The shells of mollusks consist of a dense epithelial layer.
- The shells of mollusks consist of an organic lipid layer and an inner nacre layer.
- The shells of mollusks contain an organic glycoprotein layer, an outer prism layer, and an inner nacre layer.

Pedagogical content knowledge (PCK)

In the lesson before, 8th grade students have learned that blue mussels need water to be able to breathe.

Please create a short outline for a problem-oriented beginning of a lesson with the topic "survival of the blue mussels during low tide."

Curricular knowledge (CuK)

In the national educational standards for the intermediate school-leaving certificate in biology (KMK, 2010), three basic concepts indicate the substance dimension of the competences.

Please name the three basic concepts.

Student level (Brandstädter et al., 2012)

Structural system thinking

Why do mussels filtrate the sea water?

- to clean their bodies
- to breathe
- to filtrate food
- to move

Procedural system thinking

Oysters don't feed on mussels and don't kill them. Why are they still so threat-generating for mussels?

8 STUDY 4: Does Motivation Matter? - The Significance of Teachers' Motivational Orientations for Students' Performance⁴

Abstract

Teachers' motivational orientations seem to be predictors of students' learning. However, there are several dimensions of motivation, and their relative importance is unclear. Thus, we have examined the relationships between students' performance and three of these dimensions: self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject. 48 biology teachers and 1036 students participated. Teachers' motivational orientations were measured by paper and pencil tests, while concept maps and paper and pencil tests were used to measure students' performance. Our results indicate that students' performance is significantly positively related to teachers' subject-specific enthusiasm, and tends to be positively related to teachers' enthusiasm for teaching the subject.

Keywords: *Teacher motivation; Self-efficacy; Teacher enthusiasm; Student performance*

8.1 Introduction

Supporting students to learn is a superordinate aim of education. Apart from individual factors (e.g., students' cognitive abilities), the teacher is one of the most important determinants of students' performance (e.g., Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000; Hattie, 2009; Rivkin, Hanushek, & Kain, 2005). In fact, teachers have more

⁴ Mahler, D., Großschedl, J., & Harms, U. (submitted). Does Motivation Matter? - The Significance of Teachers' Motivational Orientations for Students' Performance. *Teaching and Teacher Education*.

impact than fiercely politically-debated issues such as school budgets and class sizes (Hattie, 2009). This raises questions regarding the characteristics of an effective teacher. A broad research base has been established on teachers' professional knowledge and its importance for students' learning or performance (e.g., Baumert et al., 2010; Baumert & Kunter, 2013; Fennema et al., 1996; Hill, Ball, Blunk, Goffney, & Rowan, 2007; Rowan et al., 1997). However, as teaching is a very demanding profession with uncertain success (Baumert & Kunter, 2013) and high risks of job stress or even burn-out (Stoeber & Rennert, 2008), being an effective and content teacher clearly requires more than professional knowledge (e.g., Baumert & Kunter, 2013). Teachers' motivational orientations are also important (Kunter, 2013; Lee, Cawton, & Dawson, 2013). Motivational orientations are related to the "psychological dynamics of behavior, the maintenance of intentions, and the monitoring and regulation of occupational behavior" (Baumert & Kunter, 2013, p. 38). We have previously explored aspects of teachers' motivational orientations and identified three unique domains: self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject (Mahler, Großschedl, & Harms, submitted a).

Several studies have addressed the relationship between one of these domains of teachers' motivational orientations and students' performance (e.g., Abernathy-Dyer, Ortlieb, & Cheek, 2013; Goddard, Hoy, & Hoy, 2000; Kunter, 2013; Mohamadi & Asadzadeh, 2012), but no previous studies have compared the domains' predictive power. Thus, the relative importance of the domains remains unclear. Furthermore, few studies have considered possible differences in the relevance of teachers' subject-related enthusiasm and teachers' enthusiasm for teaching the subject (Kunter et al., 2008; Kunter, 2013; Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011). The aim of this study is to contribute to the clarification of these issues by comparatively examining the relations between students' performance and both cognitive (self-efficacy) and affective (enthusiasm for the subject and teaching the subject) domains of teachers' motivational orientations (Kunter et al., 2011).

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8.2 Background

8.2.1 Teachers' Self-Efficacy - Conceptualization and Importance for Students' Performance

According to Bandura (1977), in the framework of social cognitive theory, self-efficacy is an individual's belief that he or she is capable of performing the behaviors required to produce a desired outcome. Self-efficacy is linked to a particular task (Moulding, Steward, & Dunmeyer, 2014). Consequently, we consider teachers' self-efficacy as a teachers' belief in their ability to complete a teaching-related task successfully by performing specific behaviors (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). Schmitz and Schwarzer (2000) identified three core areas apart from purely teaching-related aspects that teachers have to cope with in their professional lives: skill development on the job; interactions with students, parents, and colleagues; and coping with job stress.

There is a consensus in research literature that teachers' self-efficacy is important for students' performance. The relationship between teacher's self-efficacy and students' performance has been confirmed in language (Abernathy-Dyer et al., 2013; Armor et al., 1976; Ashton & Webb, 1986; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992), mathematics (Allinder, 1995; Ashton & Webb, 1986; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992), science (Mohamadi & Asadzadeh, 2012), and social studies (Mohamadi & Asadzadeh, 2012; Ross, 1992). Previous studies have also found that self-efficacy seems to be particularly relevant for three groups of teacher outcomes: teachers' professional engagement (Evans & Tribble, 1986; Schmitz & Schwarzer, 2001); effective instructional strategies (Allinder, 1994; Ashton & Web, 1986; Gibson & Dembo, 1984; Guskey, 1988; Ross, 1994; Soodak & Podell, 1996); and openness to "demanding" students (Gibson & Dembo, 1984; Larsen & Samdal, 2012).

8.2.2 Teacher Enthusiasm - Conceptualization and Significance for Students' Performance

Teacher enthusiasm reflects the affective part of teachers' motivational orientations (Kunter et al., 2011). Partly because researchers rooted in several disciplines (e.g., pedagogy and psychology) are engaged in enthusiasm research there is no universally accepted definition of enthusiasm, and several conceptualizations have been developed. However, in two prominent approaches in the literature teacher enthusiasm is regarded as a personality trait

or instructional behavior (Keller, Goetz, Becker, Morger, & Hensley, 2014). Treating teachers' enthusiasm as a personality trait involves focusing on internal processes, that is teachers' positive affective experience (Kunter et al., 2008; Keller et al., 2014), while in the instructional behavior-based conceptualization (e.g., Brophy & Good 1984), it is treated as teachers' ability to convey the positive value of the learning topic to the students (Patrick, Turner, Meyer, & Midgley, 2003). The level of enthusiasm is often derived from observed behaviors, for example the teaching style (Long & Hoy 2006) or gestures and facial expressions (Collins, 1978).

Following the first conceptualization, here we treat teacher enthusiasm as a personality trait. This is because we assume that the observation of expressed behavior – the basis of analyses grounded in the second conceptualization – may be biased, as teachers generally suppress negative feelings while teaching and feel pressurized to show positive emotions in the classroom (Sutton, Mudrey-Camino, & Knight, 2009). Moreover, the observation of enthusiastic behavior gives no information about what enthusiasm is related to (e.g., the subject or teaching the subject; Kunter et al., 2011). Teacher enthusiasm as a personality trait comprises the excitement, enjoyment, and pleasure associated with both a school-subject and the activity of teaching (Kunter et al., 2011). Thus, according to this definition there are two main dimensions of teacher enthusiasm: subject-specific enthusiasm and enthusiasm for teaching (the subject) (Kunter et al., 2011). Recognition of these two dimensions facilitates more detailed examination of what teachers are enthusiastic about.

Subject-specific enthusiasm is defined as a topic-related affective orientation (Kunter et al., 2011). It concerns – like individual interest (Krapp, 2002) – a person-object relation, in this case a teacher-subject-relation. Kunter et al. (2011) define *enthusiasm for teaching (the subject)* as enjoyment related to the activity of teaching a specific subject. Again, this construct concerns a person-object-relation. Here, the object is the interaction with students during teaching a specific subject.

Although teacher enthusiasm and individual interest are closely related they must be distinguished. Teacher enthusiasm represents the affective domain of teachers' motivational orientations, while individual interest also involves cognitive aspects (Kunter et al., 2008). More detailed, an integrative part of individual interest concerns the tendency to deal with a specific topic and to acquire additional topic-related knowledge (Kunter et al., 2008; Long &

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Hoy, 2006). Moreover, the interaction with students, which is also an important part of effective teaching, is not adequately considered in the definition of individual interest.

The significance of teacher enthusiasm for students' performance has been addressed in various studies. However, most of the studies are rather old and treated teacher enthusiasm as instructional behavior. Rosenshine (1970) reviewed research related to teacher enthusiasm and its impact on student performance prior to 1970 and drew a predominantly positive picture, but results of subsequent research have been more mixed. Some studies have supported the relevance of teacher enthusiasm (e.g., Brigham, Scruggs, & Mastropieri, 1992; Williams and Ware, 1977; Wood, 1989), while others have found no apparent effect of enthusiasm on students' learning (Bettencourt, Gillet, Gall, 1983; Mc Kinney et al., 1983). However, to compare different levels of enthusiasm the participating teachers were trained to express a certain level of enthusiasm. Thus, the teachers did not show their "real" enthusiasm but behaved artificially enthusiastically or lethargically. Moreover, in the studies that detected no relationship between teacher enthusiasm and students' performance, a group behaving artificially enthusiastically was compared to a "normal" control group rather than a "lethargic" group.

Keller, Neumann, & Fischer (2013) identified three theoretical mechanisms that may help to understand if (and if so how) enthusiastic behavior affects students' performance. One is that teachers' enthusiastic behavior may increase students' attention (Bettencourt et al., 1983) because elements of enthusiastic behavior (e.g., gestures and body movements; Collins, 1978) reportedly catch students' attention more effectively than other external factors, like disturbances or objects in the classroom (Hilgard, Attkinson, & Attkinson, 1975, p. 150). The second is that students may adopt enthusiastic behaviors of their teachers, in other words, an enthusiastic teacher may serve as a role model (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009). The third, rooted in the concept *emotional contagion* (cf. Hatfield, Cacioppo, & Rapson, 1994), is that students may be "infected" by their teachers' enthusiastic behavior and subsequently feel enthusiastic themselves. However, it should also be noted that students' enthusiasm is related to various student behaviors (e.g., concentration and on-task behavior), which may increase or impair students' performance (Brigham et al., 1992).

A few recent studies have considered teacher enthusiasm as a personality trait. Notably, Kunter et al. (2008) examined the relationships between subject-specific enthusiasm, enthusiasm for teaching the subject and classroom management/monitoring, cognitive autonomy support, and social support: three facets of instructional quality, which are associated with students' performance (Kunter et al., 2013). The results indicate that enthusiasm for teaching is related to all three of these aspects of instructional quality, but subject-specific enthusiasm is related to just one of them (cognitive autonomy support). Other scholars support the relevance of teacher enthusiasm for the quality of instruction (e.g., Frenzel et al., 2009; Long & Hoy, 2006; Walberg & Paik, 2000). Kunter (2013) also found evidence that both dimensions of teacher enthusiasm are positively associated with students' mathematics performance. However, research considering teacher enthusiasm in such a differentiated manner is very rare.

8.3 Research Questions and Hypotheses

The aim of this study is to elucidate associations between teachers' motivational orientations and students' performance. Accordingly, we address the following research question. How are teachers' self-efficacy, subject-related enthusiasm, and enthusiasm for teaching the subject related to students' performance?

Teachers' self-efficacy is reportedly an important determinant of students' performance (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Ross, 1992). Hence, we expect to find a positive relationship between this domain of teachers' motivational orientation and students' performance.

Teachers' enthusiasm is also widely considered as important for students' performance (Brigham et al., 1992; Kunter, 2013; Rosenshine, 1970; Williams and Ware, 1977; Wood, 1989). Hence, we expect both facets of teacher enthusiasm to be positively associated with students' performance. However, according to results presented by Kunter et al. (2008) and Kunter (2013), we expect students' performance to be related more strongly to teachers' enthusiasm for teaching a specific subject than to teachers' enthusiasm for the subject.

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8.4 Methods

8.4.1 Sample and Procedure

Sample. 48 biology teachers (75% female) with an average age of 40.9 years ($SD = 11.0$, range 24-64 years) and an average teaching experience of 11.6 years ($SD = 10.5$, range 0-42 years) participated in this study. The teachers were recruited from both academic and non-academic track schools (intended to enable students to start an academic career and certify students for a vocational career, respectively) in Hamburg and Schleswig-Holstein (northern Germany). Of the participating schools, 54.2 and 45.8% are assigned to the academic and non-academic tracks, respectively. Similarly, 58.3 and 39.6% of the teachers were certified to teach in academic and non-academic track schools, respectively and 2.1% held a degree which is not related to teacher education (e.g., a master's degree in biology). The teachers participated together with their 7th (20.1%) or 8th (79.9%) grade classes ($N = 1036$ students, 50.6% female, age: $M = 13.5$ years, $SD = 0.73$ years, range 12-16 years).

Procedure. The participating teachers were recruited by telephone or mail. In order to examine the relationship between teachers' motivational orientations and students' performance the teachers completed questionnaires designed to measure their self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject. The teachers were subsequently asked to plan and implement a short unit related to a biological topic (the Wadden Sea ecosystem). The teachers received material for the realization of the unit (blue mussels and an aquarium) as an incentive. Students' performance was measured both before and after this unit (to allow us to account for variations in students' prior knowledge in the following analysis).

8.4.2 Measures

In order to examine relationships between teachers' motivational orientations and students' performance we applied both teacher- and student-level measures.

Teacher level

Self-efficacy. To measure teachers' self-efficacy we used 10 items developed by Schmitz and Schwarzer (2000) inviting Likert-type responses (4 = fully applies; 3 = largely applies; 2 = does not much apply; 1 = does not apply at all). The items consider self-efficacy beliefs related to

coping with specific tasks, namely: job accomplishment (e.g., *I am convinced that I am able to successfully teach all relevant subject content to even the most difficult students.*); skill development on the job (e.g., *I am convinced that, as time goes by, I will continue to become more and more capable of helping to address my students' needs.*); social interaction with students, parents, and colleagues (e.g., *I know I can maintain a positive relationship with parents even when tensions arise.*); and coping with job stress (e.g., *Even if I am disrupted while teaching, I am confident that I can maintain my composure and continue to teach well.*) (Schmitz & Schwarzer, 2000; Schwarzer, Schmitz, & Daytner, 1999).

Teacher enthusiasm. To measure this construct we used an instrument originally developed in the framework of the COACTIV-project (Baumert et al., 2009) to assess mathematics teachers' enthusiasm. As our participants were biology teachers we reformulated the (Likert-type) items by replacing the word 'mathematics' with 'biology'. Subject-specific enthusiasm was measured with three items (e.g., *I am enthusiastic about the subject biology*) and enthusiasm for teaching the subject with two items (e.g., *I teach biology with great enthusiasm*) inviting Likert-type responses (4 = fully applies; 3 = largely applies; 2 = does rather not apply; 1 = does not apply at all).

Control variable. The single control variable considered is the teachers' (and their classes') type of school (non-academic or academic track).

Student level

Conceptualization and measurement of students' performance. As 'performance' is a very vague construct, we considered a specific aspect of students' performance: thinking about complex systems in biological contexts (*system thinking*), which represents a crucial ability to develop in biology education. The Wadden Sea ecosystem was selected as an exemplary complex system, partly because it is widely used for such pedagogical purposes in Northern Germany.

