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Article

Learning to Plan by Learning to Reflect?—Exploring Relations between Professional Knowledge, Reflection Skills, and Planning Skills of Preservice Physics Teachers in a One-Semester Field Experience

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Abstract: Following concepts describing lesson planning as a form of anticipatory reflection, preservice physics teachers' reflection skills are assumed to be positively connected with their planning skills. However, empirical evidence on this is scarce. To explore how relations between these specific skills change over the course of a field experience controlling for influences of professional knowledge, we conduct a pre-post field study with $N = 95$ preservice physics teachers in a one-semester field experience. Content knowledge (CK) and pedagogical content knowledge (PCK) (paper-and-pencil tests), and reflection and planning skills (standardized performance assessments) were assessed before and after the field experience. Path analyses revealed almost no influence of reflection skills on planning skills. Reflections skills did not contribute to preservice teachers planning skills beyond knowledge, indicating both constructs might represent rather independent abilities. The results show the need for further development of models describing the development of teachers' professional knowledge and skills in academic teacher education and for the development of concepts for a better integration of reflection and lesson planning in field experiences.

Keywords: reflection; lesson planning; PCK; CK; field experience; teacher education; professional skills; core practice

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1. Introduction

Physics teachers need a complex set of knowledge and skills to initiate and support their students' learning adequately. This includes professional knowledge (such as physics content knowledge), as well as the skills to plan a physics lesson and reflect on physics instruction (cf. [1]). Physics teacher education programs in many countries often combine extensive phases of academic studies emphasizing the acquisition of knowledge with more or less extensive field experiences (for example, school practicums, school placements, school internships), in which preservice physics teachers are expected to apply their theoretical knowledge acquired at the university [2,3]. For example, preservice teachers observe mentor teachers' instruction and conduct physics lessons on their own. Field experiences are often seen as an important moderator for the transformation of academic knowledge into practical skills [4], and general positive effects of field experiences are reported [2]. From an empirical point of view, the relation between theory and practice remains a major challenge [5]. In recent years, the development of preservice teachers' knowledge and skills in field experiences has become a more prominent research topic [3]. Thus, it could be shown that sufficient professional knowledge at the beginning of field experiences supports the adequate development of explaining skills of preservice physics teachers during the field experience [6]. In addition, adequate reflection skills can support the development of professional knowledge [7]. However, little is known about the interplay of different aspects of knowledge and skills and their changes during the path of a school practicum. Lesson planning can be conceptualized as anticipatory reflection [8,9]. Therefore, it is reasonable to assume that the skills to reflect on physics instruction should contribute to the skills to plan a physics lesson beyond aspects of professional knowledge. However, evidence on the relationship between planning skills and reflection skills is scarce.

In this article, we explore how the relationship of content knowledge, pedagogical content knowledge, lesson planning skills, and reflection skills of preservice physics teachers change during a one-semester field experience using path analyses. We chose those variables because they are important aspects of physics teachers' competence [1,10,11]. In the sense of our study, we understood the assessed knowledge as academic knowledge, acquired mainly in the university parts of teacher education, whereas the skills represent typical tasks of beginning teachers, or in other words, core practices [12,13]. All variables were assessed in a proximal way using standardized knowledge tests and performance assessments for lesson planning and reflection on physics instruction. This provides higher validity than often-used approaches to assess skills through self-reports (cf. [4]). In our paper, we will argue that skills to reflect on physics instruction of other teachers' are not necessarily related to the skills to plan one's own physics lessons when professional knowledge is controlled for.

2. Background

2.1. Relations between Physics Teachers' Professional Knowledge and Professional Skills

In recent decades, a vast body of research on science teachers' professional knowledge has been conducted [14–16]. Based on Shulman's work [17], most models distinguish between three areas of professional knowledge: content knowledge (CK), pedagogical content knowledge (PCK), and pedagogical knowledge (PK) [1,15,18]. In short, CK means the knowledge about the content teachers want or have to teach. In the case of physics, of course, CK refers to subject matter knowledge in physics. PCK refers to knowledge of how to teach a particular content, for example, choosing appropriate instructional strategies or knowing about typical misconceptions of physical concepts [11,19,20]. PK is knowledge about more general principles of learning and instruction not linked to specific content.

In particular, PCK has been the subject of extensive research, resulting in the Refined consensus model of PCK (RCM) [11]. Formulated by a group of international researchers, the model proposes different dimensions or aspects of PCK to describe the relation between science teachers' knowledge and classroom actions. First, collective PCK refers to explicable knowledge of teacher educators, for example, the community of researchers in science education. Second, personal PCK means knowledge held by one individual teacher. Third, enacted PCK refers to knowledge that is only observable in a teacher's action. Furthermore, enacted PCK means "the specific knowledge and skills utilized by an individual teacher in a particular setting, with [a] particular student or group of students, with a goal for those students to learn a particular concept [. . .]" [11] (p. 83). Following this, specific skills of a teacher are reflected in his or her enacted PCK applied in a specific situation. Personal PCK, on the other hand, influences enacted PCK and vice versa. For example, on the one hand, the personal PCK of a teacher can affect his or her observable actions in the classroom. On the other hand, she or he can reflect on these actions and transform experiences into a form of personal PCK [21].

The relation between teachers' professional knowledge and their action-related skills can also be described with another theoretical approach. The continuum model of professional competence of Blömeke, Gustafson, and Shavelson (MoC) [22] describes teachers' professional competence as a continuum between dispositions and observable performance, aiming to describe how "knowledge, skills and affect are put together to arrive at performance" [22] (p. 6). In short, in the MoC, cognitive and affective–motivational dispositions such as professional knowledge are seen as resources, which can be transformed into situation-specific skills, namely the perception of a situation, its interpretation, and decision making. Finally, applied in complex teaching situations, these skills result in observable performance. According to the MoC, the integration of all these resources leads to adequate performance.

Both models describe the relation between teachers' knowledge and skills as similar in many respects. For example, situation-specific skills and performance in the MoC can be identified as enacted PCK in the RCM (cf. [6]). Nevertheless, there are a few differences. In the RCM, CK, and PK build a foundation of PCK. In the MoC, CK, PCK, and PK contribute to situation-specific skills in parallel. On the other hand, even in the RCM, for example, it can be assumed that CK can have a direct impact on teachers' observable behavior (in the sense of enacted CK) (cf. [6]). However, both models share the idea that theoretical or academic knowledge held as a disposition has an impact on teachers' actions in teaching practices.

In the domain of physics, empirical evidence for these assumed relations is inconclusive [18,23]. The ProwiN project did not find a significant relation between teachers' instructional quality and their CK or PCK (measured with paper-and-pencil tests). This holds true whether the instructional quality is operationalized as cognitive activation [23] or as content structure [24], both measured via observer ratings. The same holds true for student achievement [18]. The QuiP project found low correlations between PCK and learning outcomes moderated by the level of cognitive activation [25].

