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University Teacher Students' Learning in Times of COVID-19

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Abstract: At the beginning of the COVID-19 pandemic in spring 2020, school and university learning were abruptly switched to distance learning, coming along with psychological strains and various learning lags on the part of the students. These problems come to a head when focusing on university teacher students, since an expectable competence lag on their part, similarly arising from pandemic-caused distance learning in university teacher training, could affect their future teaching in schools, possibly then disadvantaging school students a second time. To determine changes of teacher students' self-concept of professional knowledge, we used data of a repeated cross-sectional survey carried out in a period from 2018 to 2021, including several comparable cohorts of overall $N = 395$ teacher students. This design allowed for splitting the participants in two groups relating to times before and after switching to distance learning. Our results show that the switch to distance learning goes hand in hand with lower scores on almost every dimension of teacher students' self-concept of professional knowledge, although, in parallel, their scores on variables such as openness to experiences, agreeableness, and conscientiousness increased significantly, indicating a certain degree of compliance with the new situation. Beyond that, we report on an evaluative survey among $N = 84$ teacher students carried out in July 2020, offering further insights into their situation during the first semester of distance learning. Its results primarily show which specific aspects of distance learning the students consider in need of improvement. On the other hand, it becomes clear that they experienced handicaps in various areas, accompanied by a significant decrease of their core self-evaluations when comparing them to a reference sample. Practical implications and recommendations that can be derived from these results are discussed.

Keywords: teacher students; COVID-19; distance learning; professional knowledge; self-concept of abilities

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1. Introduction

In spring 2020, the similar measures against the pandemic spread of the COVID-19 virus that were taken by nations around the world spontaneously focused on so-called lockdowns. As a result, economic and social life have been restricted as much as possible in terms of reducing them to what is absolutely necessary [1,2]. A comprehensive overview of the various publications on global COVID-19 management is provided by Karakose et al. [3]. Many people experienced isolation and psychological stress due to the restriction of social contacts [4–6]. Some studies on consequences of COVID-19-related lockdowns even suggest changes on central dimensions of personality [7,8], which are actually considered to be rather stable under normal circumstances [7,9,10]. However, such results turn out to be quite inhomogeneous by indicating no [11], more [7], or less changes [8] on different rather adaptive (e.g., decreased neuroticism, increased conscientiousness) [7,8] as well as rather non-adaptive personality traits (e.g., decreased agreeableness) [8].

When focusing on education in particular, lockdowns imply the closure of universities and schools, and thus affect both the teachers in these institutions and, of course, primarily students [12]. The abrupt switch of learning from school and university to previously

unfamiliar distance learning [1,13] can be related to difficulties in students' understanding, knowledge acquisition and, finally, academic achievement [14–17]. Causes of these difficulties are, to some extent, certainly to be found in basic conditions related to education policy and digital infrastructure [18,19]. Beyond that, rather individual factors can be assumed on the part of both learners and teachers.

On part of the learners, on the one hand, the deprivation of social experience of learning in school and restriction to the family context seems questionable from a developmental psychological perspective [1,20–22]. On the other hand, with respect to academic achievement in particular, social distancing from the relevant reference group of fellow pupils/students means diminishment of the social dimension of comparison that is decisive for the development of a stable and realistic self-concept of abilities [23,24]. According to the approach of self-enhancement [24,25] and the reciprocal effects model (REM) [26–28], the self-concept of abilities is, in turn, strongly positively related to academic achievement [24,25,29,30]: poor achievement leads to a weaker self-concept of abilities and a weaker self-concept of abilities in turn leads to even poorer achievement. Therefore, questions about the basic cause for current difficulties of learners remains open, since both factors occurred concomitantly during the pandemic situation: declines in academic achievement [14–17] and reduction of social comparisons regarded essential for the development of a stable self-concept [1,20–24].

Finally, individual factors on the part of teachers (e.g., professional knowledge) must be considered as a potential (co-) cause for students' learning difficulties, too. In the 1990s, Sanders and Rivers [31] were able to show that the crucial factor regarding students' learning success relates to the teacher's professional competence—a result that has also been approved by Hattie's [32] well-known meta-analysis. In practical terms, this means that good teachers enable their students to learn successfully regardless of the type of school or other structure characteristics of the educational system and the learning environment (e.g., class size or equipment). This most meaningful characteristic of a good teacher is particularly relevant for low-achieving students or those from low-income or poorly educated parents. Especially for these learners, a permeability of social stratification can be supported by teachers' professional competence [32]. Although (in fairness) it cannot be assumed that Hattie and other researchers were able to refer to such an exceptional situation as the COVID-19 pandemic, it certainly cannot be ruled out that teachers' professional competence at least can have a significant impact on students' learning success in times of COVID-19 as well.