To measure students' performance in this respect we used both a paper-and-pencil test and concept maps. The paper-and-pencil test was validated in a prior study (Brandstädter, Harms, & Großschedl, 2012) and includes two subscales. One subscale is intended to measure *structural system thinking*, covering the ability to identify, connect and organize the elements of a system in a reference framework (Brandstädter et al., 2012; Sommer &

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Lücken, 2010). The other is intended to measure *procedural system thinking*. This covers the following abilities: to differentiate between the properties of a system and properties of its elements; to identify dynamic relationships, and to understand and predict consequences of changes within a system; and to understand and evaluate effects and reactions within a system (Brandstädter et al., 2012; Sommer & Lücken, 2010). Results of the paper and pencil test were analyzed using the Weighted Maximum Likelihood (WLE) method, as implemented in ACER Conquest, to estimate person ability (Warm, 1989). For further information about this procedure see Großschedl, Mahler, Kleickmann, & Harms (2014). Concept maps are diagrams displaying concepts (key terms of a topic) linked by arrows with appropriate labels (e.g., in this context *Eat* or *Breed*). We examined the most valid way of applying concept maps in a prior study (Brandstädter et al., 2012), in which a paper-and-pencil design and a computer based-design were compared. We also compared the utility of highly-directed and non-directed computer-based designs (in which the software does and does not provide concept and relation options) in the previous study. The results indicated that a highly-directed computer-based design is the most valid in this context, hence in the present study we used such concept maps constructed using MaNet software (Eckert, 1998). The software provides 10 concepts (e.g., starfish and blue mussel, see Fig. 8-1) and four relating words (e.g., creates, see Fig. 8-1). The students were trained to use this software in advance.

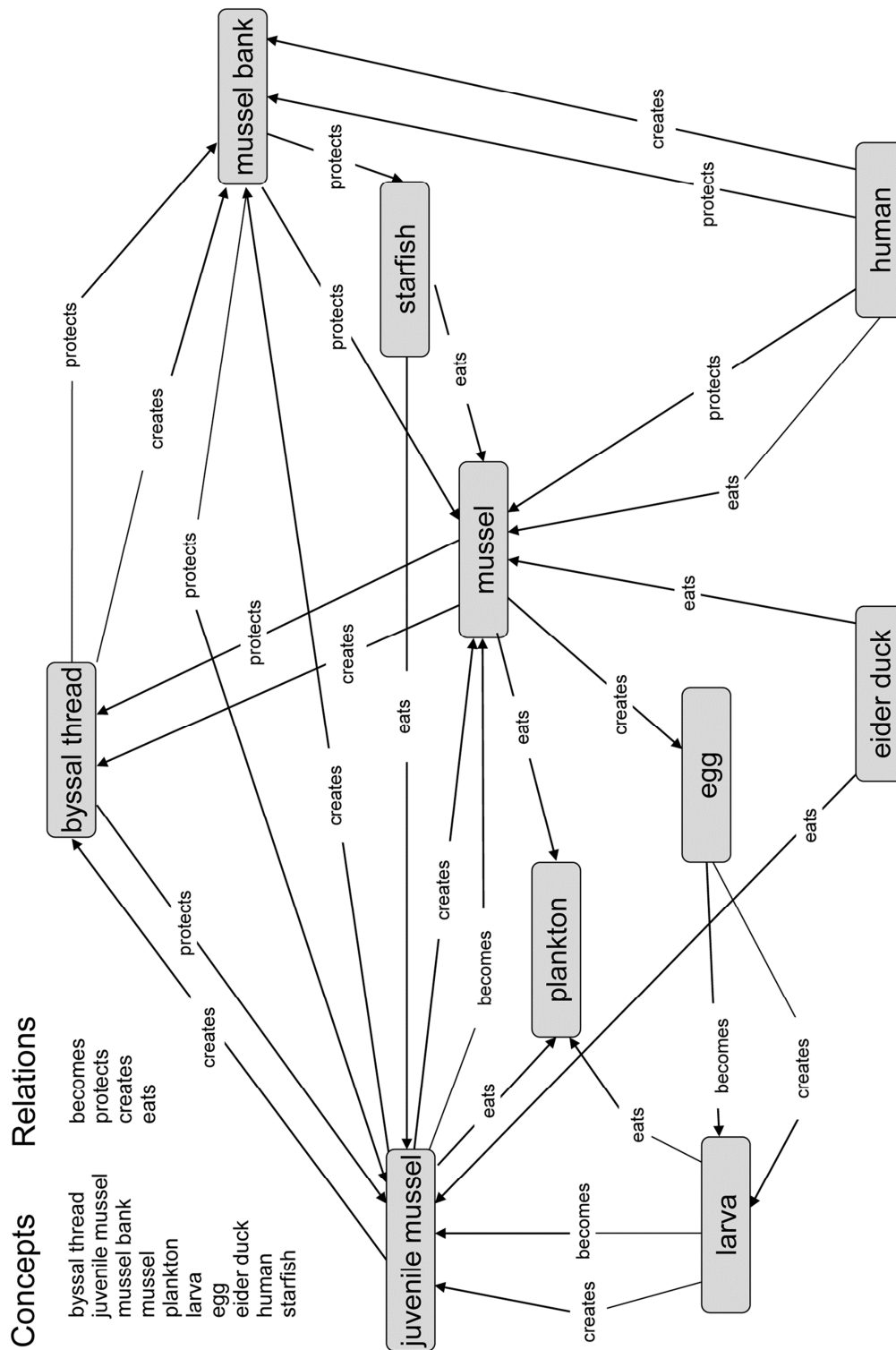


Figure 8-1. Reference Map Related to Nutrition, Living, and Reproduction of *Mytilus edulis*.

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Using a tool provided by MaNet (Eckert, 1998) we analyzed students' concept maps by comparing each of them to a reference map (Fig. 8-1) developed with the help of biology and biology education experts, following procedures also described by Mahler, Großschedl, & Harms (submitted b). This tool generates a weighted correspondence coefficient (C_w) that indicates the similarity between a reference map and another map (Eckert, 1998), based on: the presence of connections between pairs of concepts (yes or no); selected relations (right or wrong); and the correctness of relations' directions, e.g., starfish eats mussel (right) or mussel eats starfish (wrong) (Eckert, 1998). The weighting of the coefficient adjusts for the variation in significance of relations in maps, which declines with increases in the number of relations (Eckert, 1998). This weighted coefficient was used in the following analysis.

A problem with the applied software is that it is only possible to define *one* correct relationship between a given pair of linked concepts. As our set of concepts and relating words allow different correct answers, we had to recode some of the concept maps. To evaluate concept maps with alternative but correct relating words we defined an alternative reference map that included the dummy "correct" instead of a relating word. We then recoded the student maps by changing alternative but correct relating words using the dummy "correct" as well. This enables us to consider different correct alternatives.

Control variables (student level). As cognitive abilities are important determinants of students' performance (Boulanger, 1981; Hattie & Hansford, 1982; Piburn, 1993), we considered their cognitive abilities as control variables in our analysis. For this purpose we used the KFT 4-12+ R instrument (Heller & Perleth, 2000) to measure students' cognitive abilities in two dimensions: verbal abilities (relationships between words), and non-verbal abilities (figural relationships). To avoid copying, two versions of the KFT 4-12+ R were given to the students.

In addition to students' cognitive abilities, we considered their prior knowledge (i.e., knowledge before the teaching unit focused on the Wadden Sea ecosystem) as a control variable. This was measured using a paper-and-pencil test and concept maps, analogously to the procedure described above. Table 8-1 provides information about the measures.

Table 8-1
Measures – Descriptive Statistics

Measure	N of items	Scoring	M	SD	min	max	Cronbach's α	Facets of knowledge	Reference
<i>Teacher-level measures</i>									
self-efficacy	10 (closed)	Likert type	20.51	3.30	1	4	.68	-	Schmitz & Schwarzer (2000)
subject-specific enthusiasm	3 (closed)	Likert type	8.35	1.01	1	4	.78	-	Baumert et al. (2009)
enthusiasm for teaching the subject	2 (closed)	Likert type	5.27	0.93	1	4	.88	-	Baumert et al. (2009)

(continued)

Table 8-1 (continued)

Measure	N of items	Scoring	M	SD	min	max	Cronbach's α	Facets of knowledge	Reference
<i>Student-level measures</i>									
system thinking	26 (22 closed and 4 open items)	dichotomous: N = 9; polytomous: N = 17	19.04 (pre); 25.50 (post)	4.71 (pre); 5.60 (post)	0	2	.71 (pre); .76 (post)	(a) structural system thinking (N=18); (b) procedural system thinking (N=8)	Brandstädter et al. (2012)
verbal cognitive abilities	20 (closed)	dichotomous: N = 20; polytomous: N = 0	11.19	4.25	0	20	.76 (A); .81 (B)	relationships between words	Heller & Perleth (2000)
non-verbal cognitive abilities	25 (closed)	dichotomous: N = 25; polytomous: N = 0	16.78	5.90	0	25	.87 (A); .90 (B)	figural relationships	Heller & Perleth (2000)

Note. Pre and post respectively refer to before and after the teaching unit focused on the Wadden Sea ecosystem. In the dichotomous scoring 0 = wrong and 1 = correct, while in the polytomous scoring 0 = wrong, 1= half correct (partial credit), 2 = correct.

8.4.3 Statistical Analysis

Multilevel analysis

Multilevel data structure. Since our participants were teachers and their classes the acquired data had a hierarchical structure, i.e., data pertaining to one level (individual student) were clustered in another (class) (Nezlek, Schröder-Abé, & Schütz, 2006). In such structured datasets observations are not independent, and to avoid errors in the estimation of effects and standard errors it is highly important to account for the hierarchical data structure (Nezlek et al., 2006). We specified unconditional models to decompose the variance in students' performance into the proportions lying within and among the classes. As we used two types of instrument to measure students' performance (paper and pencil tests and concept maps), scores obtained were used as latent indicators to model students' performance. Accordingly, we constructed separate unconditional models based on the structural system thinking, procedural system thinking, and concept map (correspondence coefficient) scores. The results indicate that between-class variance accounts for 27.3, 22.7 and 23.9% of the total variance in these scores. Accordingly, we specified models that account for a multilevel structure.

Doubly-latent models. To investigate if teachers' motivational orientations are predictive of students' performance, we specified doubly-latent models (Marsh et al., 2009), which integrate a structural equation model and a multilevel model. The dependent variable is treated as a latent trait on both individual and class levels. The advantage of such models is that they control for both measurement error (arising from sampling on both levels) and sampling error (arising from sampling individuals in the aggregation from individual to class level) (Marsh et al., 2009).

The *dependent variable* here is students' performance (post-teaching unit) modeled with structural system thinking, procedural system thinking, and concept map (correspondence coefficient) scores as indicators. As required for a doubly-latent model, the dependent variable is considered as a latent trait on both individual level and class level. As shown in Figure 8-2, the indicators of the dependent variable appear as latent variables on the class level. More detailed, the variance between classes within these indicators (intercept modeled as random effect) is added as latent variable on the class level. To examine the

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relationship between teachers' motivational orientations and students' performance according to our research question, teachers' self-efficacy, subject-related enthusiasm, and enthusiasm for teaching the subject are considered as *independent variables* in the models.

We included *control variables* on both levels. On the class level, the type of school ("track", academic vs. non-academic track, see 'measures') was considered. On the individual level we included students' performance in the pre-teaching unit test, modeled as a latent trait, analogously to their performance in the post-unit test. Students' cognitive abilities (verbal and non-verbal) were also included as control variables on the individual level.

We specified five models to examine the relationships between teachers' motivational orientations and students' performance. Model 1 considers only the control variables on both levels. In addition to the control variables, Models 2 to 4 respectively consider teachers' self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching as independent variable. Finally, the control variables and all three domains of teachers' motivational orientations are considered in Model 5 (illustrated in Fig. 8-2 as an example of the models).

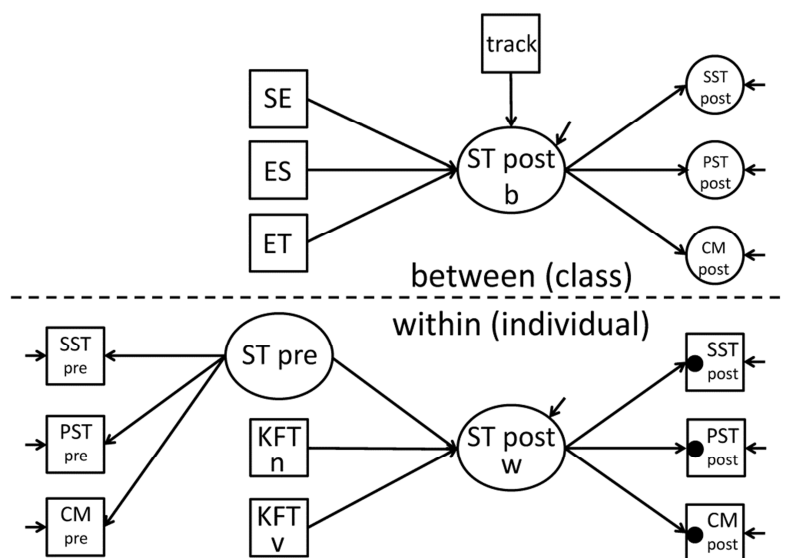


Figure 8-2. Doubly-Latent Model.

Note. SE = self-efficacy; ES = subject-specific enthusiasm; ET = enthusiasm for teaching; ST = system thinking; SST = structural system thinking; PST = procedural system thinking; CM = concept mapping performance; KFT n = non-verbal cognitive abilities; KFT v = verbal cognitive abilities; pre = pre-teaching unit test; post = post-teaching unit test; ● = Intercept (DV on indicators) is modeled as a random effect, varying between classes.

Missing values. Our dataset includes missing values on different variables (concept mapping performance pre: 11.7%, concept mapping performance post: 14.6%, cognitive abilities verbal: 0.19%, cognitive abilities non-verbal: 0.78%, self-efficacy: 5.0%, enthusiasm for teaching biology: 4.2%). Deleting participants with missing values reduces the sample size and weakens the statistical power (Peugh & Enders, 2004). In order to avoid this, we used *multiple imputation* to estimate the missing values. The underlying principle is the generation of a certain number of datasets (here: $N = 10$) in which plausible values substitute the missing values. The consideration of more than one dataset in this procedure (multiple imputation) accounts for uncertainty in the imputation of plausible values. The following analysis is computed with each of these ten data sets. The estimates are combined to generate a single result.

8.5 Results

The results of model 1 reveal that students' performance in the pretest as well as their verbal and non-verbal cognitive abilities are significantly positively related to students' performance in the posttest. Accordingly, we considered these control variables in the further models. The results of model 2 reveal no relationship between teachers' self-efficacy and students' performance. Accordingly, the consideration of teachers' self-efficacy as independent variable does not contribute to the explanation of variance. Model 3 considers teachers' subject-specific enthusiasm as independent variable and shows a significantly positive relationship between subject-specific enthusiasm and students' performance. Including subject-specific enthusiasm in the model does markedly contribute to the explanation of variance ($R^2 = 20\%$). In model 4 teachers' enthusiasm for teaching the subject was added as independent variable. Although we found no significantly positive relationship the contribution to the explanation of variance when compared with model 1 ($R^2 = 8\%$) indicates at least a positive trend. The same relationship-patterns remained in Model 5, which considers all three domains of teachers' motivational orientations. See Table 8-2 for detailed results.