One reason for these mixed results—besides possible validity issues [18,26]—might be the fact that the mentioned research measured instructional quality mostly via ratings of videotaped lessons from field studies. In the complexity of a real classroom, teachers' professional knowledge is just one factor influencing instructional quality [27]. Other variables can also have an impact (e.g., unplanned interruptions); therefore, the relation between teachers' knowledge and instructional quality is confounded by many uncontrollable factors leading to little or no observable effects on teachers' knowledge. Kulgemeyer and Riese [28] focused on one specific skill of physics teachers assessed through a standardized performance assessment: the skill of explaining physics. This assessment was conducted following concepts of medical education [29]. Preservice teachers were asked to explain a complex physics phenomenon in a simulated adaptive dialogue with a "standardized" student in a controlled setting. The student was trained to react in a certain way to make the explanation performances of different preservice teachers comparable. In this assessment, the complexity of an actual instructional explanation in a real classroom was reduced to a more concise setting, which, nevertheless, reflects an authentic core practice of teachers [12,13,28]. In using such a performance assessment in a cross-sectional study, it could be shown that PCK mediated the influence of CK on explaining skills [28]. Therefore, both aspects of professional knowledge, CK and PCK, can be regarded as dispositions of teachers' skills in accordance with the MoC [22].

2.2. Physics Teachers' Reflection Skills

The ability to reflect is described as a core skill of teachers (cf. [13,30]) and has been investigated in a huge body of research in teacher education in general, e.g., [30–32] and in science teacher education (cf. [7]). Despite this long research history, there is still debate about what reflection actually is [30,33]. Dewey [34] formulated reflection as a specific kind of thinking realized with the goal of becoming aware of why one acts in a specific way. This broad concept was widely adopted and further developed in research on teacher education. Schön [31] emphasized the relation between reflection and action and distinguished between two forms of reflection: reflection-in-action and reflection-on-action. Reflection-in-action means thinking about one's own actions during the action, while reflection-on-action means a retrospective, analytic review of actions afterward. One goal of the latter is to support the generation of alternative ways of acting in the future. Both approaches to reflection are widely accepted in teacher education, and many scholars see in reflection the potential to close the gap between academic theory and practice in teacher education [33,35,36]. In doing so, teachers can reflect on their own instructional practice or on the practice of others, and both forms are expected to help to improve teachers' competence [32]. In this study, we follow the concept of reflection of Kulgemeyer et al. [7]: "Reflection is the theory-based analysis of teaching with the goal of improving the quality of instruction and/or leading to further development as a science teacher" [7] (p. 3038). Several models describing reflection as a process were developed in research. The influential ALACT model [37] postulates five phases of reflection: (1) A teacher performs an action, (2) she or he looks back on this action, (3) she or he becomes aware of essential aspects, (4) alternative actions for future situations are formulated, and (5) these alternative actions are realized in similar situations in the future.

Reflection skills mean the ability of a teacher to perform these specific thinking processes described above (reflectivity) (cf. [7,33,35]). In order to assess the reflection skills of preservice teachers in more detail, many studies used models of different levels of the depth of reflection. For example, Hatton and Smith [30] formulated four kinds of written reflection: descriptive writing (no reflection at all, just describing an experience), descriptive reflection (providing reasons for an observed action based on personal judgment or concepts from the literature), dialogic reflection (an exploration of possible reasons in the form of a dialogue with oneself), and critical reflection (contains reasons for own decisions or observed events considering a broader social, political, or historical context). From an empirical point of view, preservice teachers do not always reflect on the higher levels of such models [32]. Written reflective reports often remain on a descriptive level of reflection [30], and the reflection of preservice teachers—even after field experiences—can be described as rather superficial with an action-oriented focus [38].

Nowak et al. [39] formulated a model of reflection skills, which distinguishes between four elements of reflection: (1) description of a teaching situation or the context of a lesson, (2) evaluation of the situation, (3) formulating alternatives for the observed teachers' actions, and (4) formulating consequences. In addition, the model relates these elements to the three knowledge bases: CK, PCK, and PK. Kulgemeyer et al. [7] used this model as a basis for a measure of preservice physics teachers' reflection skills assessed via a performance assessment. In this assessment, participants take part in a simulation collaborative reflection in a field experience with a fellow intern who asks them for feedback on his instruction. Using this measure, they showed that higher levels of reflection skills at the beginning have a positive impact on the development of PCK and PK during a one-semester field experience ($N = 94$) [7]. Correlations between reflection skills and professional knowledge changed during the field experience. Whereas reflection skills are only positively correlated with PCK at the beginning ($r = 0.48$, $p < 0.001$), after the field experience there was only a correlation between reflection skills and PK ($r = 0.34$, $p < 0.05$). Overall development of reflection skills was not observed, which was in line with the results of studies analyzing written reflections and showing that reflection quality did not develop positively during typical field experiences [40,41]. Similar correlations between PCK and professional vision (as a form of reflection, cf. [42]) of science preservice and in-service teachers for elementary schools (preservice: $N = 113$, in-service: $N = 110$) were observed by Meschede et al. [43] ($r = 0.56$, $p < 0.001$). Kramer et al. [44] also found similar relations between diagnostic activities and PCK of preservice biology teachers using path analysis ($N = 186$; $\beta = 0.29$; $p < 0.001$). In addition, studies showing that reflective processes are more of a content-specific rather than a context-independent skill indicate that reflection skills and content-specific knowledge are related [45].

2.3. Physics Teachers' Lesson Planning Skills

Another core practice of teachers is lesson planning cf. [12,13]. Lesson planning is seen as an essential prerequisite for successful instruction itself [46,47]. The literature provides many normative guidelines or prescriptive frameworks describing aspects and steps of lesson planning [48]. However, research shows that teachers do not plan lessons according to such guidelines [49]. Some models describe lesson planning not as a linear process but more as an integration of several thought processes. For example, in the CODE-PLAN model, König et al. [50] describe six main cognitive demands teachers have to meet during lesson planning: content transformation, task creation, adaptation to learning dispositions, clarity of learning objectives, unit contextualization, and phasing. In planning a lesson, a teacher has to consider all of these demands, not necessarily in a particular order, but in an integrative way to design a coherent instructional plan. However, lesson planning depends on the context [51], so concrete operationalizations of planning skills have to be specified, for example, for a specific subject or domain, the learning prerequisites of the students or how a lesson plan is required to be documented (e.g., with or without extensive commentary).