1.1. Teachers' Professional Knowledge and Digital Skills

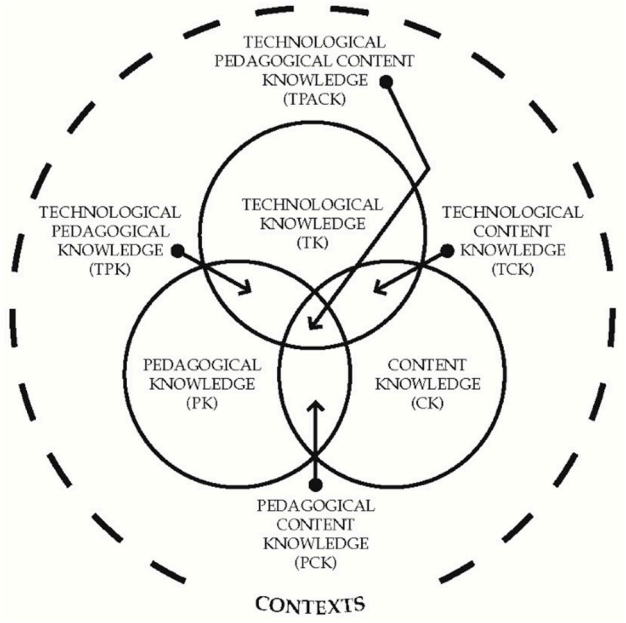
A meaningful facet of teachers' professional competence is their professional knowledge, whose conceptualization follows a well-known approach by Shulman [33,34], differentiating three decisive domains of knowledge:

- Content knowledge (CK) describes in-depth knowledge and understanding of the teaching subject that enables teachers to organize lessons successfully and monitor the students' learning progress adequately in terms of the subject's content.
- Pedagogical knowledge (PK) is regarded as being interdisciplinary and refers to knowledge about learning and learners, classroom management, educational psychology, and development processes.
- Pedagogical content knowledge (PCK) refers to a specific transformation of CK, intending an effective and flexible use in the classroom to make the content understandable to the learners. This combination of CK and PK elements constitutes PCK as a specific domain of professional knowledge, whose theoretically assumed independence has also been confirmed empirically in the meantime [35,36]. PCK includes aspects such as knowledge about conceptual ideas of learners or specific instruction strategies.

In addition to these domains of professional knowledge, teachers are expected to hold specific affective, motivational, volitional, and attitude-related characteristics and skills

as well, which enable them to adequately respond to individual learners and to motivate their activity in the classroom [32,37].

Since digital teaching and learning have become increasingly important during the past two decades, Mishra and Koehler [38] proposed an enrichment of the three domains of teachers' professional knowledge by adding relevant aspects in this regard. Accordingly, their technological pedagogical content knowledge (TPACK) model specifies additional domains of knowledge, relating to skills that enable teachers to use technology successfully in the classroom. The TPACK model is made up of three basic domains, (1) technological knowledge (TK) as well as (2) PK and (3) CK in terms of Shulman [33,34], and the four possible overlaps between them, (4) PCK, (5) technological content knowledge (TCK), (6) technological pedagogical knowledge (TPK), and (7) TPACK [38,39]. Similar to PCK in terms of Shulman [33,34], TPACK is designed as an independent domain of knowledge which, however, is made up of the transformation of learning content, considering educational *and* technological aspects [38–42] (see Figure 1).



TK	Knowledge of the functionality, application and possibilities of hardware, software, and associated technology
PK	Knowledge about learning and learners, classroom management, educational psychology, and development processes
CK	In-depth knowledge and understanding of the discipline to be taught
PCK	Knowledge of how to deal with subject-specific knowledge in the classroom, knowledge of conceptual ideas of learners and specific instruction strategies
TPK	Knowledge of different technologies and their potential for the design of learning environments, knowledge of problems and constraints related to technology when used for learning
TCK	Knowledge of how specific technologies can be used to design and present subject-specific content effectively
TPACK	Knowledge of how to use certain technologies to support learners' knowledge acquisition and overall learning success

Figure 1. Knowledge domains represented by the TPACK model [38].