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Table 8-2

Results of the Multilevel Analysis (standard errors in parenthesis)

Parameter	Model 1 (control variables)	Model 2	Model 3	Model 4	Model 5
<i>Individual level</i>					
Pretest	.83*** (.05)	.83*** (.05)	.83*** (.05)	.83*** (.05)	.83*** (.05)
KFT verbal	.14*** (.03)	.14*** (.03)	.14*** (.03)	.14*** (.03)	.14*** (.03)
KFT n-verbal	.19*** (.04)	.19*** (.04)	.19*** (.04)	.19*** (.04)	.19*** (.04)
R ²	.77	.77	.77	.77	.77
<i>Class level</i>					
self-efficacy		-.02 (.25)			-.25 (.28)
subject-specific enthusiasm			.41** (.14)		.41* (.20)
enthusiasm for teaching				.28 (.18)	.16 (.29)
Track	.53*** (.15)	.53*** (.15)	.56*** (.14)	.53*** (.15)	.56*** (.13)
R ²	.28	.28	.48	.36	.53

Note. KFT = cognitive abilities test; track = non-academic track vs. academic track.

8.6 Discussion

Contrarily to our hypothesis, intuitive expectations and previous findings (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Goddard et al., 2000; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Ross, 1992) the results of our study indicate that there is no significant relationship between teachers' self-efficacy and students' performance. We assume that this is due to inappropriate specificity in the instrument, developed by Schmitz & Schwarzer (2000), selected to measure the teachers' self-efficacy. The instrument probes teachers' self-reported efficacy with respect to important tasks in their professional lives, but not to tasks related to a specific subject (in our case biology). In contrast, the instrument we developed to measure students' performance focuses strongly on biological topics. We surmise that the participating teachers did not necessarily think about teaching biology when they completed the questionnaire. Moreover, some of the items concern areas that are not directly related to teaching (e.g., interaction with parents). It should be noted that the optimal level of specificity in assessment of self-efficacy is controversial. As the level of self-efficacy varies

across contexts (or tasks), an instrument that measures self-efficacy in a very general manner lacks validity (Frenzel, Becker-Kurz, Pekrun, & Goetz, 2015; Kunter et al., 2011), while a very specific instrument (e.g., an instrument measuring self-efficacy related to teaching a very specific biological content) would only be applicable in very specific corresponding situations (Pajares, 1996). Although the instrument we used is not general but related to tasks in the teaching profession, it appears to be too vague to address our research question.

Regarding the two considered dimensions of teacher enthusiasm, our results indicate that students' performance was positively related to the teachers' subject-specific enthusiasm, but not significantly related to enthusiasm for teaching the subject. However, as the sample of teachers was small ($N = 48$), and teachers' subject-specific enthusiasm explained a substantial proportion of variance in student's performance ($R^2 = 8\%$), we cautiously conclude that the results at least indicate a weak positive correlation between these constructs. The detected importance of teacher enthusiasm partially corroborates findings of several previous studies (Brigham et al., 1992; Kunter et al., 2008; Kunter, 2013; Rosenshine, 1970; Williams and Ware, 1977; Wood, 1989). It is especially interesting to compare our results to those presented by Kunter et al. (2008) and Kunter (2013), because they also conceptualized enthusiasm as a personality trait and differentiated between subject-specific enthusiasm and enthusiasm for teaching a specific subject. They found — in contrast to our results but in accordance with our hypothesis — that enthusiasm for teaching is particularly associated with students' performance. As Kunter and colleagues are the only other group who has distinguished these facets, further research is needed to clarify the inconsistency of the results. Theoretical approaches have been developed in attempts to describe how teacher enthusiasm affects students' performance in detail, e.g., through emotional contagion (Hatfield et al., 1994) or teachers' enthusiastic behavior increasing students' attention (Bettencourt et al., 1983). These approaches treat teacher enthusiasm as instructional behavior, rather than as a personality trait as we do. Nevertheless, we think that these theoretical approaches are also helpful for addressing the mechanisms behind the relationship we detected between teachers' enthusiasm and students' performance.

In accordance with several other authors (Abernathy-Dyer et al., 2013; Allinder, 1995; Armor et al., 1976; Ashton & Webb, 1986; Brigham et al., 1992; Goddard et al., 2000; Kunter

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et al., 2008; Kunter, 2013; Mohamadi & Asadzadeh, 2012; Moore & Esselmann, 1992; Rosenshine, 1970; Ross, 1992; Williams and Ware, 1977; Wood, 1989) we assume that teachers' motivational orientations influence students' performance, but one should also consider the possibility of a reverse effect. For example, teachers' enthusiasm may be enhanced by teaching high-achieving students (Frenzel et al., 2009; Patrick, Hisley, & Kempler, 2000). This may also hold for teachers' self-efficacy. Bandura (1977) has shown that there are multiple sources of self-efficacy, and describes mastery experiences (which occur when an individual has success in performing a specific task) as important sources for teachers' self-efficacy. Thus it seems plausible that teachers' self-efficacy may be influenced by the achievements of their students.

Limitations. Concerns are related to the instrument we used to measure teachers' self-efficacy. As already mentioned in the discussion, the instrument is very broad and not related to biology as a subject or the focal biological content of the performance test. An instrument that is more closely linked to teaching biology and the biological content could have provided deeper insights into the relationship between teachers' self-efficacy and students' performance. Several instruments are available for measuring teachers' self-efficacy related to a specific subject, for example the Science Teaching Efficacy Belief Instrument, designed (as the name suggests) for assessing teachers' self-efficacy in teaching science (Riggs & Knochs, 1990). Thus, use of one or more of these instruments (possibly with modifications) could be illuminating.

As we applied a cross-sectional design in our study a further limitation is that we cannot draw causal conclusions concerning the relationship between teachers' motivational orientations and students' performance. The clarification of causality would benefit from a longitudinal study.

8.7 Implications

8.7.1 Implications for Further Research

The results of our study indicate several research desiderata.

We found, in accordance with previous findings, that teachers' subject-specific enthusiasm is related to students' performance. However, there is a paucity of empirical findings concerning the mechanisms linking teacher enthusiasm and student performance, especially for teacher enthusiasm as conceptualized in this study (i.e., as a personality trait). Thus, further research is needed to elucidate these mechanisms. We think that a first step to understand why and how teacher enthusiasm matters is to examine, if, and if yes, how the two conceptualizations are in detail related. We assume that the experienced enthusiasm (enthusiasm as personality trait) leads to a certain kind of behavior. Related to teacher enthusiasm conceptualized as behavior, there are already some theoretical assumptions how teacher enthusiasm impacts on students' performance (e.g., emotional contagion; Hatfield, et al., 1994). These could help us, to further investigate this issue. A possibility to examine this relationship is the assessment of teacher enthusiasm conceptualized as personality trait with a questionnaire and an additional lesson observation. This procedure could give information if the behaviors which are considered as enthusiastic (e.g., movements) are indeed related to teacher enthusiasm measured with the questionnaires.

Considering teacher variables that could mediate the relationship of teacher enthusiasm on students' performance, could potentially provide further important insights. We know from the work of Kunter et al. (2008) that teacher enthusiasm is positively associated with instructional quality, and that instructional quality affects students' performance (Kunter et al., 2013). However, there are also other possible mediators, for instance students' on-task behavior and students' enthusiasm (Brigham et al., 1992).

This study considered two facets of teacher enthusiasm (1) subject-specific enthusiasm, and (2) enthusiasm for teaching the subject. Only two other studies (Kunter, 2013; Kunter et al., 2008) have adopted such an approach, and our results are partially inconsistent with their findings. Thus, further research is needed to investigate possible differences in effects of subject-specific enthusiasm and enthusiasm for teaching on students' performance.

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There may also be important feedback relationships between teachers' motivational orientations and students' performance, i.e., teachers' motivational orientations may influence students' performance, and vice versa.

8.7.2 Implications for Teacher Education

The finding that not only teachers' professional knowledge, but also their motivational orientations matter for students' performance has important implications for the organization of teacher education. Pre-service teacher education focuses especially on the acquisition of professional knowledge (KMK, 2008). However, we know from a prior study that pre-service and in-service teacher education programs provide opportunities to develop self-efficacy and enthusiasm, e.g., the attendance in professional development courses or the conduction of self-study (Mahler, Großschedl, & Harms, submitted a). Thus, we assume that opportunities to develop motivational orientations in teacher education programs could be increased by providing additional courses with an appropriate focus.

Given the benefits of self-study, the universities and schools should also help their (pre-service) teachers to enhance their self-study, especially by presenting strategies for effective self-study and providing access to journals.

8.8 Conclusions

Our findings support widespread recognition that being a successful teacher requires more than professional knowledge, by revealing a positive relationship between teachers' motivational orientations and students' performance. The strength of this study is that we considered both cognitive and affective domains of teachers' motivational orientations by examining relationships between students' performance and both teachers' self-efficacy and teachers' enthusiasm, using doubly-latent models. This is the first use of the approach to our knowledge in this field of research. Moreover, we gathered deep insights into the links between teacher enthusiasm and students' performance by distinguishing between subject-specific enthusiasm and enthusiasm for teaching the subject. The results of our study suggest that teacher education should focus not only on the acquisition of knowledge, but also on the development of motivational orientations.

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9 SUMMARIES OF THE CONDUCTED STUDIES

This chapter provides summaries of the four conducted studies. The summaries are supplemented by Table 9-1, which provides an overview of the four studies including the research questions, descriptions of the samples, the research designs and methods as well as the considered variables.

Table 9-1

Overview of the Conducted Studies and the Respective Publications

Publication	Research focus	Sample	Research design and methods	Dependent and independent variables
Großschedl, J., Mahler, D., Kleickmann, T., & Harms, U. (2014).	<i>Focus 1:</i> Structure of teachers' professional competence	<i>N</i> = 134 biology teachers from secondary schools	Cross-sectional design Rasch analysis Regression analysis	<i>Dependent variables:</i> Teachers' CK, PCK, CuK <i>Independent variables:</i> Type of teacher education program, attendance in professional development courses, years of teaching experience, conduction of self-study
Content-Related Knowledge of Biology Teachers from Secondary Schools: Structure and Learning Opportunities.	<i>Focus 2:</i> Opportunities for the development of teachers' professional competence			
<i>International Journal of Science Education, 36(14), 2335-2366.</i>				

(continued)

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Table 9-1 (continued)

Publication	Research focus	Sample	Research design and methods	Dependent and independent variables
Mahler, D., Großschedl, J., & Harms, U. (submitted).	<i>Focus 1:</i> Structure of teachers' professional competence	<i>N</i> = 134 biology teachers from secondary schools	Cross-sectional design Confirmatory factor analysis	<i>Dependent variables:</i> Teachers' self-efficacy, subject-specific enthusiasm, enthusiasm for teaching the subject
Teachers' Self-Efficacy and Enthusiasm: Opportunities for Teachers to Develop Motivational Orientations.	<i>Focus 2:</i> Opportunities for the development of teachers' professional competence		Regression analysis Correlation analysis	<i>Independent variables:</i> Perceived quality of teacher education, attendance in professional development courses, years of teaching experience, conduction of self-study
<i>Journal for Educational Research Online.</i>				
Mahler, D., Großschedl, J., & Harms, U. (in preparation for resubmission after major revisions).	<i>Focus 3:</i> Significance of teachers' professional competence for students' performance	<i>N</i> = 48 biology teachers from secondary schools <i>N</i> = 1036 students (7 th and 8 th grade)	Cross-sectional design Doubly-latent multilevel modelling	<i>Dependent variable:</i> Students' performance (system thinking) <i>Independent variables:</i> Teachers' CK, PCK, CuK
Using Doubly-Latent Multilevel Analysis to Elucidate Relationships between Science Teachers' Professional Knowledge and Students' Performance.				
<i>International Journal of Science Education.</i>				

(continued)

Table 9-1 (continued)

Publication	Research focus	Sample	Research design and methods	Dependent and independent variables
Mahler, D., Großschedl, J., & Harms, U. (submitted).	<i>Focus 3:</i> Significance of teachers' professional competence for students' performance	<i>N</i> = 48 biology teachers from secondary schools	Cross-sectional design Doubly latent multilevel modelling	<i>Dependent variable:</i> Students' performance (system thinking) <i>Independent variables:</i> Teachers' self- efficacy, subject- specific enthusiasm, enthusiasm for teaching the subject
Does Motivation Matter? – The Significance of Teachers' Motivational Orientations for Students' Performance.		<i>N</i> = 1036 students (7 th and 8 th grade)		
<i>Teaching and Teacher Education.</i>				

Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge.

9.1 Study 1: Content-Related Knowledge of Biology Teachers' from Secondary Schools: Structure and Learning Opportunities

The first study is related to two foci of this dissertation. The first objective of study 1 was to clarify the empirical structure of content-related professional knowledge. The second aim was to identify opportunities for the development of content-related professional knowledge.

Structure of content-related professional knowledge. To examine whether the three assumed domains of content-related professional knowledge are empirically separable, I conducted a Rasch analysis and compared different models. The first model assumed content-related professional knowledge to be one-dimensional. This means that the three assumed domains are not unique, but assigned to a single dimension. The second model was a two-dimensional model and comprised CK to be assigned to one dimension, and PCK and CuK together to be assigned to a second dimension. I considered this model because of different scholars who assumed CuK to be integrated in PCK (Grossman, 1990; Magnusson et al., 1999; Park & Chen, 2012). Finally, the third model considered CK, PCK, and

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CuK to be assigned to three separate dimensions. Comparing the models revealed that the three-dimensional model fitted the data the best, indicating that CK, PCK, and CuK represent unique dimensions of content-related professional knowledge. It is important to mention that these constructs are, despite their empirical separability, correlated. The findings of this study are not only important in terms of the structure of content-related professional knowledge, but also for the further examination of content-related professional knowledge in this dissertation.

Opportunities to develop content-related professional knowledge. The aim of this part of study 1 was to identify opportunities for the development of content-related professional knowledge. According to the findings of the first part of study 1, CK, PCK, and CuK were considered as unique domains of teachers' content-related professional knowledge. Four aspects were considered as beneficial for the development of teachers' professional competence: (1) the type of teacher education (teacher education program for prospective academic track teachers vs. teacher education program for prospective non-academic track teachers vs. teacher education program in the former GDR), (2) the attendance in professional development courses, (3) the conduction of self-study (e.g., reading journals), and (4) the time spent in the teaching profession (i.e., teaching experience). The results of a regression analysis revealed that an intensive training in teacher education (as it is implied in the teacher education program for prospective academic track teachers), the attendance in professional development courses as well as the conduction of self-study on the whole provide beneficial opportunities for the development of teachers' content-related professional knowledge. The time spent in the teaching profession was negatively related to CuK and not related to the other domains of professional competence. The results stress the importance of both pre-service as well as in-service teacher education for the development of professional competence.

9.2 Study 2: Teachers' Self-efficacy and Enthusiasm: Opportunities for Teachers to Develop Motivational Orientations

Analogous to the first study, study 2 concerns both the clarification of the empirical structure of teachers' motivational orientations and the identification of beneficial

opportunities for the development of teachers' motivational orientations. Accordingly, this study is also related to the first two research foci.

Structure of teachers' motivational orientations. The first aspect that was examined in terms of the empirical structure was the empirical separability of the assumed domains of teachers' motivational orientations (self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject) as well as the relationships between the domains of motivational orientations and the domains of content-related professional knowledge (CK, PCK, and CuK). This relationship is important for a deep understanding of how motivational orientations develop as teacher education particularly focuses on the acquisition of professional knowledge.