Different assessment methods were used to assess preservice teachers' planning skills. Some studies applied distal measures such as self-reports or tests for knowledge of lesson planning [52]. Considering the MoC [22], these assessments are more likely to capture teachers' dispositions for lesson planning and not the actual planning skills. A more proximal approach is to analyze real lesson plans [47]. König et al. [50] used the CODE-PLAN model to rate the quality of lesson plans provided by preservice German language teachers for their demonstration lessons at the beginning and at the end of the induction phase in German teacher education (approx. 1.5 years) as a measure of their planning competence. For a subsample, they also collected ratings of the instructional quality of these lessons based, even though just based on student ratings. Results showed that planning competence at the beginning was predictive of planning competence at the end. Planning competence also correlates as expected with the given grade of the final demonstration lesson. Furthermore, quality aspects of the lesson plan could partly predict the instructional quality of the planned lesson in multilevel regression models. This is in line with results of qualitative research showing relations between the quality of lesson plans and carried out instruction by preservice teachers in field experiences [53,54]. However, further empirical evidence on the relationship between planning skills and instructional quality is scarce [55], in particular in the domain of physics.

It is rather unlikely that teachers also write such extensive lesson plans in their everyday professional life. Therefore, assessments based on such plans might not reflect the planning skills which can be applied under real conditions in the field. For example, the time teachers have for lesson planning is more or less constrained, and planning has to be done under the stressful conditions of a tight timetable. To cope with these problems, Schröder et al. [56] conducted a performance assessment to assess preservice physics teachers' planning skills, which simulates a situation in which participants are asked by a mentor teacher in a field experience to provide a lesson plan for the teaching of Newton's third law for the next day. Using these measures to assess the planning skills of preservice physics teachers' before and after a one-semester field experience, a positive development of planning skills with a small effect size ($d = 0.33$, $p < 0.05$) could be found [56]. Lesson planning skills correlated positively with PCK before ($r = 0.32$, $p < 0.001$) and after ($r = 0.33$, $p < 0.001$) the field experience, and with PK before ($r = 0.36$, $p < 0.001$) and after ($r = 0.25$, $p < 0.05$). No correlations between planning skills and CK were observed. Qualitative studies showing a positive development of the quality of lesson plans in field experiences also indicate the development of planning skills in typical field experiences (cf. [53,54,57]). Similarly, Stender et al. [58] found correlations between physics in-service teachers' ($N = 49$) topic-specific professional knowledge (similar to the concept of PCK) and the (functional) quality of lesson plans measured via a standardized online test ($\beta = 0.45$, $p < 0.001$).

2.4. Relations between Physics Teachers' Reflection and Planning Skills

While reflection skills, in theory, are related to the professional knowledge of teachers by definition [36], they are also related to teachers' lesson planning skills. Considering the ALACT model [37], one goal of reflection is to create an alternative sequence of actions (cf. [33]) while creating a sequence of actions (a plan) is also at the core of lesson planning [47]. Early research on teachers' cognitive planning processes also highlights the role of the evaluation of past planning decisions for future lesson plans [59]. Consequentially, some scholars further developed Schön's concept of reflection [31] by incorporating lesson planning as a form of anticipatory reflection [8]. During this reflection-before-action [8,9], teachers reflect on possible future actions and prepare their lessons. In a broader sense, anticipatory reflection is not limited to lesson planning and refers to all activities teachers have to undertake [60]. Some scholars assume anticipatory reflection as an important factor for the professional development of preservice teachers, in particular in field experiences [9,60].

Based on these considerations, we can assume a positive relationship between teachers' reflection skills (reflection-on-action) and teachers' lesson planning skills (which are related to reflection-before-action). Skills to reflect observed lessons, therefore, should be helpful in developing skills to plan lessons. Whether this applies only when preservice teachers reflect on their own teaching or also on the teaching of others is not clear based on the literature. On the other hand, following the MoC [22] or the RCM [11], both reflection skills and planning skills are based on professional knowledge as a cognitive resource. Therefore, it is also possible that differences in planning skills are largely explainable by differences in aspects of professional knowledge such as CK and PCK. In a qualitative study with a small sample size (N = 18) focusing on pedagogical knowledge (PK), Zaragoza et al. [61] (p. 13) found: "Participants who were able to connect PK with their lesson plans were also able to connect their PK with classroom observations". However, whether this also applies to CK and PCK in the domain of physics still needs to be examined. Reflection skills may also act as a moderator between PCK and planning skills, and, simultaneously, PCK may be a moderator of CK for planning skills (cf. [11,28]).

In many teacher education programs, preservice teachers have to observe and reflect on other teachers' instruction before they are expected to plan lessons independently on a larger scale. This is at least the case for field experiences in teacher education programs in Germany [3]. Field experiences are, therefore, a good context to investigate the proposed relations. As mentioned above, previous research indicates that the relationship between reflection skills and PCK can change over the course of a field experience, whereas the relation between planning skills and PCK remains stable [7,56]. However, it remains an open question if the mediating role of PCK for CK on explaining skills can be found for reflection or planning skills as well (cf. [11,28]).

3. Methods

3.1. Research Goals and Assumptions

In the present study, we will explore the relation between preservice physics teachers' reflection skills, planning skills, and their CK and PCK in more detail. We focus on a one-semester field experience in teacher education in Germany. We cannot trace the actual processes of reflection or planning of the preservice teachers during the whole school internship in our study, but we, nevertheless, can look at the changes in their skills and knowledge based on pre-post measures. Even if we chose an exploratory approach, we could still formulate some conjectures regarding expected outcomes.

RG1: Seeing planning as anticipatory reflection, we assume to find positive correlations between reflection skills and planning skills at both the beginning and the end of the field experience. This corresponds with an interpretation of reflection skills as a disposition for planning skills. However, since PCK and CK are dispositions for both skills following the MoC [22], and reflection in our study is operationalized as a reflection on other teachers' instruction, we assume that differences in skills can also be attributed to differences in PCK. Considering all variables, we assume a mediating role of reflection skills for planning skills and a mediating role of PCK for CK on both skills (cf. [11,28]).

RG2: Given the similarity between reflection on instruction and planning as anticipatory reflection, we assume that reflection skills at the beginning of the field experience are helpful for the development of planning skills. Given the postulated similarity between thought processes of reflection-on-action and reflection-before-action, we can also assume that planning skills at the beginning of the field experience are helpful for the development of planning skills. We cannot determine, which skill has a higher impact on the other, but we will explore if there is an impact at all.

Findings regarding our research goal can help to understand the complex development of professional knowledge and skills during field experiences in more detail. The whole design of teacher education programs is based on assumptions similar to the MoC [22] or the RCM [11], so results can strengthen these assumptions or indicate necessary modifications.

3.2. Design and Context of the Study

Our study was conducted in Germany. In physics teacher education programs in the most federal states in Germany, a one-semester field experience was implemented (the so-called practical semester [62]). It lasts approximately five months in the Master's program of the academic part of teacher education. This practical semester includes typical activities of field experiences (cf. [2]). Preservice teachers are expected to observe and reflect on the physics instruction of teachers at local schools and are obliged to plan and carry out physics lessons on their own. Experienced mentor teachers and university teacher educators collaboratively reflect on their teaching with them. Although the preservice teachers work at their school most of the time, they usually have to take some courses at the university (normally one day a week) with the goal of supporting the student teachers' practical activities and providing guided opportunities to reflect on their practice explicitly based on theoretical concepts. The quality of student teachers' instruction is not graded, and, therefore, it is not necessary to achieve a certain teaching quality to pass the practical semester. It is rather intended that preservice teachers should try themselves out in the role of teachers during the internship; class visits of teacher educators have more advisory functions and are intended to support reflection [62]. Considering the overall design of the practical semester, preservice teachers should have sufficient learning opportunities for reflection and lesson planning.