These components of the TPACK model can also be found in more recent conceptualizations such as the European Framework for the Digital Competence of Educators (DigCompEdu) [43,44]. However, with its three comprehensive domains (1) educators' professional competences, (2) educators' pedagogic competence, and (3) learners' competences, DigCompEdu goes well beyond Mishra and Koehler's [38] model by referring much more specifically to teachers' and learners' digital competence. For example, DigCompEdu explicitly operationalizes criteria such as organizational communication, formative evaluation of digital teaching and learning, or promotion of learners' digital competence, which are regarded to significantly contribute to successful teaching and learning using digital technology [43,44].

1.2. Digital Teaching and Learning before and during the COVID-19 Pandemic

In Germany, competencies related to an effective integration of digital technology in the classroom were meanwhile explicitly taken up by several initiatives of educational policy [45,46], primarily focusing on teacher training. In addition, inclusive learning, i.e., integrating heterogeneity and diversity in the classroom, is increasingly being recognized as a challenge for teachers which needs to be addressed more intensely in teacher training [47–49]. Despite these initiatives, however, it has become clear several times over the past few

years, and especially during the COVID-19 pandemic, that their effective transfer to the educational system still requires some effort [19,50–52]. Above all, digitalization's full potential regarding a successful inclusivity in the classroom has not been tapped yet, associated with the risk of continually contributing to or even increasing inequality in the end [53–55]. Accordingly, identifiable potential for optimizing the status quo became, at best, (again) particularly clear against the background of the COVID-19 pandemic. Therefore, Sliwka and Klopsch [56] consistently use the term "disruptive innovation" for those (poorly prepared) measures that have now been taken ad hoc.

Resulting challenges and consequences for learners are being highlighted by empirical studies that have promptly been carried out internationally [1,22,57–60], partly also considering aspects of the social state and equal opportunities of learners [15,61,62]. Although clear and consistent conclusions are still pending with respect to the causes of reduced learning success of students, various and, finally, interacting factors have been brought to discussion. However, it must also be considered that these factors may only have become more apparent due to the pandemic but have already existed under pre-pandemic conditions [63].

On part of the school students, the simple loss of effective learning time and the resulting learning lags seem most important [15]. Furthermore, factors such as a possible lack of support from parents and friends, a deprived social background, limited opportunities to ask understanding-related questions that are answered immediately, and a lack of familiarity with digital and self-regulated learning are discussed [59,61,64,65].

In the same way, the pandemic-related situation of university students is characterized by a loss of effective learning time, a lack of support that is usually provided in the context of face-to-face lectures, and a lack of practical exercise in particular [66–68]. In addition, the loss of students' side jobs, resulting from closing of retail, gastronomy, and other sectors, resulted in financial strain and trembling uncertainty, representing an unfavorable background for developing and maintaining solid learning motivation required for successful self-regulated learning [67,69–72].

Basically, it can be expected that teacher students are affected by these difficulties in a similar manner to students in general, but perhaps with more far-reaching consequences. At first glance, one could possibly assume that academic years of digital distance learning might even have strengthened teacher students' TPACK-related skills by gaining first-hand experience. However, it must be taken into account that merely increased use of digital tools and media per se rather strengthens skills other than those specified in the TPACK model [38]. The ability to integrate and transform CK, PK, and TK elements towards TPACK competencies [38,39] can hardly be promoted by simply transforming regular on-site university courses to digital presentations [73]. To this end, just like in the case of general PCK skills, appropriate learning opportunities including practical exercise are required [74,75]. Since the beginning of the COVID-19 pandemic, there have been extensive restrictions on practical training both for university teacher students and student teachers in school [76–78]. School teaching is a complex social situation that aspiring teachers must learn to deal with practically to become able to regulate relevant processes in terms of students' learning success [79–81]. Given this primary goal of teacher education, it seems questionable that appropriate training can be offered via mere distance learning [69,78,82–84]. Probably resulting competence lags among aspiring teachers could therefore not only relate to academic and subject-specific content knowledge but also to PCK-specific skills in particular. Since such competence lags can have a significant impact on the teacher students' future school teaching [31,32], school students could be disadvantaged twice if the worst comes to the worst: at first by pandemic-caused homeschooling and its associated problems, and some time later by teachers who are not optimally trained.