I assumed teachers' (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching the subject to represent unique domains of teachers' motivational orientations. A confirmatory factor analysis was conducted to examine the structure. Three models had been compared. The first model assumed motivational orientations to be one-dimensional. The second model assumed two dimensions, namely self-efficacy and teacher enthusiasm (which includes subject-specific enthusiasm and enthusiasm for teaching the subject as integrated construct). A three-dimensional model was examined as a third alternative model. This model considered the three assumed domains (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching the subject. The results revealed that the three-dimensional model fits the data the best.

Beyond the empirical separability of the domains, I examined the relationships between the domains of teachers' motivational orientations and the domains of content-related professional knowledge. As this further investigation aims to gather a deeper understanding of how motivational orientations develop, I considered the two domains of content-related professional knowledge which are explicitly in the focus of teacher education, namely CK and PCK (KMK, 2008). The findings show positive relationships between self-efficacy and PCK as well as between enthusiasm for teaching the subject and PCK. No relationship occurred between the domains of teachers' motivational orientations and CK. The results indicate that motivational orientations and content-related professional knowledge should not be regarded as isolated aspects of professional competence. This

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should also be considered when thinking about the development of motivational orientations.

Opportunities to develop motivational orientations. Analogous to study 1, I considered aspects during teacher education as well as aspects related to the occupational lives of teachers. I assumed (1) the perceived quality of teacher education, (2) the attendance in professional development courses, (3) the conduction of self-study (e.g., reading journals), and (4) the time spent in the teaching profession (i.e., teaching experience) as important aspects for the development of self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject. Regression analyses reveal that the perceived quality of teacher education, the attendance in professional development as well as the conduction of self-study provide opportunities for the development of self-efficacy and enthusiasm for teaching the subject. Subject-specific enthusiasm was related to none of the assumed opportunities. Analogous to the findings of study 1, teaching experience seems not to be relevant for the development of motivational orientations. The results indicate that, according to the understanding of the competence concept by Weinert (2001 a, b), also motivational orientations develop due to beneficial opportunities during teacher education at university and the time in the profession.

9.3 Study 3: Using Doubly-Latent Multilevel Analysis to Elucidate Relationships Between Science Teachers' Professional Knowledge and Students' Performance

The third study focused on the relationship between teachers' content-related professional knowledge and students' performance. The aim of this study was to elucidate if content-related professional knowledge is indeed relevant for students' performance and, if yes, which domain is the decisive one.

According to the findings of study 1, I assumed three unique domains of teachers' professional content-related professional knowledge, namely (1) CK, (2) PCK, and (3) CuK. Students' performance was conceptualized as *system thinking performance in biology* (i.e., the ability to deal with complex biological systems, see 4.2).

Different doubly-latent multilevel models were specified to examine this relationship. The results revealed a positive relationship between PCK and students' performance. Furthermore, I found no relationship between CK and students' performance as well as between CuK and students' performance.

The results stress the importance of teachers' PCK for students' performance. This supports the assumption that teachers have to be distinguished from a content-specialist as well as the relevance to foster teachers' PCK during pre- and in-service teacher education.

9.4 Study 4: Does Motivation Matter? - The Significance of Teachers' Motivational Orientations for Students' Performance

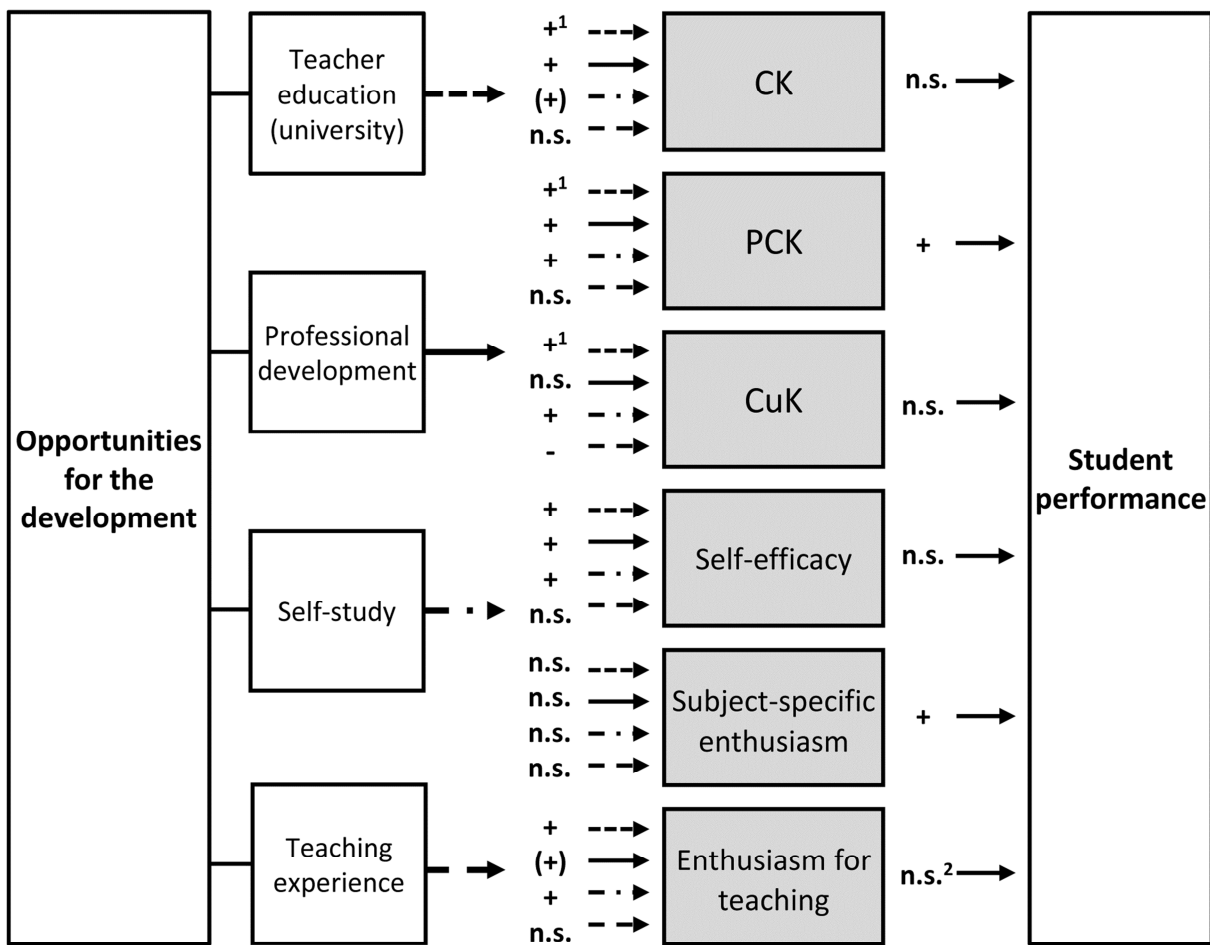
Study 4 supplemented study 3 by focusing on the question if teachers' motivational orientations are relevant for students' performance and, if yes, which domains are especially important. Considering the findings from study 2, I assumed the three domains (1) self-efficacy, (2) subject-specific enthusiasm, and (3) enthusiasm for teaching the subject to be important for students' performance. Analogous to study 3, students' performance was assessed in terms of their abilities to deal with biological systems (i.e., system thinking, see 4.2).

I specified doubly latent-models to examine the relationship between the beyond mentioned domains of teachers' motivational orientations and students' performance. The results revealed no relationship between teachers' self-efficacy and students' performance. In contrast, I found a positive relationship between subject-specific enthusiasm and students' performance and a positive trend concerning the relationship between enthusiasm for teaching the subject and students' performance. The results indicate that especially teacher enthusiasm seems to play a decisive role for students' performance when regarding teachers' motivational orientations.

The results stress the assumption that effective teaching entails more than just professional knowledge.

Figure 9-1 provides a summary of the results of the four conducted studies.

SUMMARIES OF THE CONDUCTED STUDIES



- > Relationship between teacher education (university) and the respective domain
- > Relationship between professional development and the respective domain
- · > Relationship between self-study and the respective domain
- -> Relationship between teaching experience and the respective domain

Note. CK = content knowledge; PCK = pedagogical content knowledge; CuK = curricular knowledge; + = positive relationship. ; (+) = positive relationship, $p < .10$; - = negative relationship; n.s = not significant; ¹teacher education program in the former GDR vs. academic track teachers; ²the result indicates at least a positive trend.

Figure 9-1. Overview of the results of study 1 - 4.

10 OVERALL DISCUSSION, LIMITATIONS, AND IMPLICATIONS

The following section includes an overall discussion of the results and a summary of the limitations. Furthermore, implications for further research and implications for teacher education are provided.

As the detailed results are discussed in the respective studies, this overall discussion should give a more overarching and integrated insight. Figure 10-1 enables a comparison between the hypothesized results and the actual results.

10.1 Structure of Teachers' Professional Competence

Two questions guided the examination of the structure of teachers' professional competence. The first question concerned the inner structure of the respective competence aspects and the second question asked about the interrelations between the two considered competence aspects.

I hypothesized content-related professional knowledge to be composed of the three unique domains (1) CK, (2) PCK, and (3) CuK. As can be seen in Figure 10-1, the results support the hypothesized structure. What is more, the initial conceptualization of Shulman (1986) and several empirical findings support the separability of the domains (Baumert et al., 2010; Großschedl et al., 2013; Großschedl et al., 2015; Krauss et al., 2008a; Jüttner et al., 2013; Phelps & Schilling, 2004; Schmidt et al., 2007; Shulman, 1986). See study 1 for the discussion of the detailed results.

Concerning the inner structure of teachers' motivational orientations, I hypothesized three unique domains, namely self-efficacy, subject-specific enthusiasm, and enthusiasm for teaching the subject. The results are in line with my hypothesis (see Fig. 10-1). As self-efficacy and enthusiasm are of a different nature (cognitive vs. affective) (Baumert & Kunter, 2006; Kunter et al., 2011), their separability is not surprising. What is more interesting is that indeed two facets of enthusiasm can be identified (subject-specific enthusiasm vs. enthusiasm for teaching the subject). Only few research related to this issue has been conducted. This result is in line with the findings of Kunter et al. (2011) and implies that teachers who are enthusiastic about the subject are not necessarily also enthusiastic about teaching this subject. See study 2 for the discussion of the detailed results.

The results concerning the inner structure of the two competence aspects allow for two important conclusions about the uniqueness of teachers. The assumption that a teacher as professional is characterized by a unique body of knowledge (Baumert & Kunter, 2013; Ingersoll & Merrill, 2011; Myers, 2008; Shon, 2006; Shulman, 1998) is supported by the separability of PCK and CuK from CK. CK is not only a domain of teachers' professional knowledge, but also the relevant knowledge base for a content specialist (e.g., a biologist). In contrast, PCK and CuK are domains of professional knowledge which are unique for the teaching profession. The finding that subject-specific enthusiasm and enthusiasm for

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teaching the subject embody separate domains supports the described dual character of the teaching profession and thus further supports the uniqueness of teachers. The dual character implies that a teacher has to cope with both the content and the interaction with students (Kunter, 2013). Accordingly, the enthusiasm of teachers is ideally related to both the content and the interaction with students. In contrast, a content specialist only has to cope with the subject and has to be ideally enthusiastic for this subject.

Beyond the separability of the assumed domains, a further important finding concerning the inner structure of teachers' professional competence is that the respective domains within one competence aspect are correlated (despite their separability). This finding is in line with my hypothesis and implies that the domains of content-related professional knowledge or motivational orientations should not be regarded in isolation. An example for an integrated consideration of the domains is the assumption that CK plays an important role for the development of PCK (Großschedl et al., 2015; Ball et al., 2001; Ma, 1999; Magnusson et al., 1999; Riese & Reinhold, 2012). See study 1 and study 2 for the discussion of the detailed results.

As already mentioned, the interrelationships between the competence aspects were also considered in this research focus. As hypothesized, I found several interrelationships between the domains of content-related professional knowledge and the domains of motivational orientations. This is in line with the findings of other studies (Raudenbush et al., 1992; Riese & Reinhold, 2010). See study 2 for the discussion of the detailed results. The findings indicate that the different aspects of teachers' professional competence do not act in an isolated manner. This is an important finding, for instance when thinking about the impact of teacher education on professional competence as especially teacher education at university aims at the acquisition of knowledge and does not explicitly focus on the improvement of motivational domains (KMK, 2008).

The results related to the first focus of my dissertation had very important consequences for the further course of my dissertation. Although the following foci are not of a hierarchical nature, the examination of the structure has a superordinate function. The identification of beneficial opportunities for the development as well as the examination of the meaning of professional competence for students' performance require the prior consideration if one should focus on the two competence aspects or should have a more

precise look by considering the different domains of professional competence. A precise look includes the opportunity for different results over the different domains.

10.2 Opportunities for the Development of Teachers' Professional Competence

The aim of this focus was the identification of beneficial opportunities for the development of teachers' professional competence. Two main aspects are important to discuss concerning this research focus: (1) the stability and malleability of teachers' professional competence and (2) the aspects that provide opportunities to develop professional competence.

My ground assumption was that teachers' professional competence is malleable. The results revealed that teachers' professional competence – and this concerns both content-related professional knowledge and motivational orientations – is indeed malleable and is not determined with entering a teacher education program. This matches my assumption as well as the understanding of the concept of competence described by Weinert (2001 a, b). The results also imply that some domains are more stable than others. Subject-specific enthusiasm seems to not develop due to different opportunities during teacher education programs or during the time in the profession. Hence, this domain of teachers' professional competence seems to be relatively stable. This is in line with Kunter (2013), who found subject-specific enthusiasm to be more stable than enthusiasm for teaching the subject. See study 1 and 2 for the discussion of the detailed results.

The second focus concerns the development of teachers' professional competence, more detailed the aim was to identify aspects during teacher education at university and during the occupational life of teachers that act as opportunities for the development of teachers' professional competence. I hypothesized four aspects to be important for the development of teachers' professional competence: (1) teacher education at university, (2) the attendance in professional development courses, (3) the amount of conducted self-study, and (4) teaching experience. Figure 10-1 illustrates that except teaching experience, the assumed aspects were – analogous to my hypothesis – related to the considered domains of teachers' professional competence. This finding is supported by several studies

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(*content-related professional knowledge*: Brunner et al., 2006; Clermont et al., 1993; Kleickmann & Anders, 2013; Schmidt et al., 2007; Tatto & Senk, 2011; *motivational orientations*: Bettencourt et al., 1983; Campbell, 1996; Collins, 1978; Roness, 2011). See study 1 and 2 for the discussion of the detailed results.

The following section first discusses why teacher education at university, the attendance in professional development courses, and self-study are important for the development of teachers' motivational orientations. Afterwards, the unclear role of teaching experience is discussed.

Concerning content-related professional knowledge, the findings seem relatively intuitive. Teacher education programs predominantly aim at the acquisition of knowledge (KMK, 2004a; Kunter et al., 2013a). The time spent at the university is described as the most formative phase concerning the acquisition of knowledge (Kunter et al., 2013a). The acquisition of knowledge also is in the focus of professional development courses and self-study.