We conducted a pre-post design. PCK, CK, reflection, and planning skills were assessed before and after the one-semester field experience. In the beginning, participants were also asked to fill out a questionnaire focusing on some demographic variables (such as age) to get a deeper insight into the sample. After the practical semester, participants were asked to complete another questionnaire regarding their experiences during the field experience to shed some light on the actual learning opportunities preservice teachers had. For example, they were asked about the number of observed and conducted lessons. We are aware that this just comprises the quantity and not the quality of learning opportunities, but a sufficient number of opportunities for reflection or lesson planning is the necessary basis for skills development. Written informed consent was obtained from all participants before data collection.

3.3. Sample

The sample consists of $N = 95$ preservice teachers from four German universities. Physics teacher education at these universities is structured in a similar way, including courses focusing on CK, PK, and PCK in the 6-semester Bachelor's program with similar course content. All four universities have implemented a one-semester field experience (practical semester, approx. five months) in the second semester of their 4-semester Master's program. The present study takes place immediately before and after this school internship. The sample is almost a full survey of all preservice physics teachers absolving the school internship at the four universities at the time of our study. Therefore, the sample is representative of preservice physics teacher students in Germany at the four universities. The sample is not representative of preservice physics teachers in Germany in general because it is a sample of convenience. However, since the structures of the study programs and the covered contents are quite similar to other study programs in Germany [63], conclusions drawn from our study might be transferable to other universities.

Teacher education in Germany is structured alongside different school tracks [64]. A total of 77.5% of the participants were enrolled in study programs for teaching physics for an upper secondary track (Gymnasium), 20.0% for a lower secondary track (Haupt- und Realschule), and 2.5% made no statement in the questionnaire. Preservice teachers for the upper secondary track usually had to take more and more specialized courses focusing on CK (in most cases taking courses together with BA/MA physics students) compared to preservice teachers for the lower secondary track (which mostly take courses together with BA/MA students for engineering or chemistry) (cf. [63]). In all programs, the courses in the first semesters of the BA degree programs were focused on mechanics (see Section 3.4). Preservice teachers of both tracks took the same courses focusing on PCK at their respective universities, but preservice teachers for the lower secondary track usually had to take more courses. Due to the small total number of teacher students, the similar learning opportunities for the content focus of this study (mechanics), and the instruments that were designed to be used for preservice physics teachers for all of these programs (see Section 3.4), we used the combined sample for our analyses.

All participants held a Bachelor's degree in physics education for teaching. The average age was 25.7 (21–45). All preservice teachers studied a second teaching subject, in most cases, math. During the field experience, participants planned and taught an average of 20.2 (5–50) physics lessons on their own. Of these, an average of 5.5 (0–33) lessons were focused on mechanics. They also observed an average of 62.4 (10–220) physics lessons taught by other teachers. In their second teaching subject, they taught 20.0 (4–54) lessons on their own, on average, and observed 66.7 (2–200) lessons. All participants had many opportunities to reflect with mentor teachers on lesson plans or on their own teaching. In addition, all preservice teachers were visited by a university teacher educator at least once and collaboratively reflected on their own teaching with her or him.

Due to the extensive testing time both before and after the internship (participation in all assessments required an overall testing time of 190 min each), not all preservice teachers were able to participate in all possible eight assessments. This results in missing data which are distributed as follows: CK (t_1: 23.2%; t_2: 29.5%), PCK (t_1: 26.3%; t_2: 27.4%), reflection skills (t_1: 30.5%; t_2: 40.0%), and planning skills (t_1: 6.3%; t_2: 26.3%). Only N = 31 preservice teachers participated in all eight measurements (pre and post). We will discuss how we deal with this in our analyses in Section 3.5.

3.4. Instruments

In the present study, we rely on established instruments used previously in other studies [7,56]. More details on instrument development and validation can also be found in [7,18,56,65]. Regarding the physics content, all instruments (CK, PCK, reflection skills, and planning skills) focus on mechanics. This includes concepts commonly covered in curricula of German secondary schools: mass, inertia, speed, velocity, acceleration, force, energy (potential, kinetic), linear and circular motion (including equations of typical motions such as constant translational acceleration), centripetal force, Newton's laws of motion, momentum, and conservation of momentum/energy. Not all concepts are represented in all instruments. The instruments used to assess CK and PCK refer to all (respectively most) of these mechanical concepts. The instruments for assessing reflection and planning skills focus on the specific but related concepts of conservation of momentum (see Section 3.4.3) and Newton's third law of motion (see Section 3.4.4). Another principle of instrument development was a curricular focus for a 10th-grade physics class at a comprehensive school. Regardless of which degree programs for which type of school the preservice teachers in our study were enrolled in, all of them had to be able to carry out instruction for this particular group of students based on similar 10th-grade physics curricula in their later professional life. Moreover, the preservice teachers in our study could make experiences with concepts of mechanics in the context of the field experience (see Section 3.3).

Furthermore, these foci allow relating the results of different instruments to each other and combining preservice teachers of different programs in our sample ensuring higher validity of interpretations. The respective pre- and post-tests were identical.

3.4.1. Content Knowledge

We used the CK test of the project Profile-P+ [18]. The paper-and-pencil instrument included 48 multiple-choice questions. The required testing time was 60 min. The underlying model distinguishes between three subdimensions of CK represented in subscales in the instrument. All subscales have sufficient reliability: (1) school knowledge (physics knowledge represented in school textbooks) (EAP/PV reliability: 0.82); (2) a deeper understanding of physics school knowledge (e.g., knowledge of different solution procedures) (EAP/PV reliability: 0.81); and (3) university knowledge (physics knowledge from a university textbook) (EAP/PV reliability: 0.82). During development, also, several analyses for validity were conducted: content validity (curricular analysis, textbook analysis), construct validity (Rasch analyses), and cognitive validity (think-aloud study). The overall score is also reliable (EAP/PV reliability: 0.84). More details can be found in [18]. In the present study, we only use the manifest overall score.