1.3. Research Questions

Only if potential lags are recognized and specified would it be possible to correct them early enough to prevent the possible far-reaching consequences described above.

Against this background, we conducted two different studies to contribute to the status quo's clarification by taking a closer look at the current situation of teacher students and their professional knowledge in particular. Within this scope, we tried to answer one major (RQ1) and three exploratory minor research questions (RQ2 to RQ4):

- RQ1: Do two comparable groups of teacher students, of which one was surveyed before and the other after switching to distance learning, show differences regarding their self-concept of professional knowledge? Additionally, if that should be the case, are such differences to the disadvantage of the group surveyed after switching to distance learning?
- RQ2: Do the two groups considered in RQ1 score differently regarding main personality characteristics? Does the group surveyed after switching to distance learning, for example, score higher on neuroticism (sensitivity/nervousness), and if that should be the case, do such differences suggest any clarification regarding RQ1?
- RQ3: What are teacher student's perceptions of distance learning? How do they evaluate factors associated with successful teaching and learning at the end of the first semester of distance learning (spring semester 2020)? How could their digital competence and attitude towards digital teaching and learning be characterized? How do they rate the technical conditions? Do they report specific handicaps at that time?
- RQ4: How could teacher students' view of their own person and confidence in their own abilities be characterized in spring semester 2020? Are their core self-evaluations congruent with those of a reference sample or do they deviate significantly?

2. Materials and Methods

The two different studies we conducted to answer our research questions both focus on teacher students' learning in times of COVID-19. Although both studies were originally independent of each other, we decided to report them together, as their research questions turned out to be an excellent match (see Section 1.3). Furthermore, they provide interesting findings, which can be used to interpret their respective results reciprocally (see Section 4). Study 1 was based on a repeated cross-sectional design and was carried out in a period from 2018 to 2021 among biology teacher students. This study primarily aimed at assessing the teacher students' self-concept of professional knowledge (RQ1) as well as personality characteristics (RQ2). Study 2 included only one cross-sectional survey in July 2020 (after COVID-19's outbreak), aiming at assessing perceptions of distance learning among teacher students of different majors (RQ3) as well as their core self-evaluations (RQ4). In both studies, all surveys were designed as web-based questionnaires using the Qualtrics Survey software (SAP America, Newtown Township, PA, USA) [85].

2.1. Study 1

2.1.1. Sample and Procedure

In the period from 2018 to 2021, we repeatedly carried out cross-sectional surveys of several (basically comparable) cohorts of teacher students. These surveys always took place as part of the same courses at the Institute of Biology Education at our university, which were offered one time per academic year and should be completed by each student at a defined point in his or her teacher education program (nonrecurring participation). With this study, we originally aimed at answering the question of whether specific relationships between personality traits and commitment to innovation, as found in other contexts of organizational psychology, can also be shown in samples of teacher students. However, due to COVID-19's unpredictable outbreak, a part of the collected data can now also be used to specifically focus on pandemic-associated changes regarding the self-concept of professional knowledge (RQ1) and personality traits (RQ2). In total, N = 395 biology teacher students participated in our survey over the four academic years (see Figure 2). About 76% of the participants were female, 23% were male, and 1% was non-binary gender. On average, the sample was 22.50 (SD = 2.93) years old, and the students had already completed 4.78 (SD = 1.52) semesters of their teaching degree. In each of the surveys, the

participants were asked to complete both a questionnaire on the self-concept of professional knowledge and one on personality characteristics.

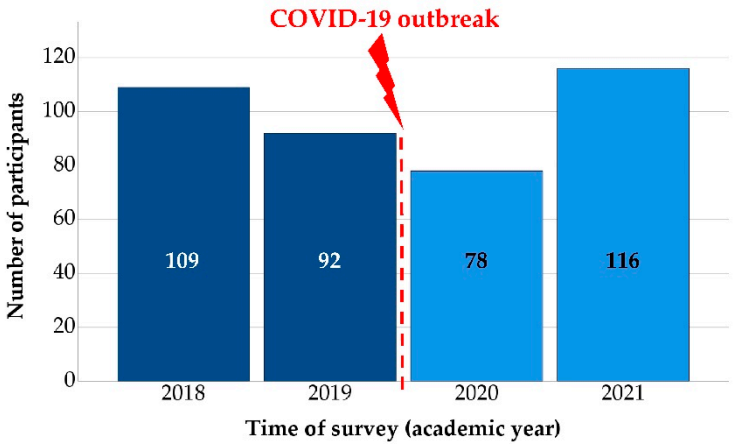


Figure 2. Numbers of participants per academic year.