Concerning teachers' motivational orientations, the considerations of Bandura (1977) and Deci and Ryan (2000) help to explain my results. Bandura (1977) identified mastery experiences to be the most relevant source for self-efficacy. Moreover, he identified vicarious experiences to be fruitful. An important need that has to be fulfilled in terms of intrinsic motivation (I assume intrinsic motivation as very closely related to enthusiasm [see Kunter et al., 2011; Kunter, 2013]) is the experience of the own competence. A broad body of content-related professional knowledge facilitates these mastery experiences during teaching and enables individuals to experience the own competence. As mentioned before, teacher education at university, professional development, and self-study aim at the acquisition of content-related professional knowledge. Moreover, the attendance in professional development courses provides the opportunity to learn from vicarious experiences (e.g., from the lecturer or teacher colleagues), which are described as further source for self-efficacy.

Against my hypothesis, teaching experience does not help to explain the interindividual differences in terms of neither content-related professional knowledge nor motivational orientations. This seems surprising as the time in the profession provides the opportunity to further develop and integrate knowledge (Krauss et al., 2008a). Moreover, the time in the

profession provides several opportunities to gain mastery experiences during teaching, which are, as already mentioned, the most important source for teachers' self-efficacy. Nevertheless, capturing only the number of years spent in the profession does not give any information about the quality of this time (e.g., the amount of mastery experience or failure). A further reason for the lacking relationship could be the conceptualization of content-related professional knowledge in this dissertation. As stated in the theoretical background, I refer to formal knowledge and not to practical knowledge. However, experience represents a source for practical knowledge (Baumert & Kunter, 2013; Fenstermacher, 1984). Accordingly, my assumption is that teaching experience is more important for the development of practical knowledge (which is not part of my dissertation) than for the development of formal knowledge.

In sum, the findings are very encouraging as they show that the effectiveness of teachers is not determined with entering a teacher education program, but develops over the whole career. Thus, it is possible to actively influence teachers' professional competence by improving pre- and in-service teacher education.

10.3 Significance of Teachers' Professional Competence for Students' Performance

The significance of teachers on students' performance is one of the most important indicators for teacher effectiveness. It is widely accepted that the teacher plays an important role for the learning and the performance of students (Cochran-Smith & Zeichner, 2005; Darling-Hammond, 2000b; Hattie, 2009). The guiding research question of this focus was which factors in detail cause the importance of teachers. In terms of this question, I examined the relationship between teachers' professional competence and students' performance. I assumed both the domains of content-related professional knowledge (CK, PCK, CuK) as well as the domains of teachers' motivational orientations (self-efficacy, subject-specific enthusiasm, enthusiasm for teaching the subject) to be related to students' performance (see Fig. 10-1).

My results reveal that teachers' PCK is indeed related to students' performance. In contrast to my hypothesis, no relationships occur between teachers' CK and students'

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performance as well as between CuK and students' performance (see Fig. 10-1). This finding is in line with the findings of several other studies and different theoretical assumptions (Ball et al., 2001; Baumert et al., 2010; Fennema et al., 1996; Lange et al., 2015; Kunter et al., 2013; Magnusson et al., 1999; Sadler et al., 2013). See study 3 for the discussion of the detailed results. The finding that teachers' PCK is important for students' performance is a very relevant finding in terms of the distinction between teachers and content specialists. The result that mere CK does not suffice in fostering students' performance reveals that the teacher has to be regarded as a professional with a unique body of knowledge. Concerning the lacking relationship between CK and students' performance, I assume a possible indirect effect. It seems plausible to assume that the relationship between CK and students' performance is mediated by PCK because CK is assumed to be a crucial prerequisite for the development of teachers' PCK (Großschedl et al., 2015; Ball et al., 2001; Ma, 1999; Magnusson et al., 1999; Riese & Reinhold, 2012).

Concerning teachers' motivational orientations, I found subject-specific enthusiasm and enthusiasm for teaching to be positively related to students' performance (see Fig. 10-1). The importance of enthusiasm is supported by different studies, but it is important to mention that most of these studies consider teacher enthusiasm as instructional behavior (for reviews see: Brophy & Good, 1984; Rosenshine, 1970; Brigham et al., 1992; Williams & Ware, 1977; Wood, 1989) and only few consider teacher enthusiasm as personality trait like I do (Kunter et al., 2008; Kunter, 2013). See study 4 for the discussion of the detailed results. The positive relationship I found between subject-specific enthusiasm as well as enthusiasm for teaching the subject and students' performance contributes to a relatively new field of research which assumes teacher enthusiasm as personality trait and considers the object of enthusiasm (i.e., the subject itself or teaching this subject) (Kunter et al., 2008, 2011; Kunter, 2013). According to this little body of research, it is only possible to hypothesize why teacher enthusiasm impacts on students' performance. An integration of the two conceptualizations could be helpful (personality trait vs. instructional behavior). As motivation is understood as an important predictor for behavior (Schiefele & Schaffner, 2015; Woolfolk, 2008), I assume that enthusiasm as effective teacher orientation leads to a certain behavior. Concerning the significance of enthusiastic behavior of teachers, there are some assumptions available that could help to explain the relevance of enthusiasm. One

example is the assumption that enthusiastic behavior “infects” the student, which leads to a more intensive confrontation with the subject of learning (emotional contagion: Hatfield et al., 1994).

10.4 Reverse Effects

When identifying the meaning of different opportunities for the development of teachers’ professional competence or when identifying the impact of teachers’ professional competence on students’ learning, I assume a certain direction of the effects. The theoretical assumptions I made are supported by a broad body of research. Nevertheless, reverse effects should also be discussed as my research design is cross-sectional. A reverse effect can occur when thinking about the development of teachers’ professional competence. This particularly concerns teachers’ motivational orientations. For instance, it can be assumed that a highly motivated teacher is more likely to engage in professional development or self-study. This point is also important when thinking about the significance of teachers’ professional competence for students’ performance. As students’ performance is based on complex interrelationships between the teacher and the student (Helmke, 2009), an influence of students’ performance on teachers’ professional competence can be hypothesized. An example for such interrelationships concerns the mistakes or misconceptions of students. Instead of considering them as failure they can also be understood as an input for teachers to improve their teaching (Gropengießer & Kattmann, 2013; Helmke, 2009).

10.5 Limitations

Studies 1 to 4 list different limitations and concerns. This section gives an overview of more general aspects which concern all studies in general.

Cross-sectional design

The major concern is related to the cross-sectional research design in all conducted studies because a cross-sectional design does not allow for causal conclusions. This concern is

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especially related to the second and the third focus, i.e., the identification of opportunities for the development of professional competence and the examination of the relationship between teachers' professional competence and students' performance. As mentioned before, my hypothesized relationships are theoretically and empirically well-grounded. Nevertheless, possible reverse effects cannot be ruled-out.

No insight into the concrete learning situations

I focused on the direct relationships between the domains of teachers' professional competence and students' performance. The lessons the teachers conducted were not observed by an external observer. In order to give at least a small insight into their lessons, the teachers were asked to complete a grid to provide an overview of the planning and the conduction of their lessons. Unfortunately, these grids were of extremely different quality and could not be further considered. Thus, I have no information about how teachers' professional competence is reflected in the activity of teaching. Moreover, possible disturbing factors that could have caused bias in the data could not be detected.

Data collection

The students completed the paper and pencil tests as well as the concept maps in the classroom context, i.e., they were observed during the completion of the tests. On the contrary, the teachers completed the tests on their own. Thus, it was not possible to control if the teachers used external devices like the internet (although they were strictly advised not to do so). This problem particularly concerns the test for content-related professional knowledge. Nevertheless, the items were developed in a manner (especially PCK) that made sure that the use of external devices was not possible in an adequate expenditure of time.

Selection of the instruments

Further concerns are related to the selection of two instruments in this dissertation.

First, the CuK-measure, which was developed in the framework of this project (Großschedl et al., 2014), causes concerns. This measure refers to a very narrow conceptualization of CuK. More detailed, it exclusively measures factual knowledge about the *National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2004a). I assume that an instrument which covers not only factual knowledge about the standards, but also the implementation of these standards in the planning and conduction of lessons (i.e., a more teaching-related conceptualization) would have given more information about the meaning of teachers' CuK for the performance of their students.

Beyond the CuK-measure, the instrument which was selected to measure teachers' self-efficacy (Schmitz & Schwarzer, 2001) caused problems. This instrument is not related to the teaching of a specific school subject, but to teaching in general and to activities that go beyond teaching (e.g., the interaction with parents and colleagues). As my sample consists of biology teachers, I assume that a more specific instrument would have given more information about the meaning of self-efficacy for students' performance. More subject-specific instruments like the *Science Teaching Efficacy Belief Instrument (STEBI)*, which was developed to assess teachers' self-efficacy related to teaching science (Riggs & Knoch, 1990), are available.

10.6 Implications for Further Research

The four studies conducted in the framework of this dissertation generated important results concerning (1) the structure of teachers' professional competence, (2) the development of teachers' professional competence due to different opportunities during teacher education at university and during the professional life of teachers, and (3) the significance of teachers' professional competence for students' performance. The integration of the results leads to implications for further research, which are presented in the next section.

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Examining teachers' professional competence in a longitudinal design

As mentioned before, concerns are related to the cross-sectional design of my studies. In contrast to a cross-sectional design, a longitudinal design allows to examine causal relationships.

The conduction of a longitudinal study could help to develop a deep understanding of how teachers' professional competence develops. This would allow for important implications for teacher education. Beyond my dissertation project, I engage in the IPN KeiLa-project (*Kompetenzentwicklung in mathematischen und naturwissenschaftlichen Lehramtsstudien-gängen*), which started in 2014. This project examines the development of pre-service biology, chemistry, physics, and mathematics teachers' professional competence in a longitudinal design.

Beyond the examination of the development of teachers' professional competence, a longitudinal design would also further clarify the impact of teachers' professional competence on students' performance.

Further examination of interrelationships

The results of study 1 and study 2 show that content-related professional knowledge and teachers' motivational orientations comprise empirically separable, but correlated domains. The correlations occur within one competence aspect as well as between the competence aspects. Accordingly, teachers' professional competence should not be regarded as a loose collection of different capabilities and motivational components. Implications for further research concern both the interrelationships within the respective competence aspects as well as interrelationships between the respective competence aspects.

An interesting question that concerns the interrelationships within one competence aspect asks for the meaning of teachers' CK for the development of PCK. Several authors (Ball et al., 2001; Großschedl et al., 2015; Ma, 1999; Magnusson, et al., 1999; Riese & Reinhold, 2012) support the assumption that CK is important for the development of PCK. The cross-sectional design of my studies does not allow answering this question. As already stated, the longitudinal KeiLa-study could help to further examine the development of pre-service teachers' professional competence. Furthermore, it would be interesting to see whether the inner structure of the competence aspects remains stable over time. My

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assumption is that the correlation coefficients for the relationships between the domains of teachers' content-related professional knowledge increase over time in the profession, as teaching experience provides the opportunities for the integration of knowledge (Krauss et al., 2008a).

Beyond the interrelationships within the respective competence aspects also the detected interrelationships between the competence aspects lead to implications for further research. Although there is a broad body of research focusing on the single domains of content-related professional knowledge and teachers' motivational orientations, an integrated approach is lacking so far. The interrelationships between the different domains of teachers' content-related professional knowledge and teachers' motivational orientations become especially important when thinking about the development of professional competence. My results indicate that teachers' content-related professional knowledge and their motivational orientations do not act in an isolated, but in an interrelated manner. The question arises if the interrelationship changes over the time in the profession. One example in this context concerns the relationship between content-related professional knowledge and self-efficacy. My assumption is that this relationship does not remain stable over the time in the profession. High academic achievement during the first phase of teacher education (which requires a high level of content-related professional knowledge) leads to mastery experiences, for instance due to good grades in the teacher education program. As already stated, mastery experiences represent the most important source of teachers' self-efficacy (Bandura, 1977). When the teacher enters the profession, the demands change. In contrast to the time in the teacher education program at university, the interaction with students is now the core task. The adaption to the new demands causes stress and could include the experience of failure. The knowledge which was acquired during teacher education at university has to be transferred to the demands of the teaching profession. This gap between theory and practice is a demanding situation for novice teachers (Brouwer & Korthagen, 2005; Korthagen, 2009). Accordingly, I assume the relationship between teachers' content-related professional knowledge and teachers' self-efficacy to be weaker in this phase of the professional life. After some time in the profession the teacher gets used to the new demands and adapts their content-related professional knowledge to the new demands (e.g., by the integration of different knowledge types; Berliner, 2001;

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Krauss et al., 2008a). Mastery experiences related to the teaching activity are now more likely. Accordingly, I assume a stronger relationship between teachers' content-related professional knowledge and teachers' self-efficacy in this phase of the professional life. I am currently planning a project which focuses on the complex interrelationships that occur within teachers' professional competence. This project aims to examine how these interrelationships change when teachers finish their teacher education program at the university and start the second phase of teacher education as a trainee teacher. This project could help to support my mentioned assumptions.

Instrument development

As stated in the beginning, teachers' content-related professional knowledge is conceptualized as *formal knowledge* (cf. Fenstermacher, 1994). A further focus on the practical knowledge of teachers would allow a deeper insight into the unique body of knowledge of teachers. For instance, a further investigation of the role of teaching experience would be possible, as experience is described as important source for *practical knowledge* (Baumert & Kunter, 2013; Fenstermacher, 1984). The assessment of teachers' practical knowledge requires the application of methods that go beyond paper and pencil tests. Lesson vignettes are an example for a more activity-related approach. Further research on how teachers' professional competence could be validly measured in a more situational and activity-related manner is needed.

CuK was measured in a very narrow manner in my dissertation. The items refer to factual knowledge related to the *National Educational Standards for the Intermediate School Leaving Certificate in Biology* (KMK, 2004a). As educational standards play a superordinate role in several countries (for example standards related to science education: ACARA, 2013; DfE, 2013; EDK, 2011; KMK, 2004a; NGSS, 2013), a further investigation of CuK is, to my opinion, of crucial importance. In order to do this, a more predictive instrument has to be developed. This instrument should not only focus on factual knowledge, but rather on the consequences the standards have for lesson planning and for the conduction of lessons. As different countries draw on different standards, the instrument should be easily adaptable to the requirements of other countries. The identification of overarching concepts that guide education in several countries would be beneficial. Such superordinate concepts for science

education are for instance *system* or *energy* (ACARA, 2013; DfE, 2013; EDK, 2011; KMK, 2004a; NGSS, 2013).

Going beyond linear relationships

I exclusively focus on linear relationships in my studies. However, other non-linear relationships could also exist. An example for a possible non-linear relationship is a u-shaped relationship. The consideration of a u-shaped relationship could for instance be interesting in terms of the relationship between teachers' self-efficacy and their teaching experience. The assumption is that prospective teachers have a relatively high level of self-efficacy when they finish their teacher education program at university. When they enter the profession, however, they have to bridge the gap between theory and practice, which is very demanding (Brouwer & Korthagen, 2005; Korthagen, 2009). Therefore, the demands change after leaving university and thus the possibility to have master experiences in the first time spent in the profession is less likely. Accordingly, the level of self-efficacy decreases. With the time spent in the profession, the teacher gets used to the new demands and has time to integrate knowledge (Krauss et al., 2008a). Accordingly, the level of self-efficacy increases and a u-shaped relationship appears.

Going beyond direct relationships

In the four studies conducted I focused on direct relationships. Nevertheless, I also assume different indirect relationships, which are important to further understand teachers' professional competence.