3.4.2. Pedagogical Content Knowledge

We used the Profile-P test on PCK [18] developed by Gramzow et al. [20,66] based on other models and instruments for PCK, e.g., [19] and the analyses of curricula of German physics teacher education programs. In the test development process, several analyses for validity were conducted: content validity (expert ratings), construct validity (Rasch analyses, analyses of nomological networks), and cognitive validity (think-aloud study). The paper-and-pencil test consisted of 43 items, including some open situational–judgment items and some multiple choice items. The required testing time was 60 min. The instrument was used in several previous studies [6,7,56,66]. It has good overall reliability (EAP/PV reliability: 0.84) and a good level of interrater reliability regarding the coding of open answers ($\kappa = 0.87$). The test comprises four sub-scales that also have good reliability: instructional strategies (EAP/PV reliability: 0.62); students' misconceptions and how to deal with them (EAP/PV reliability: 0.69); experiments and teaching science adequately (EAP/PV reliability: 0.74); and PCK-related theoretical concepts (EAP/PV reliability: 0.76). In this study, we only use the manifest overall score. This score can be interpreted as a measure of personal PCK of the participating preservice teachers.

3.4.3. Reflection Skills

We used the performance assessment for the reflection skills of the authors [7]. As mentioned before, many studies assessed reflection skills by relying on self-reports or knowledge of reflection [4]. To overcome issues of limited validity in such measures, the authors [7] developed a performance assessment following assessment concepts of medical education [29]. In such performance assessments, typical professional situations or core practices [Quelle] are simulated with so-called standardized patients or, in the case of teacher education, students [67]. The goal is to provide an authentic assessment of action-related skills under standardized conditions [28,68]. Similar to research in medicine, sufficient reliability and validity can be ensured, e.g., [69].

The instrument simulates a collaborative oral reflection situation typical for field experiences in a digital format. In this assessment, participants have to follow a video-based reflective conversation with a peer intern ("Robert") who shows them video clips of a staged lesson on the conservation of momentum and asks them for feedback on his instruction. Overall, 13 video vignettes have to be reflected. After each clip, "Robert" asks for feedback, and at the end of the conversation, the lesson as a whole has to be reflected. Participants do not have to write down their reflections but can give answers verbally, which are audio-recorded. The required testing time for the whole assessment is 70 min. See [7] for more details on the structure of the instrument.

Recorded answers were analyzed using categories derived from the qualitative content analysis [70] of the whole material. The categories were based on the model of reflection of Nowak et al. [39] (Figure 1).

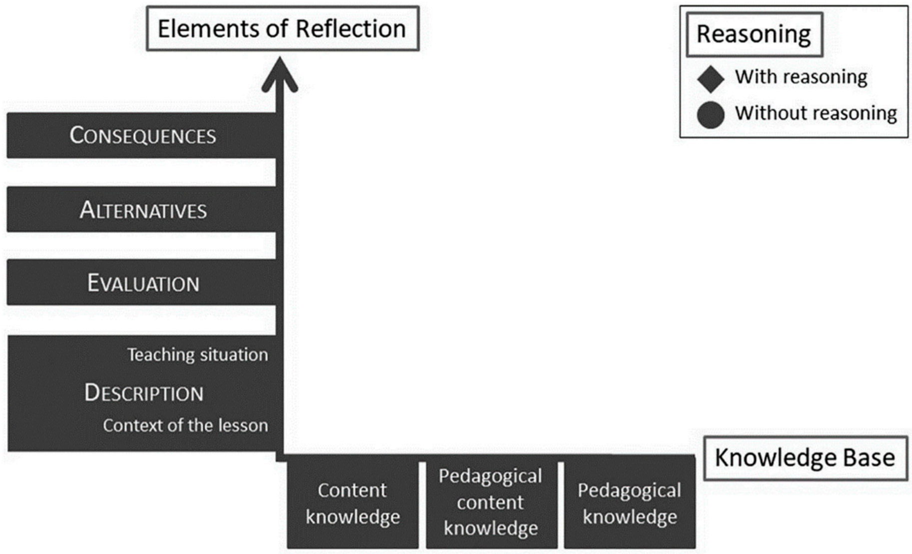

Figure 1. Model of reflection skills (adapted from [38]).

The model distinguishes between elements of reflection, representing different reflective thought processes, and the knowledge bases reflective statements are based on. These elements rely on the model of Plöger and Scholl [71]. In the rating process, every reflective statement of a preservice teacher was matched with an element of reflection (e.g., a description of a teaching situation or the formulation of alternative actions for a situation), a knowledge base, and if an evaluation, alternative, or consequence was explicitly based on any form of reasoning (yes/no). Triple coding of 17% of the statements indicates good interrater agreement (*Gwet's AC1* = 0.90). After coding, scores were applied to rate the quality of each reflective statement for all knowledge bases in the form of levels of reflection (Table 1).

For simple descriptions, participants received one point, whereas a reasoned consequence was awarded seven points. In the end, points for all statements were added up. During the development process, several analyses for validity were conducted: construct validity (study with in-service teachers) and content validity (interview for the perception of the situation). In the present study, we only use the manifest overall score, which has sufficient reliability (α = 0.74).

3.4.4. Planning Skills

For the assessment of lesson planning skills, we used the performance assessment of the authors [56,72]. Since teachers in practice do not usually write extensive lesson plans in their everyday work, the performance assessment was developed to assess planning skills in a more authentic and proximal way, but under standardized conditions. Similar to the instrument for the assessment of reflection skills, concepts from medical education were references for the development [29].

The assessment simulates a situation similar to everyday planning situations in field experiences. Participants were asked by a fictive mentor teacher to provide a lesson plan for the teaching of Newton's third law the next day. Therefore, planning time is constrained. The mentor teacher determines the learning objectives of the lesson, and the only other requirement is to include an experiment. Experiments are, in general, not a mandatory element of physics instruction, but planning experiment represents an important core practice of physics teachers. Participants were provided with standardized materials: a short description of the class (e.g., including information on learning prerequisites) and excerpts from two frequently used school textbooks and a popular German website on physics for teachers and students.

Table 1. Levels of reflection (adapted from [7], p. 3046).

Points	Level of Reflection	Sample Statement
7	Reasoned consequences for future instruction or personal development	"You might consider working more with cooperative learning techniques in the future. For the next lesson, that would be worth trying explicitly. It might help to let the students discuss the question with their peers before calling them up. Cooperative learning explicitly suggests following a 'think-pair-share' approach, which includes a phase of peer discussion."
6	Consequences for future instruction or personal development	"You might consider working more with cooperative learning techniques in the future. For the next lesson, that would be worth trying explicitly."
5	Reasoned alternatives to the teaching situation	"You might consider letting the students discuss the question with their peers before you call them up because talking about one's own misconceptions requires a lot of courage. It is important to make it part of the experience to say that other students have the same misconceptions."
4	Alternatives to the teaching situation	"You should wait longer before you call someone up or let the students talk to each other before you call them up."
3	Reasoned evaluation of the teaching situation	"It was not good to call this student up so fast because the other students did not have a chance to really think about the task."
2	Evaluation of the teaching situation	"It was not good to call this one student up so fast."
1	Description of the teaching situation or lesson context	"Two students held up their hands and you called one of them up immediately."

The preservice teachers did not have to provide a fully formulated lesson plan but were expected to document their planning on a pre-structured planning paper with prompts covering different aspects of a lesson plan [56,72]: an analysis of the physical content, possible student misconceptions, intended experiments and tasks or questions, explanations or justifications, a short conclusion for the blackboard, and a lesson draft in the form of a table. The required testing time for the whole assessment was 60 min.

In order to find a measure of planning skills, a model for the quality of the provided lesson plans was conducted, including seven categories [56,72]:

- Physical content and correctness
- Elementarization
- Presentation and consideration of students' perspectives
- Reachability of learning objectives
- Presentation and use of experiments
- Presentation and use of tasks or questions
- Use of examples and contexts

Based on these categories, 45 dichotomic coding items to rate the quality of the lesson plans were developed. Some coding items primarily focus on the local quality of different elements of the lesson plans (e.g., the concrete description of planned experiments and their expected outcomes), while other coding items focus on the global quality, especially on how the elements are integrated into a coherent instructional sequence (e.g., planned experiments are implemented according to the learning goals) (cf. Table 2).

Table 2. Example of a dichotomic rating item: considering typical misconceptions of students on Newton's third law (adapted from [72], p. 1480).

Experiment—Materials	
Aim: The Experiment is Described in Such a Way That Others Would be Able to Prepare the Experiment by Themselves. Required Materials are Specified.	
Item Solved (1P)	**Item Not Solved (0P)**
Required Materials are specified in description of the experiment or in the lesson draft, e.g., • "2 students on separate skateboards, connected with a rope. Both students hold on to one end of the rope. First, only student A pulls in the rope, [. . .]. Can be repeated with force meters attached to the ends of the rope" • "Materials: 2 skateboards, 2 students, 1 rope, 2 force meters" • "A student is standing on roller skates and has to throw away different balls (tennis ball, basketball, medicine ball) horizontally. The balls and his motion shall be observed." • . . .	Important materials are not mentioned, e.g., • Within the experiment, forces are to be measured, but no force meters are mentioned • Description of experiment not clear • No materials mentioned at all No experiment described

For each coded item as "yes", participants received one point. If they did not provide information on one of the elements, this was coded as missing, and they received zero points for this item. For a measure of planning skills, these points were summed about for all items. Double coding of 52 lesson plans indicates good interrater agreement (*Gwet's AC1* = 0.83).

Several analyses for validity were conducted: content validity (expert ratings, comparison with real lesson plans conducted in the field experience) and construct validity (sensitivity for changes during teacher education, analyses of nomological networks). For more details on validation see [18,56]. The overall score of planning skills has sufficient reliability ($\alpha = 0.74$).

3.5. Data Analysis

We used path analyses to investigate relations between all assessed variables according to our research goal. Path analyses can be used to estimate the explained variance of one variable by a set of other variables. In the literature, a sample size of at least ten cases per variable is proposed for path analyses [73]. As all our models include a maximum of four variables, our sample is appropriate for our planned analyses. While, in general, our sample size is rather low, it still allows the observation of middle to large effects.

We have to deal with many "missing" coded items in all variables because most of the preservice teachers did not participate in all measurements before and after the field experience. Therefore, we used robust maximum-likelihood estimation (MLR) [74] and full information maximum likelihood (FIML) [75] to estimate the path models. Additionally, we rely on manifest values, which are more appropriate to deal with low overall sample size. This is a rather conservative approach and may lead to an underestimation of possible effects. For analyses of manifest correlations, we use all cases with pairwise deletion.

All analyses were conducted using AMOS 28.0 [76]. As measures for model fit, we report CFI (comparative fit index; very good fit $CFI > 0.95$), RMSEA (root mean square error of approximation; required RMSEA < 0.05), and χ^2-tests (required $p > 0.05$) [77].

4. Results

4.1. Descriptive Analyses of PCK, CK, Reflection, and Planning Skills before and after the Field Experience

Table 3 shows the descriptive results for all measures before and after the field experience.

Table 3. Descriptive results of PCK, CK, reflection skills, and planning skills [1].

		Pre			Post		
	N	*M*	*SD*	*Range*	*M*	*SD*	*Range*
PCK	60	0.52	0.13	0.17–0.78	0.58	0.11	0.29–0.82
CK	64	0.60	0.13	0.31–0.96	0.64	0.12	0.40–0.93
Reflection skills	48	0.14	0.05	0.06–0.29	0.15	0.06	0.03–0.29
Planning skills	65	0.47	0.13	0.11–0.71	0.52	0.15	0.18–0.87

[1] All variables are standardized as relative share of possible points achieved.

To estimate the significance of differences between pre-and post-measures, we used paired *t*-tests including all available pre-post data for each variable (pairwise deletion, see Table 3). We chose a *p*-value of $p = 0.05$. The pre-post differences of all variables were normally distributed, as assessed by the Shapiro–Wilk test, with the exception of the difference of CK ($p = 0.005$). However, the paired *t*-test is rather robust for not normally distributed variables for sample sizes of $N > 30$ [78], so we conducted paired *t*-test for all variables.

We can observe a statistically significant positive development between pre- and post-measures for PCK using *t*-tests ($d = 0.48$; $p < 0.001$), CK ($d = 0.32$; $p = 0.002$), planning skills ($d = 0.36$; $p = 0.009$), but not for reflection skills ($p = 0.234$) (cf. [7]).

Table 4 shows the intercorrelations (Pearson's r) between all measures. Before the field experience, we found a correlation between PCK and reflection skills (r = 0.48, $p < 0.001$) as well as between PCK and planning skills ($r = 0.33$, $p < 0.01$) (cf. [7,56]). In addition, we can observe a statistically significant correlation between reflection and planning skills ($r = 0.27$, $p < 0.05$). After the field experience we found a correlation between PCK and CK ($r = 0.33$, $p < 0.001$), and the correlation between PCK and planning skills ($r = 0.35$, $p < 0.01$) remains stable. The correlations between PCK and reflection skills and between reflection and planning skills vanished. However, in terms of effect size, the latter is still close to the correlation before the internship. We found no correlations between CK and reflection or planning skills before and after the internship.

Table 4. Manifest intercorrelations of PCK, CK, reflections skills, and planning skills—pre/post [1].

	PCK_1	CK_1	R_1	P_1	PCK_2	CK_2	R_2	P_2
PCK_1	1							
CK_1	0.17	1						
R_1	0.43 **	−0.05	1					
P_1	0.33 **	−0.04	0.27 *	1				
PCK_2	0.70 **	0.38 **	0.15	0.34 **	1			
CK_2	0.11	0.33 **	−0.01	0.07	0.33 **	1		
R_2	0.23	0.11	0.54 **	0.37 **	0.11	−0.06	1	
P_2	0.53 **	0.35 **	0.33 *	0.48 **	0.35 **	−0.19	0.23	1

[1] * $p < 0.05$, ** $p < 0.01$; PCK = pedagogical content knowledge, CK = content knowledge, R = reflection skills, P = planning skills, 1 = pre, 2 = post.