Against my hypothesis, I found no relationship between teachers' CK and students' performance. Nevertheless, according to the empirical (Baumert et al., 2010; Hill et al., 2005; Ohle, Fischer, & Kauertz, 2011; Rowan et al., 1997; Sadler et al., 2013) and theoretical (Baumert & Kunter, 2006; Cochran & Jones, 1998; Darling-Hammond, 2000b; Hashweh, 1987; Leinhardt & Smith, 1998; Rowan et al., 1997; Shulman, 1986) support of its relevance for students' performance, I do not assume that CK is irrelevant. I rather assume that CK is particularly important in a phase previous to teaching in the classroom, namely for the development of PCK during teacher education at university. This assumption is supported by different scholars, who identify CK to be a relevant prerequisite

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of PCK (Ball et al., 2001; Großschedl et al., 2015; Ma, 1999; Magnusson et al., 1999; Riese & Reinhold, 2012). More detailed, I assume that the relationship between teachers' CK and students' performance is mediated by PCK. Accordingly, a mediation analysis with PCK as mediator would help to gather an insight into this indirect relationship. As CK and PCK have been simultaneously measured in the framework of my dissertation, I am not able to examine this indirect effect. The previously mentioned longitudinal design (e.g., in the framework of the KeiLa-project) would provide an adequate research design for this question.

Furthermore, the consideration of possible indirect effects could help to understand the meaning of teacher enthusiasm for students' performance. This examination includes the integration of the different research traditions concerning teacher enthusiasm. Motivational orientations are an important prerequisite for behavior (Schiefele & Schaffner, 2015; Woolfolk, 2008). Accordingly, I assume that teacher enthusiasm (as conceptualized in my dissertation) leads to enthusiastic behavior which in turn impacts on students' performance. In this case, the enthusiastic behavior of teachers' would mediate the relationship between teacher enthusiasm and students' performance. Further research is needed to examine the relationship between the two conceptualizations of teacher enthusiasm. In order to do this, a research design that combines the evaluation of teachers' enthusiasm (as it is conceptualized here) by using a paper and pencil test with the observation of teacher behavior is needed. I assume that such an integrated approach would provide beneficial opportunities for a further understanding of teacher enthusiasm and its significance for students' performance.

Other possible mediators which could help to understand the significance of teachers for students' performance are lesson planning, the quality of instruction or the level of cognitive activation.

Further aspects of teachers' professional competence and teacher effectiveness

I considered teachers' content-related professional knowledge as well as teachers' motivational orientations as important aspects of professional competence and teacher effectiveness. This importance is supported by the results of my studies. Nevertheless, a broader look on how an effective teacher could be characterized would be interesting. This

concerns further aspects of teachers' professional competence as well as outcomes that go beyond students' performance.

As stated in the beginning, teachers' (P)PK represents a further domain of teachers' professional knowledge (Shulman, 1987; Baumert & Kunter, 2006; Hohenstein, Köller, & Möller, 2015; Hohenstein, Kleickmann, Zimmermann, Köller, & Möller, in press). The assumption is that (P)PK acts as a further important predictor for the performance of students. This is stressed by Voss et al. (2014), who describe (P)PK to be important for different characteristics of effective teaching and learning (e.g., the prevention of disruption and the constructive support of students). Considering this domain in my multilevel model could have helped to further explain the variance in students' performance.

Beyond students' performance, the motivation of students is a very important outcome when thinking about an effective teacher (e.g., Kunter et al., 2011). Reviewing the literature reveals that teachers' motivational orientations have impact on students' motivational orientations. More detailed, teachers' self-efficacy is described to impact on students' motivation (Midgley, Feldlaufer, & Eccles, 1989), whereas teacher enthusiasm is described to impact on students' enthusiasm (Hatfield et al., 1994). What is important to mention is that not only student outcomes are relevant when thinking about an effective teacher. Teacher outcomes like health or the level of job stress are very important, too, considering the high demands in the teaching profession (e.g., Baumert & Kunter, 2013; Brouwer & Korthagen, 2005; Korthagen, 2009; Stoeber & Rennert, 2008).

Teachers' technology-related professional knowledge and self-concept

The conceptualization of teachers' professional competence in this dissertation is strongly related to the demands of the teaching profession. The demands in the teaching profession changed over time. What characterizes the current situation is the increasing implementation of technologies (e.g., tablet computers or interactive whiteboards) in schools. This leads to new challenges and teachers often have concerns due to a lack of knowledge and a lack of support (IQSH, 2015). Nevertheless, the use of technologies seems fruitful as it improves students' media literacy and facilitates learning of abstract concepts (e.g., in science subjects as biology) (BMBF, 2010; Maxton-Küchenmeister & Meßinger-Koppelt, 2014; Weizel, 2013;

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Yerrick, 2010). Accordingly, further research in this field is important to widen up the understanding of professional competence according to these new demands.

This is the aim of the currently started project DigiLaB (*Digitale Medien in der Lehramtsausbildung Biologie*) (Mahler & Arnold, in prep.). This project aims to examine the technology-related self-concept and the technology-related professional knowledge of prospective biology teachers in order to understand the underlying mechanisms for the implementation of technologies in the planning and conduction of lessons. The assumption is that technology-related professional knowledge does not directly lead to the implementation of technologies. We rather assume that this relationship is mediated by the technology-related self-concept of the teachers. Findings concerning the relationship between professional knowledge and self-concept (e.g., Paulick, Großschedl, Harms, & Möller, 2016) and concerning the relationship between self-concept and the intention to act (e.g., Schöne et al., 2003) support this assumption. We draw on the model of Mishra and Koehler (2006), who made an important step to examine this assumed relationship. They developed the TPACK-model which is grounded on the domains of professional knowledge initially described by Shulman (CK, PCK, and PK). This model represents an expansion of the original understanding by adding a technological component. The expanded model comprises, beyond the traditional domains, the technological domains: (1) technological knowledge (TK), (2) knowledge of technology related to a certain content, i.e., technological content knowledge (TCK), (3) knowledge of the implementation of technology to improve learning processes, i.e., technological pedagogical knowledge (TPK), and (4) knowledge of the implementation of technology to improve content-related learning processes, i.e., technological pedagogical content knowledge (TPCK). We are currently validating an instrument which we developed to assess the technology-related self-concept of teachers. As a next step, we aim to develop an instrument which validly measures teachers' TPACK as there is no instrument available to date. Developing an instrument which focuses on TPACK is especially challenging as a normal paper and pencil test does presumably not allow to validly measure teachers' TPACK. My assumption is that this requires the development of action-related items which include the use of certain technologies (e.g., tablet computers).

10.7 Implications for Teacher Education

The integration of the results of the four studies allows for concrete implications in terms of a tailored teacher education. My results indicate that PCK and teacher enthusiasm are important characteristics of effective teachers. Moreover, I found PCK and teacher enthusiasm to not act in an isolated manner, but to be related to other domains of teachers' content-related professional knowledge and teachers' motivational orientations. Finally, I identified beneficial opportunities for the development of PCK and teacher enthusiasm, namely teacher education at university, the attendance in professional development courses, and the conduction of self-study. These findings lead to the following implications for teacher education.

Improvement of PCK

According to its relevance, teachers' PCK should be consequently fostered during teacher education at university and during the whole professional life. Teacher education at university should provide a wide range of courses which explicitly focus on the improvement of PCK. Moreover, practical phases during this first phase of teacher education additionally provide beneficial opportunities for the development of PCK (Großschedl et al., 2015). During the professional life of teachers, professional development courses should also focus on issues related to teachers' PCK (e.g., professional development courses which concern students' understanding related to a certain subject-related topic like photosynthesis).

Improvement of teacher enthusiasm

Teacher education at university should, beyond its focus on the acquisition of knowledge, also aim to foster teacher enthusiasm. I assume three aspects to be beneficial in order to foster teacher enthusiasm.

First of all, courses which explicitly aim at the improvement of teacher enthusiasm or which have a more motivation-related focus should be developed. Dealing with stress and failure or time management are relevant topics in this context. This concerns both teacher education at university and professional development courses during the professional life of teachers.

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Furthermore, also courses which aim at the acquisition of content-related professional knowledge should be regarded as important opportunities for the development of teacher enthusiasm. This consideration is grounded on the assumption that content-related professional knowledge enables the teacher to act and to feel competent during teaching. As already stated, the experience of competence is important for the manifestation of intrinsic motivation (Deci & Ryan, 2000), which is closely related to enthusiasm (Kunter et al., 2011; Wigfield & Eccles, 2000).

Finally, the communication of empirical findings on teacher effectiveness in courses at university and in professional development courses could support the experience of the own competence and increase the level of teacher enthusiasm. Studies which are, in my opinion, adequate to illustrate the relevance of teachers are the Coactiv study (e.g., Baumert & Kunter, 2013) as well as the meta-analysis conducted by Hattie (2009). Also, the findings of my third and fourth study stress the relevance of teachers. The consideration of empirical studies in teacher education includes the preparation of the study results in a vivid manner. For instance, Hattie (2009) additionally presented his study in a way that is vivid and useful for teachers.

Implementation of integrated courses

My results reveal that the domains of teachers' content-related professional knowledge as well as the domains of teachers' motivational orientations are separable but correlated. These correlations concern not only the relationships within one competence aspect (content-related professional knowledge or motivational orientations), but also the relationships between domains of teachers' content-related professional knowledge and motivational orientations. This finding indicates that the domains of professional competence should not be considered in an isolated manner. This is a very important point when thinking about the orientation of teacher education at university. More detailed, different courses are provided which focus on the content (i.e., related to CK) or on teaching the content (i.e., related to PCK or CuK). As my results reveal that CK, PCK, and CuK are related constructs, an integration of these domains in teacher education at university also seems useful. An example for a beneficial integration is the consideration of both the content and teaching the content, i.e., the integration of CK and PCK. Prospective teachers could learn

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about a specific content (e.g., photosynthesis), but could simultaneously be taught about learning problems which can occur when teaching this content or be taught about representations which are useful for teaching this. The consideration of the embedding of the respective content in the educational standards (CuK) would be even more fruitful. The call for an integration of the domains of content-related professional knowledge should not neglect the relevance of courses during teacher education which exclusively focus on one single domain of content-related professional knowledge. Nevertheless, my findings indicate that additional courses which aim at the integration of knowledge would be beneficial to help prospective teachers to bridge the gap between theory and practice when they enter the teaching profession.

Improvement of in-service teacher education

The attendance in professional development courses provides opportunities to develop both content-related professional knowledge as well as motivational orientations (see study 1 and 2; see also Bettencourt et al., 1983; Brunner et al., 2006; Campbell, 1996; Clermont et al., 1993; Collins, 1978; Roness, 2011). Although its relevance for the development of teachers' professional competence is empirically supported, the guidelines for the attendance in professional development courses are not very strict. The mandatory amount of professional development varies between the different federal states or is not regulated at all (see 2.5.2). Schools should provide incentives for the voluntary attendance in professional development courses. As teachers' suffer from a high level of job stress (Stoeber & Rennert, 2008), the possibility to substitute lessons could be fruitful.

I identified self-study as beneficial for the development of content-related professional knowledge as well as teachers' motivational orientations. The effectiveness of the conduction of self-study strongly depends on the teacher. The effective conduction of self-study should be already initiated prior to the entry in the teaching profession. Teacher education at university should provide strategies for effective self-study (e.g., strategies for literature research). Furthermore, schools could help their teachers to conduct self-study by providing access to relevant journals.

11 CONCLUSIONS

„Those who can, do. Those who understand, teach.“

Shulman (1986) ends his popular article with rewriting the quote he stated in the beginning. The results of my studies support this considerably more optimistic view as they reveal that an effective teacher is characterized by different profession-specific and learnable aspects both of cognitive and affective nature.

The aims of my dissertation were to gather a deeper insight into the structure of teachers' professional competence, to identify important opportunities for the development of teachers' professional competence, and to examine the significance of teachers' professional competence for students' performance. The strength of this work is that it takes a holistic view on teachers' professional competence by considering both content-related professional knowledge and motivational orientations. Moreover, this work is the first which explicitly examines CuK in detail. Regarding the relevance of the national educational standards in Germany and in other countries all around the world, a stronger focus on this domain of content-related professional knowledge – as it was conceptualized in my work – is absolutely necessary. A further strong point of my work is the detailed look on teachers' motivational orientations. This is the first work which simultaneously focuses on both cognitive domains (i.e., self-efficacy) as well as affective domains (i.e., teacher enthusiasm). Moreover, the consideration of the object of teachers' enthusiasm allows a deep insight into teachers' affective orientations.

The results of this work significantly contribute to the field of research on teachers' professional competence and help to improve teacher education in terms of a tailored approach.

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APPENDIX

Appendix A - Measures – Teacher Level

Content knowledge/Fachwissen (Großschedl, Mahler, Kleickmann, & Harms, 2014)

Bitte beantworten Sie die folgenden biologischen Fragen, indem Sie die für Sie zutreffende Antwort ankreuzen. In diesem Teil des Fragebogens ist immer nur eine Antwort richtig. Wenn Sie eine Antwort korrigieren möchten, kennzeichnen Sie dieses bitte deutlich.

1. **Das Nervensystem der Muschel ist ein ...**
 - Strickleiternnervensystem.
 - Nervensystem mit drei zentralen Ganglienpaaren.
 - zentrales Nervensystem mit Gehirn.
 - vegetatives Nervensystem.

2. **Was unterscheidet die Miesmuscheln von allen anderen heimischen Muschelarten?**
 - Die Miesmuschel filtert das Meerwasser.
 - Die Miesmuschel besitzt einen Fuß, mit dem sie sich fortbewegen kann.
 - Die Miesmuschel lebt nur oberirdisch auf dem Meeresboden.
 - Die Miesmuschel produziert freischwebende Larven.

3. **Die Miesmuschel produziert einen körpereigenen „Klebstoff“, der aufgrund seiner hohen Elastizität und Festigkeit für die Industrie von großem Interesse ist. Um welchen körpereigenen Stoff der Miesmuschel handelt es sich?**
 - Scheinkot
 - Hormon
 - Sekret
 - Proteinfaden

4. **Aufgrund ihrer Lebensweise sind Miesmuscheln für Biologen und Toxikologen sehr interessant. Welche Aussage ist zutreffend?**
- Miesmuscheln filtern in kurzer Zeit große Mengen an Meerwasser. Diesen Vorteil machen sich die Biologen und Toxikologen zu Nutze. Sie verwenden Miesmuscheln zur Säuberung von Seen und Teichen.
 - Miesmuscheln geben beim Filtrieren Schlick ab. Diesen nutzen Biologen und Toxikologen für die Analyse des Meerwassers.
 - Miesmuscheln nehmen mit dem Meerwasser Schadstoffe und Gifte auf. Diese lagern sich im Körper der Miesmuscheln ab. Biologen und Toxikologen analysieren die Miesmuscheln und können Rückschlüsse auf die Schadstoffbelastung des Wassers ziehen.
 - Biologen und Toxikologen können anhand der Färbung der Kalkschale der Miesmuschel Aussagen über die Wasserqualität tätigen.
5. **Für einen Demonstrationsversuch wird Schlickwasser in zwei Bechergläsern (1l Volumen) angesetzt. In eines der Bechergläser werden 5 – 10 Miesmuscheln hineingesetzt (siehe Abb.1). Nach etwa 20 Minuten schauen Sie sich beide Bechergläser wieder an und vergleichen. Was können Sie feststellen?**
- Es gibt keinen Unterschied zwischen den beiden Bechergläsern.
 - Im Becherglas mit den Miesmuscheln hat die Trübung des Wassers abgenommen.
 - Im Becherglas mit den Miesmuscheln hat die Trübung des Wassers zugenommen.
 - Die Miesmuscheln haben den Versuch nicht überlebt.
6. **Das Wattenmeer stellt einen Lebensraum der Miesmuscheln dar. Was passiert mit den Miesmuscheln bei Ebbe?**
- Die Miesmuscheln werden mit dem Wasser weggespült, da sie sonst vertrocknen. Bei Flut spült sie das Wasser wieder zurück.
 - Die Miesmuscheln graben sich für einige Stunden im feuchten Wattboden ein und bleiben so geschützt.
 - Die Miesmuscheln schließen ihre Schalen und überleben mit einem kleinen Wasservorrat.
 - Da Miesmuscheln nur im sublitoralen Bereich (ständig unter Wasser) leben, ist die Ebbe für sie kein Problem.
7. **Warum haben Muschelfischer einen großen Einfluss auf die Population der Eiderenten?**
- Muschelfischer ernten die Jungmuscheln auf den küstennahen Muschelbänken und entziehen den Eiderenten damit die Nahrungsgrundlage im Wattenmeer.
 - Muschelfischer schießen zum Schutz ihrer Miesmuschelkulturflächen die Eiderenten ab.
 - Infolge der Muschelzucht steht den Eiderenten eine immer größer werdende Menge an Miesmuscheln als Nahrung zu Verfügung.
 - Muschelfischer legen zum Schutz ihrer Miesmuschelkulturbänke Fangnetze aus, in denen die Eiderenten hängen bleiben und sterben.