A first look at the correlations between pre- and post-measures reveals that every pre-measure correlates significantly with its post-measure. PCK and CK before the field experience both positively correlate with planning skills after the field experience ($0.33 < r < 0.53$; at least $p < 0.05$). In addition, planning skills before the school internship are correlated with reflection skills after the internship ($r = 0.37$, $p < 0.01$) and vice versa ($r = 0.33$, $p < 0.05$).

4.2. Relations between PCK, CK, Reflection Skills, and Planning Skills before and after the Field Experience

We investigated the impact of reflection skills on planning skills while simultaneously controlling for the influence of CK and PCK using path analyses. Following our assumption (see Section 3.1), we specified reflection skills as a moderator between PCK and planning skills and PCK as a moderator for CK as well. To explore changes in the relations during the field experience, we conducted a path model for each measurement (pre and post) (Figures 2 and 3).

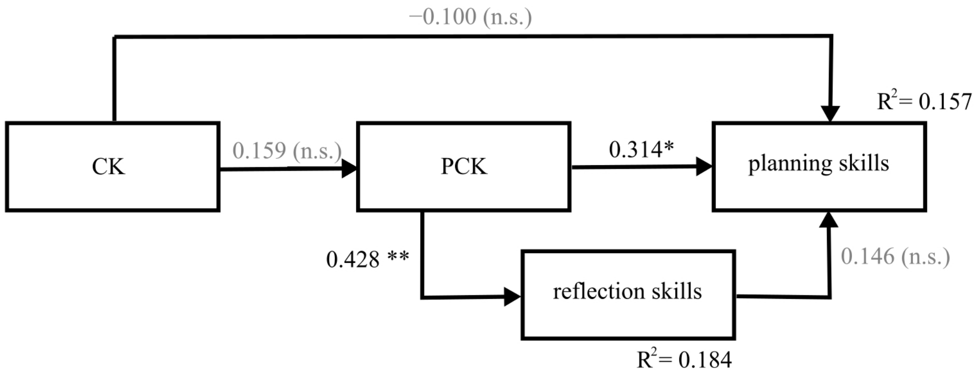

Figure 2. Path model for the relations between CK, PCK, reflection, and planning skills before the field experience, * $p < 0.05$, ** $p < 0.01$, model fit: RMSEA = 0.000; CFI = 1.000; $\chi^2 = 0.483$; $p = 0.487$.

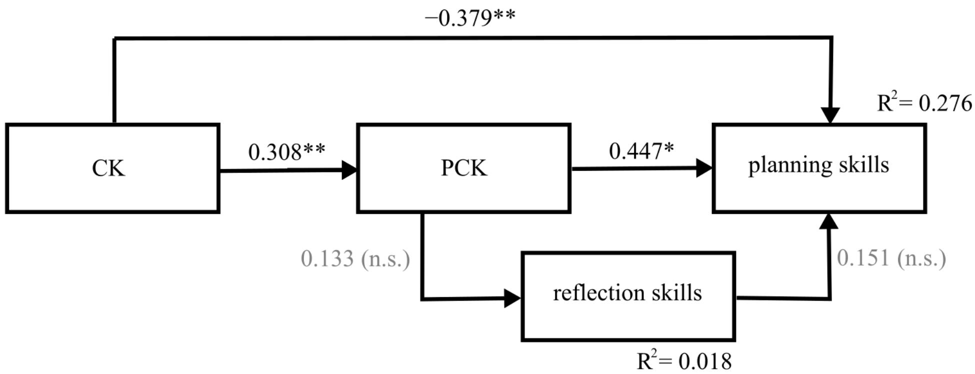

Figure 3. Path model for the relations between CK, PCK, reflection, and planning skills after the field experience, * $p < 0.05$, ** $p < 0.01$, model fit: RMSEA = 0.000; CFI = 1.000; $\chi^2 = 0.901$; $p = 0.343$.

Both models have a good fit. Considering the standardized regression weights before and after the field experience, the most important factor influencing preservice teachers' planning skills was PCK, whereas the relation is even stronger after the internship. In addition, reflection skills show no influence on planning skills in both path models when we control the influence of PCK and CK.

All other relations change between the beginning and the end of the field experience. We cannot observe PCK playing a mediating role in the influence of CK on planning skills before the internship, as both paths from CK to PCK and planning skills are not significant. However, after the field experience, the model indicates that PCK is a mediator for CK on planning skills. Additionally, the direct path from CK to planning skills shows a significant negative standardized regression weight ($\beta = -0.379$, $p < 0.01$). The relation between PCK and reflection skills also changes. Before the internship, PCK has a significant influence on reflection skills in this model, and PCK explains 18.4% of the variance of reflection skills. After the internship, PCK shows no significant influence on reflection skills, explaining just 1.8% of the variance. CK, PCK, and reflection skills together explain 15.7% of the variance of planning skills before the field experience and 27.6% after the field experience.

To investigate if reflection skills at the beginning of a field experience are helpful for the development of planning skills as anticipatory reflection and vice versa, we conducted path analyses in a cross-lagged panel design [64] (Figure 4).

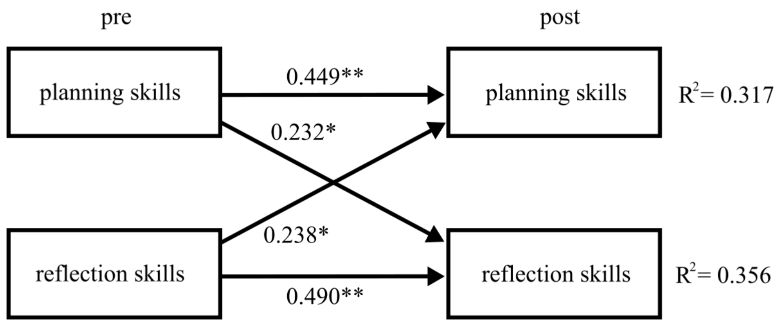

Figure 4. Cross-lagged panel analysis, * $p < 0.05$, ** $p < 0.01$, model fit: RMSEA = 0.000; CFI = 1.000; $\chi^2 = 0.179$; $p = 0.672$.

Both reflection and planning skills at the beginning of the field experience have an impact on the respective scores after the field experience. On the one hand, planning skills and reflection skills before can explain 31.7% of the variance of planning skills afterward. Planning skills at the beginning alone can only explain 23.7% of the variance afterward. Therefore, roughly one-third of the variance can be explained by reflection skills before the internship. On the other hand, planning skills and reflection skills before can explain 35.6% of the variance of reflection skills after the field experience. Reflections skills before alone explain 32.4% of variance afterward. Therefore, the contribution of planning skills to the development of reflection skills is rather low.

5. Discussion

Our research goal was to explore the relations between professional knowledge and professional skills of preservice physics teachers in the context of field experiences in more detail.

In RG1 (see Section 3.1), we assumed that skills to reflect on physics teaching might be helpful in planning physics lessons following the notion that planning was a form of anticipatory reflection [8]. Overall, our results seem not to confirm this conjecture. In our path analyses, preservice teachers' reflection skills showed no significant influence on planning skills, both before and after the completion of a one-semester field experience. In light of our results, lesson planning and reflecting on physics instruction might not be based on such similar cognitive processes as indicated by the concept of planning as anticipatory reflection [9]. However, we operationalized reflection skills as a reflection of the physics instruction of other teachers. Anticipatory reflection as a concept itself is more related to reflection on one's own actions or the development of one's own professional self [60]. Reflections of one's own actions or own physics instruction might evoke other cognitive processes than the reflection on actions of others (cf. [33]). Research on preservice teachers' reflections of videos of their own lessons compared to videos of others show that reflection of one's own instruction often comes together with more effective thought processes and emotions, which leads to other forms of reflection [79]. This could provide an explanation for why we found almost no relations between reflection and planning skills before and after the field experience.

However, since planning a physics lesson is also a rather analytic process in which PCK seems to play an important role, we would argue that we should at least see some connections to the more analytic reflection of physics instruction of others (cf. [71]). The cross-lagged panel analyses show some evidence for this assumption by the fact that reflection skills at the beginning of the field experience explain more variance of planning skills after the field experience than planning skills before the other way around (RG2, see Section 3.1). However, looking at the path models controlling for PCK and CK, we would conclude that reflection skills alone do not support the development of planning skills. Our explorative results rather support the claim that planning and reflection skills both might need a profound, shared knowledge base but develop rather independently over the course of a field experience (cf. [61]).

However, relations between professional knowledge and skills showed to be complex and to change over time. We cannot replicate PCK to be a mediator for CK for planning skills at the beginning of the field experience as well, as we assumed based on results of previous research [28]. Furthermore, planning skills do not directly correlate with CK of the participants before and after the field experience (cf. [56]). On the other hand, considering our path analyses for the variables measured after the field experience, we found PCK to be the expected mediator between CK and planning skills. Furthermore, we found a direct negative influence of CK on planning skills. The latter can be interpreted in a way that a high amount of CK alone does not help in lesson planning and has to be mediated through PCK to have a positive impact. It seems that just pre-service teachers with a high PCK benefit from their CK. The direct impact of CK being negative is related to Kulgemeyer's [80] observation regarding the relationship between CK and explaining skills: in this study, explainers with high content knowledge tend to have less developed explaining skills and, thus, explain worse than explainers with less physics CK. This "expert blindspot" (content experts are usually not aware of this effect) can likely be compensated with PCK. Our results here, again, highlight the importance of PCK for being a successful teacher. For both the core practices of explaining and lesson planning, it is not sufficient to have just a high level of CK; an unreflected high CK without a high PCK might even do more harm than good.

It was also quite surprising that PCK showed no influence on reflection skills after the internship, while the impact was relatively strong at the beginning. Previous research indicates that the way preservice teachers reflect on teaching in field experiences changes over time [7]. In the beginning, they highly relate to theoretical concepts learned through university studies. Afterward, reflection is lesser based on theory but more on mentors' notions or generalized own experiences, which were not related to concepts of physics education learned at the university before. In addition, a shift regarding the knowledge bases could be observed, in the sense that preservice teachers refer in their reflections more to concepts of PK than PCK [7]. This also could explain why we see a shift in the relations between knowledge and reflection skills in our study but no development of reflection skills in total if the reflection score is a sum over all knowledge bases (see Section 3.4.3). Another explanation lies in research indicating that preservice teachers' belief that knowledge learned at university might not be helpful for practical teaching demands [81]. Field experiences might intensify these beliefs, and accordingly, preservice teachers do not deliberately apply their knowledge in reflection. For the more analytic task of lesson planning, the use of knowledge learned at university is more likely overall since student teachers have at least to think about how to present physical concepts in a planned instructional sequence.

We have to consider some limitations. Our sample size is rather low, which limits our analyses to finding small effects, which is quite probable since our data is based on a field study and not an experimental design. Therefore, our study did not allow for causal interpretations [82]. Our analyses may also be biased by the fact that, on average, reflection skills do not change over the course of the field experience (possible floor effect). In addition, we had to deal with some missing data, in particular for the assessment of reflection skills after the field experience. Although we applied robust statistical methods for analyses [74,75], this is a challenge to the validity of our interpretations in general. Nevertheless, it has to be noted that our study is one of the first in physics teacher education that relys solely on proximal measures for the two skills and for PCK and CK.

The sample consists of preservice physics teachers from four different universities in Germany. Although the study programs of these universities are typical for physics teacher education programs in Germany [63], further studies are needed to determine whether the results are generalizable to students at other universities. In addition, we used a combined sample of preservice teachers of programs for two different school tracks. We do not expect the outcome to be different between the two sub-groups in our sample due to the instruments being developed for both groups (see Section 3.4) and the large similarities in study programs. However, further research with a larger sample is needed to validate these assumptions.

However, our instruments focused on the physical domain of mechanics. Further research is needed to estimate whether our results can also be transferred to other domains of physics. Lastly, we operationalized reflection skills through the reflection of other teachers' physics instruction. Therefore, it is difficult to compare our results with research analyzing reflection skills based mainly on the reflections of one's own instruction (cf. [33]). As discussed above, this could lead to other relations between reflection and planning skills. Overall, more future research is needed to look at these relations in more detail.

6. Conclusions

The MoC [22] describes the relationship between professional knowledge as a disposition and situation-specific skills in a rather static sense. How these relations can or should change over time during the course of teacher education is not specified in detail in the model. The RCM [11] formulates such relations in a more dynamic way. However, it is hard to derive how relations, for example, between personal and enacted PCK, should change during a field experience based on the model. Our results show evidence that the assumptions of both models tend to be valid, at least for the relationship between lesson planning skills, and remain stable before and after the field experience.

However, future research is needed to develop further such models to describe empirically-based trajectories for preservice physics teachers' competence development over the course of academic teacher education programs. Such trajectories also had huge practical implications because they would enable decisions on which kinds of knowledge and skills should be developed at which point in teacher education. They would at least enable us to estimate if a non-found correlation between professional knowledge and skills is more or less typical for a specific stage of professional development.

More closely, our results might indicate that in field experiences, at least in Germany, reflection on the physics instruction of others is not used in a sufficient way to support preservice teachers' skills to plan one's own lessons. Following typical process models of reflection [37], this should be the main path of professional development, which, however, is apparently not yet fully explored. Therefore, there is a need for the development of training concepts that better relates to reflection and lesson planning for the mean of skills development. Performance assessments such as the ones we used in our study may be a helpful tool [68].

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

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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