8. **Welches der folgenden Beispiele stellt kein System per Definition dar?**
- Sonnenblume
 - Fahrrad
 - Sandhaufen
 - Zelle
9. **Welche der folgenden Erklärungen beschreibt den Begriff „Sukzessionen“ richtig? Sukzessionen sind...**
- ...kurzfristige Änderungen innerhalb eines Ökosystems, die keinen bleibenden Einfluss auf die Lebensgemeinschaft haben.
 - ...langfristige Entwicklungsprozesse von Ökosystemen, die mit einem Ausgangsstadium beginnen und über zahlreiche Zwischenphasen in eine Schlussgesellschaft einmünden.
 - ...langfristige Entwicklungen, bei denen das Ökosystem über zahlreiche Zwischenphasen wieder zum Ausgangsstadium zurückkehrt.
 - ...eine Reihe von parallel verlaufenden Umwandlungsprozessen, die zu einer spontanen Veränderungen des Ökosystems führen.

In diesem Teil des Fragebogens kann mehr als eine Antwort richtig sein. Dabei ist es auch möglich, dass alle Antworten richtig sind.

Bitte beantworten Sie die folgenden biologischen Wissensfragen, indem Sie die für Sie zutreffenden Antworten ankreuzen.

10. **Welche Merkmale zeichnen gleichwarme Tiere gegenüber den wechselwarmen Tieren aus?**
- Der Nahrungs- und Energiebedarf ist sehr niedrig.
 - Die Aktivitätsmöglichkeiten der Tiere sind weitgehend unabhängig von den Außentemperaturen.
 - Sie regulieren ihre Körpertemperatur durch geeignetes Verhalten.
 - Sie können fast alle Lebensräume der Erde besiedeln.
11. **Welche der folgenden abiotischen Faktoren bestimmen die Lebensbedingungen im Meer?**
- Salzkonzentration
 - Temperaturverhältnisse
 - Lichtverhältnisse
 - Windverhältnisse

12. **Muschelbänke sind für Miesmuscheln wichtig. Haben sie darüber hinaus einen Nutzen für das Ökosystem Meer?**
- Ja, Muschelbänke bieten Siedlungsflächen für eine Vielzahl von Tier- und Pflanzenarten.
 - Nein, Muschelbänke sind nur für die Miesmuscheln und ihren Nachwuchs wichtig.
 - Ja, Muschelbänke stellen für viele Tierarten eine Nahrungsquelle dar.
 - Ja, durch die Miesmuscheln wird der Meeresboden stabilisiert.
13. **Aristoteles (384 – 322 v. Chr.) ist einer der ersten großen Systematiker und von ihm stammt das Zitat: „Das Ganze ist mehr als die Summe seiner Teile“. Was wird mit diesem Satz ausgesagt?**
- Um ein System zu verstehen, ist es nicht ausreichend, die einzelnen Systemelemente und deren Eigenschaften zu kennen.
 - Die Eigenschaften der einzelnen Systemelemente ergeben zusammen die Eigenschaft des gesamten Systems.
 - Um ein System zu verstehen, muss man die Zusammenhänge zwischen den einzelnen Systemelementen kennen und verstehen.
 - Ein System kann durch das Verständnis seiner isolierten Systemelemente erfasst werden.
14. **Die Ursache-Wirkungsbeziehung ist eine Beziehung zwischen Elementen im System. Was bedeutet diese Beziehung?**
- Die Wirkung bedingt nicht nur eine Reaktion, sondern wirkt auf andere Elemente.
 - Der Output steht in direkter oder indirekter Beziehung zum Input.
 - Ein Input hat eine bestimmte Wirkung zur Folge.
 - Eine Wirkung wirkt auf das Ausgangselement zurück.
15. **Was ist der Unterschied zwischen einer wilden Muschelbank und einer Muschelbank in der Zuchtanlage?**
- Im Gegensatz zu der wilden Muschelbank ist die Muschelbank in der Zuchtanlage sehr langlebig.
 - Im Gegensatz zu der wilden Muschelbank ist die Muschelbank in der Zuchtanlage artenarm.
 - Im Gegensatz zu der wilden Muschelbank liegt die Muschelbank in der Zuchtanlage in einem geschützten Bereich, indem die Miesmuscheln geringeren Gefährdungen ausgesetzt sind.
 - Im Gegensatz zu der wilden Muschelbank bietet die Muschelbank in der Zuchtanlage der Flora und Fauna einen vielfältigen Lebensraum.

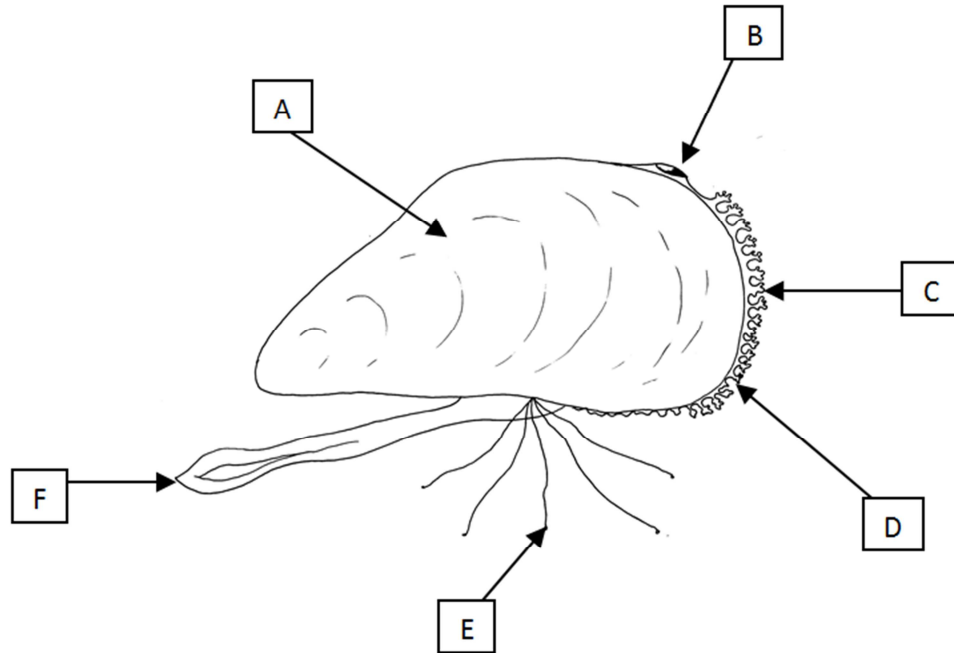
16. Welche der folgenden Aussagen bezüglich des Schalenaufbaus der Weichtiere sind richtig?

- Die Schale der Weichtiere besteht aus drei Schichten.
- Die Schale der Weichtiere besteht aus einem derben Mantelepithel.
- Die Schale der Weichtiere besteht aus einer organischen Schicht aus Lipiden und einer inneren Perlmuttertschicht.
- Die Schale der Weichtiere besteht aus einer organischen Schicht aus Glykoproteinen, einer äußeren Prismenschicht und einer inneren Perlmuttertschicht.

17. Welche der folgenden Aussagen zum Begriff „Raspelorgan“ sind richtig?

- Das Raspelorgan dient der Fortbewegung.
- Das Raspelorgan dient dem Abraspeln von Nahrung.
- Das Raspelorgan kommt nicht bei Muscheln vor.
- Das Raspelorgan dient der Umhüllung der Spermien vor der Kopulation.

18. Bitte beschriften Sie die folgende Abbildung einer Muschel.

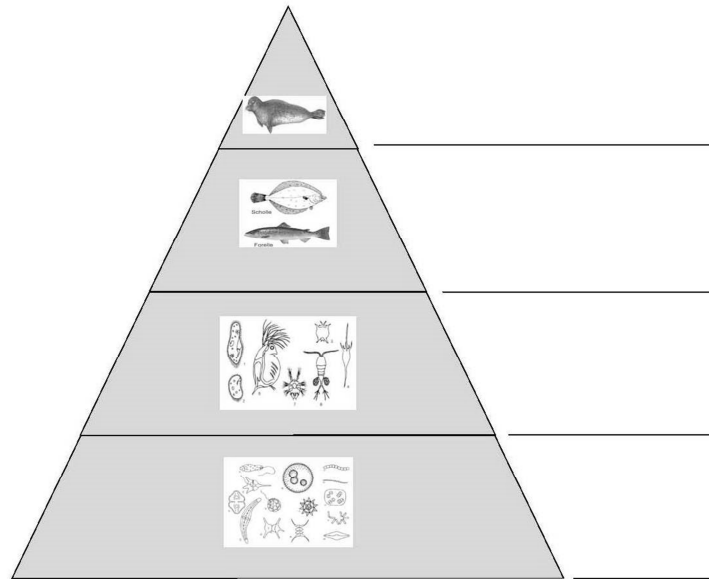


A: _____ B: _____
 C: _____ D: _____
 E: _____ F: _____

APPENDIX

19. **Die Abbildung zeigt eine Nahrungspyramide.**

Bitte benennen Sie die einzelnen Stufen der Nahrungspyramide. Verwenden Sie dazu die Fachtermini.



Pedagogical content knowledge/Fachdidaktisches Wissen (Großschedl et al., 2014)

Bitte beantworten Sie die folgenden fachdidaktischen Fragen. Wenn Sie eine Antwort korrigieren wollen, streichen Sie die falsche Antwort bitte deutlich durch.

1. **Ein Referendar hat im Biologieunterricht einer 8. Klasse ausführlich eine Unterrichtseinheit zum Thema „Schnecken“ behandelt. Die Schülerinnen und Schüler sollen nun die Besonderheiten der übrigen Klassen der Weichtiere in einer vergleichenden Übersicht zusammentragen.**

Skizzieren Sie, wie der Referendar die Unterrichtsstunde gestalten sollte, damit die Schülerinnen und Schüler ihr eigenes Interesse in die Aufgabenlösung einbringen können.

2. **Ein Referendar hat in einer 8. Klasse ein Experiment zur Filterleistung der Miesmuscheln durchgeführt. Nach der Unterrichtsstunde geben Sie ihm den Hinweis, dass es sinnvoll gewesen wäre, wenn die Schülerinnen und Schüler bei der Durchführung des Experimentes ein Protokoll erstellt hätten.**

Erläutern Sie, warum die Erstellung eines Protokolls beim Experimentieren für die Schülerinnen und Schüler bedeutsam ist.

3. **Schülerinnen und Schüler der 8. Klasse sollen selbstständig ein Experiment planen und durchführen.**

Bitte nennen Sie mögliche Defizite der Schülerinnen und Schüler beim Planen eines Experimentes sowie bei der Auswertung und Interpretation der Daten.

4. **Die Schülerinnen und Schüler der 8. Klasse haben in einer vorherigen Stunde gelernt, dass Miesmuscheln zum Atmen Wasser benötigen.**
Bitte skizzieren Sie kurz einen problemorientierten Unterrichtseinstieg in das Thema „Überleben der Miesmuscheln bei Ebbe“.
5. **Bitte nennen und beschreiben Sie die vier Kompetenzbereiche, die in den Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2004) dargestellt sind.**
6. **In den Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2004) bilden drei Basiskonzepte die inhaltliche Dimension der zu erwerbenden Kompetenzen ab.**
Bitte nennen Sie diese drei Basiskonzepte!
7. **Ein Referendar möchte zu Beginn der Unterrichtsstunde die Schülervorstellungen zur Thematik „Die Rolle des Menschen in der Natur“ erfassen. Er bittet Sie um fachdidaktische Hilfe.**
Stellen Sie zwei verschiedene Methoden dar, wie der Referendar die Schülervorstellungen erheben kann.
8. **Schülerinnen und Schüler der 5. Klasse erhalten die Aufgabe verschiedene Lebewesen zu selbstgebildeten Tiergruppen zuzuordnen.**
Nennen Sie vier fachlich falsche Kriterien nach denen die Schülerinnen und Schüler vermutlich die Lebewesen ordnen werden.
9. **Sie möchten in einer 8. Klasse die Ernährungsweise der Miesmuschel erklären.**
Skizzieren Sie drei Möglichkeiten, wie Sie den Schülerinnen und Schülern den Inhalt des folgenden wissenschaftlichen Textes verständlich darstellen können.

Curricular knowledge/Curriculares Wissen (Großschedl et al., 2014)

Bitte beantworten Sie die folgenden fachdidaktischen Fragen. Wenn Sie eine Antwort korrigieren wollen, streichen Sie die falsche Antwort bitte deutlich durch.

1. **Nach den Bildungsstandards müssen Schülerinnen und Schüler mit einem Mittleren Schulabschluss im Fach Biologie Kompetenzen erworben haben, die neben der inhaltlichen Dimension (Wissen fachlicher Inhalte) auch die Handlungsdimension umfassen (KMK, 2004).**
Bitte erläutern Sie kurz, was unter der Handlungsdimension verstanden wird!
2. **In den Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2004) steht: „Die Schülerinnen und Schüler beschreiben und beurteilen die Auswirkungen menschlicher Eingriffe in ein Ökosystem“ (B5).**
Stellen Sie dar, wie dieser Standard in Ihrem Biologieunterricht in der 8. Klasse zur Thematik Miesmuschel berücksichtigt werden kann.

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3. **In einer 8. Klasse beginnt ein Referendar die Unterrichtseinheit „Weichtiere“, indem er die drei Klassenbezeichnungen „Muscheln“, „Schnecken“ und „Kopffüßer“ an die Tafel schreibt. Ein Schüler meldet sich und fragt, warum er die Quallen nicht an die Tafel geschrieben hat.**

Beschreiben Sie, wie der Referendar seinen Unterricht besser gestalten kann, um die Vorstellungen der Schülerinnen und Schüler aufzugreifen und sie dann in den Unterrichtsverlauf zu integrieren.

4. **In den Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2004) werden drei Anforderungsbereiche für Aufgaben dargestellt. Diese bilden die verschiedenen Schwierigkeitsgrade innerhalb ein und derselben Kompetenz ab.**

Erläutern Sie kurz, welche Anforderungen diese drei Anforderungsbereiche jeweils abbilden.

Anforderungsbereich I: _____

Anforderungsbereich II: _____

Anforderungsbereich III: _____

Subject-specific enthusiasm/Fachbezogener Enthusiasmus (Baumert et al., 2009)

Inwieweit treffen folgende Aussagen für Ihren Biologieunterricht zu? Bitte beurteilen Sie die Aussagen, in dem Sie das zutreffende Kästchen ankreuzen. Wenn Sie eine Antwort korrigieren wollen, streichen Sie bitte das falsche Kästchen deutlich durch.

1. **Ich finde, dass Biologie ein spannendes Fach ist.**

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

2. **Ich versuche im Unterricht, die Schülerinnen und Schüler für das Fach Biologie zu begeistern.**

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

3. **Ich bin selbst von Biologie als Wissenschaft begeistert.**

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

Enthusiasm for teaching the subject/Enthusiasmus für das Unterrichten eines Faches
(Baumert et al., 2009)

Inwieweit treffen folgende Aussagen für Ihren Biologieunterricht zu? Bitte beurteilen Sie die Aussagen, in dem Sie das zutreffende Kästchen ankreuzen. Wenn Sie eine Antwort korrigieren wollen, streichen Sie bitte das falsche Kästchen deutlich durch.

1. Das Unterrichten von Biologie macht mir großen Spaß.

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

2. Ich unterrichte Biologie mit Begeisterung.

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

Self-efficacy/Selbstwirksamkeitserwartungen (Schmitz & Schwarzer, 2000)

Inwieweit treffen folgende Aussagen für Ihren Biologieunterricht zu? Bitte beurteilen Sie die Aussagen, in dem Sie das zutreffende Kästchen ankreuzen. Wenn Sie eine Antwort korrigieren wollen, streichen Sie bitte das falsche Kästchen deutlich durch.

1. Ich weiß, dass ich es schaffe, selbst den problematischsten Schülerinnen und Schülern den prüfungsrelevanten Stoff zu vermitteln.

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

2. Ich weiß, dass ich zu den Eltern guten Kontakt halten kann, selbst in schwierigen Situationen.

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

3. Ich bin mir sicher, dass ich auch mit problematischen Schülerinnen und Schülern in guten Kontakt kommen kann, wenn ich mich darum bemühe.

- stimmt nicht
- stimmt kaum
- stimmt eher
- stimmt genau

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4. **Ich bin mir sicher, dass ich mich in Zukunft auf individuelle Probleme der Schülerinnen und Schüler noch besser einstellen kann.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau
5. **Selbst wenn mein Unterricht gestört wird, bin ich mir sicher, die notwendige Gelassenheit bewahren zu können.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau
6. **Selbst wenn es mir mal nicht so gut geht, kann ich doch im Unterricht immer noch gut auf die Schülerinnen und Schüler eingehen.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau
7. **Auch wenn ich mich noch so sehr für die Entwicklung meiner Schülerinnen und engagiere, weiß ich, dass ich nicht viel ausrichten kann.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau
8. **Ich bin mir sicher, dass ich kreative Ideen entwickeln kann, mit denen ich ungünstige Unterrichtsstrukturen verändere.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau
9. **Ich traue mir zu, die Schülerinnen und Schüler für neue Projekte zu begeistern.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau

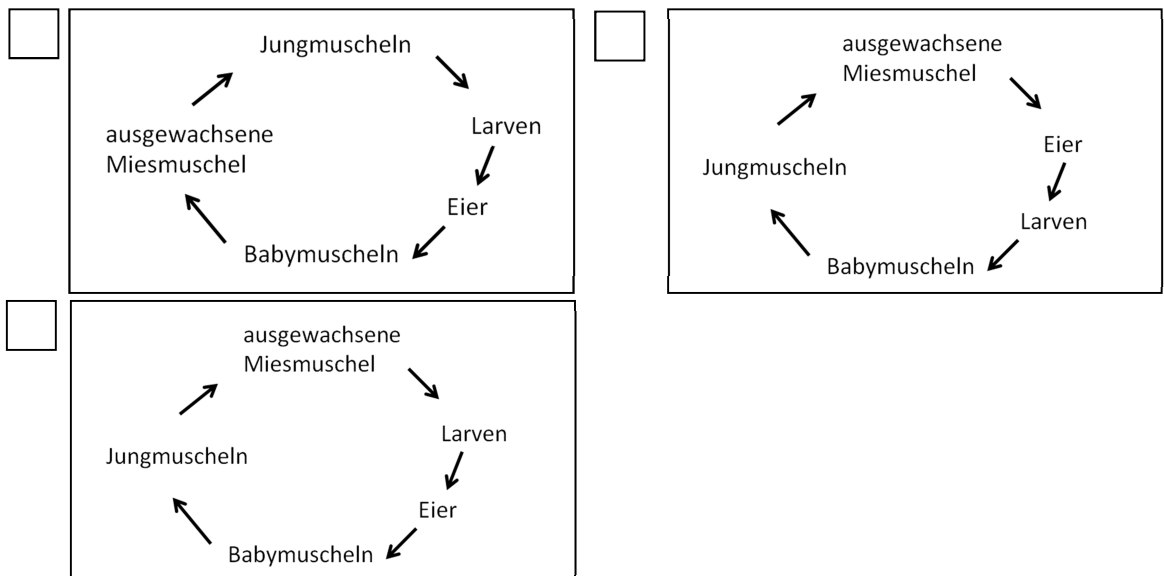
10. **Ich kann innovative Veränderungen auch gegenüber skeptischen Kolleginnen und Kollegen durchsetzen.**
- stimmt nicht
 - stimmt kaum
 - stimmt eher
 - stimmt genau

Appendix B – Measures – Student Level

System thinking/Systemdenken (Brandstädter, Harms, & Großschedl, 2012)

1. **Wie viele Miesmuscheln können auf einer Muschelbank leben?**
- 10 - 100
 - 100 - 200
 - 200 - 800
 - viele tausend
2. **Du sollst einem Freund erklären, wie sich Miesmuscheln ernähren. Welche Begriffe brauchst du? Kreise ein!**
- Einströmöffnung Luft Plankton Wasser filtern
 kauen Ausströmöffnung Sauerstoff

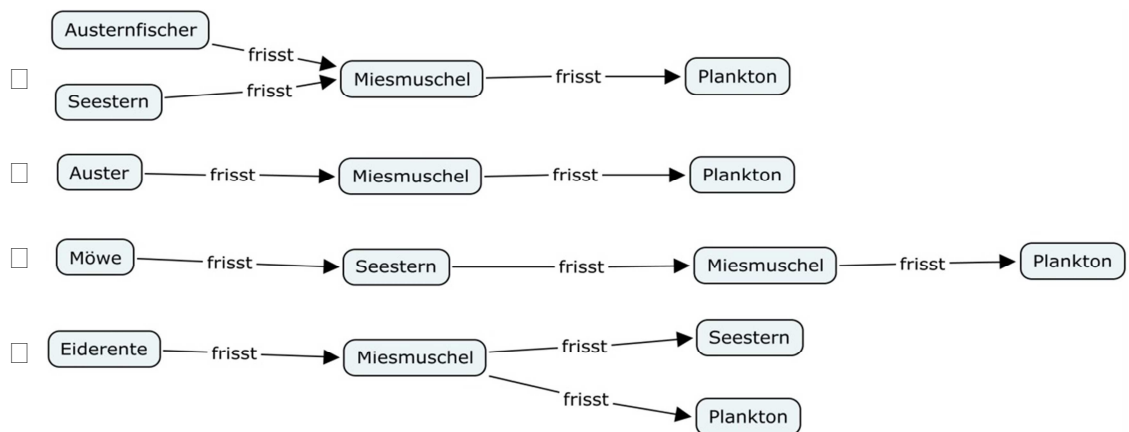
3. **Welcher Kreislauf ist richtig?**



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4. **Jedes Miesmuschelweibchen produziert Millionen Eier im Frühjahr.
Warum sind so viele Eier sinnvoll?**
- Viele Eier werden gefressen, deshalb müssen sie so viele produzieren.
 - Das hat keinen bestimmten Grund.
 - Die Muscheln fühlen sich von Feinden bedroht, deshalb produzieren sie so viele Eier.
 - Viele Eier werden weggespült, deshalb müssen sie so viele produzieren.
5. **Warum filtern Miesmuscheln das Meerwasser?**
- um ihren Muschelkörper sauber zu spülen
 - um zu atmen
 - um Nahrungsteilchen heraus zu filtern
 - um Seesterne zu vertreiben
6. **Das Miesmuschelbecken in einer Nordsee-Ausstellung soll mit Algen bepflanzt werden.
Wird die Miesmuschel dadurch eingeschränkt?**
7. **Kreise alle Begriffe ein, die mit der Atmung der Miesmuschel zu tun haben!**
- | | | | | |
|----------------|----------|-----------------|-------------|------|
| Sauerstoff | Wasser | Austernfischer | Sand | Luft |
| Auströmöffnung | Plankton | Einströmöffnung | Miesmuschel | |
8. **Können Miesmuscheln atmen?**
- Nein, unter Wasser können Miesmuscheln nicht atmen.
 - Ja, aber nur bei Ebbe.
 - Ja, sie nutzen den Sauerstoff aus dem Wasser.
 - Nein, sie brauchen nicht zu atmen.
9. **Muschelfischer möchten viele Muscheln ernten. Die wilden Muschelbänke sind aber schon stark abgefischt.
Wie kommen sie trotzdem an ausreichend Miesmuscheln?**
10. **In einem Aquarium befinden sich Miesmuscheln und viel Plankton.
Wenn Seesterne hinzugesetzt werden, ...**
- nimmt die Menge des Planktons ab.
 - nimmt die Menge des Planktons zu.
 - bleibt die Menge des Planktons gleich.
 - nimmt die Menge der Miesmuscheln ab.

11. Wer frisst wen?



12. Was wäre, wenn die Miesmuscheln ihren Fuß nicht hätten?

- Sie könnten nicht vor Möwen flüchten.
- Sie könnten sich nicht festhalten.
- Sie könnten sich nicht fortpflanzen.
- Sie würden langsam im Schlamm versinken.

13. Austern sind viel härter als Miesmuscheln. Stell dir vor, in ein paar Jahren hätten die Austern die Miesmuscheln verdrängt.

Welche Folgen hätte das in der Zukunft für die Eiderenten?

14. Wie vermehren sich Miesmuscheln?

- Aus den großen Miesmuscheln wachsen winzig kleine Muscheln heraus.
- In den großen Muscheln wachsen Larven, daraus schlüpfen später kleine Muscheln.
- Sie produzieren Eier, die sie ins Meerwasser spülen, später schlüpfen daraus kleine Larven. Diese entwickeln sich zu Muscheln.
- Sie produzieren Larven, aus denen sich Eier entwickeln. Aus ihnen schlüpfen Muscheln.

15. Welche Dinge braucht die Miesmuschel nicht zum Leben? Streiche durch!

Seestern	Fuß	Sand	Mensch
Luft	Wasser	Sauerstoff	Schale

16. Bei besonders starken Stürmen kann es vorkommen, dass das Wasser bei Ebbe nicht richtig abfließt. Was bedeutet das für die Miesmuscheln?

- Die Miesmuscheln können länger atmen und fressen.
- Seesterne müssen nicht vor der Ebbe flüchten und können mehr Miesmuscheln fressen.
- Die Muscheln bekommen nicht genug Luft.
- Die Muscheln bekommen nicht genug Wasser.

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17. **Können Miesmuscheln ohne Wasser überleben?**
- Ja, kein Problem, das funktioniert unendlich lange.
 - Nein, sie können ohne den frischen Wasserstrom nicht überleben.
 - Nein, sie sterben sofort an der Luft.
 - Ja, aber nur für wenige Stunden.
18. **Austern greifen Miesmuscheln nicht an und fressen sie auch nicht. Warum sind Austern trotzdem eine ernste Bedrohung für die Miesmuscheln?**
19. **Warum sind Muschelbänke für das Wattenmeer wichtig?**
- Sie schützen Tiere, die in der Muschelbank leben.
 - Sie verwirren Feinde, die einzelne Muscheln nicht so leicht erkennen können.
 - Sie schützen die Miesmuscheln.
 - Sie bieten jungen Muscheln festen Grund zum Festkleben.
20. **Wie entstehen Muschelbänke?**
- Junge Muscheln werden durch das Wasser zusammengespült und bleiben als Haufen liegen.
 - Die Muscheln kleben sich aneinander und bilden so große Bänke.
 - Möwen treiben die Muscheln zusammen, so entstehen große Bänke.
 - Fischerboote treiben die Muscheln zusammen, so entstehen große Bänke.
21. **Bei Ebbe läuft das Wasser für einige Stunden ab und der Wattboden wird trocken. Was passiert mit den Miesmuscheln?**
- Sie lassen sich vom Wasser wegspülen, um nicht zu vertrocknen.
 - Sie halten sich aneinander auf dem Wattboden fest und überstehen dort die Ebbe.
 - Sie graben sich für einige Stunden im feuchten Wattboden ein.
 - Sie schließen ihre Schalen und überleben mit einem kleinen Wasservorrat.
22. **Wovon ernähren sich Miesmuscheln?**
- Sie filtern kleine Würmer.
 - Sie filtern kleine Teilchen aus dem Wasser.
 - Sie fressen Plankton.
 - Sie fressen kleine Fische.
23. **Welche Feinde hat die Miesmuschel? Kreise ein!**
- | | | | | |
|---------|---------|----------------|---------|------|
| Seehund | Flunder | Strandkrabbe | Scholle | Möwe |
| Mensch | Auster | Austernfischer | Hai | |
24. **Miesmuscheln können sich aneinander festkleben. Wie machen sie das?**
- mit ihrem Kot
 - mit Salzkristallen aus dem Wasser
 - mit Byssusfäden
 - mit Nahrung

25. **Welchen Unterschied gibt es zwischen natürlichen Muschelbänken und den Muschelzuchten?**
- Aus Muschelzuchten werden Seesterne entfernt.
 - Die natürlichen Muschelbänke können sehr alt werden.
 - Die Muschelzuchten werden häufig abgeerntet.
 - Aus natürlichen Muschelbänken werden Seesterne entfernt.
26. **Im Sommer kann es bei Ebbe im Watt sehr heiß werden. Wie schützen sich die Miesmuscheln vor der Hitze?**
- Sie öffnen die Schale ein wenig und kühlen durch den Luftzug ab.
 - Sie ziehen sich ins Wasser zurück.
 - Sie graben sich ein.
 - Sie verbrauchen nur wenig Wasser und begeben sich in eine Art „Schlafzustand“.

DANKSAGUNG

Ich habe während dieses wichtigen Lebensabschnitts sehr viel Unterstützung erfahren, für die ich mir an dieser Stelle herzlich bedanken möchte.

Mein allererster Dank geht an meine beiden Gutachterinnen Prof. Dr. Birgit Brouër und Prof. Dr. Ute Harms. Liebe Frau Brouër, ich möchte mich ganz herzlich bei Ihnen für Ihre Unterstützung bedanken. Ohne Sie wäre ich wohl nicht nach Kiel gekommen. Ganz herzlichen Dank auch dafür, dass Sie bereit waren, mich als Erstgutachterin zu betreuen. Liebe Frau Harms, ich möchte mich ganz herzlich bei Ihnen für die zahlreichen Möglichkeiten, die Sie mir eröffnet haben sowie die inhaltliche und moralische Unterstützung bedanken. Ich freue mich darauf, auch in der Zukunft mit Ihnen zusammen zu arbeiten!

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