2.1.2. Self-Concept of Professional Knowledge in Biology Questionnaire

The assessment of teacher students' self-concept of professional knowledge was based on the TPACK model's seven dimensions [38], which have been described in Section 1.1. To this, we used the TPACK questionnaire by Schmidt et al., whose validation study confirmed the instrument's objectivity, factorial structure, and validity [39]. The authors' subscales for the assessments of TK, PK, and TPK were adopted without any changes. Items for the assessments of the remaining subject-specific dimensions (CK, PCK, TCK, and TPCK) were specifically adapted for the subject of biology by replacing the original subjects of "mathematics", "social studies", "science", and "literacy" by those areas our biology teacher students were familiar with: "botany", "zoology", and "human biology". The two supplementary subscales ("models of TPACK" and open-ended questions) of Schmidt et al.'s [39] questionnaire were not used to make the survey as short and motivating as possible for our participants. Thus, our final questionnaire comprised overall 40 items, which should be answered on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). Homogeneity of the subscales ranged between $\alpha = 0.84$ and 0.90 in our sample.

2.1.3. NEO Five-Factor Inventory

According to personality research's popular Big Five model [86], everyone can be characterized on a total of five cross-cultural replicable dimensions [87–89]:

- Neuroticism (sensitive/nervous vs. resilient/confident);
- Extraversion (outgoing/energetic vs. solitary/reserved);
- Openness to experience (inventive/curious vs. consistent/cautious);
- Agreeableness (friendly/compassionate vs. critical/rational);
- Conscientiousness (efficient/organized vs. extravagant/careless).

The German version of the NEO Five-Factor Inventory (NEO-FFI) [90] allows for a self-assessment on these dimensions using five 12-item scales. These 60 items should be rated each on a 5-point Likert scale (0 = *strongly disagree* to 4 = *strongly agree*). The NEO-FFI's objectivity, factorial structure, and validity are supported by previous findings [90,91]. Homogeneity of the subscales ranged between $\alpha = 0.71$ and 0.85 in our sample.

2.1.4. Statistical Methods

Our major research question (RQ1) referred to potential differences regarding biology teacher students' self-concept of professional knowledge before and after switching to distance learning, whereas the first of our minor research questions (RQ 2) related to potential changes of Big Five dimensions of personality. We answered RQ1 and RQ2 by

splitting the overall number of $N = 395$ participants into two groups (see Figure 2): The first group ($N = 201$; dark blue in Figure 2) was surveyed in academic years of regular on-site learning, the second group ($N = 194$; pale blue in Figure 2) was surveyed after switching to distance learning due to COVID-19.

Since the sample splitting was based on COVID-19's outbreak, we had to ensure the two groups' basic comparability next. All participants were biology teacher students who had been recruited from the same courses every academic year, so comparable teaching subjects and semesters of study were already ensured inherently. Thus, it was only necessary to test for potential baseline differences regarding gender and age variables, using χ^2- and t-tests, respectively. Afterwards, we checked for parametric assumptions of the variables' multivariate normal distributions before carrying out group comparisons. To test whether there were global differences regarding the self-concept of professional knowledge (RQ1) and personality characteristics (RQ2) between the two groups, a multivariate analysis of variance (MANOVA) was each carried out first. The box test indicated unequal variance–covariance matrices in case of RQ1, which, however, was negligible in our case of large groups and almost equal sample sizes [92]. Univariate comparisons regarding both constructs' single dimensions were each checked in subsequent t-tests, considering inequality of variance where required (see Section 3.1).

2.2. Study 2

2.2.1. Sample and Procedure

To evaluate perceptions of distance learning, a large-scale survey among teachers and students belonging to different faculties and departments of our university was carried out. Among others, $N = 84$ teacher students of different majors participated in this study, whose data were extracted to report them separately in this paper. This means that all other participants of this university-wide evaluation (students and teachers of psychology, medicine, economics, etc.) are not considered here. About 85% of the $N = 84$ teacher students were female, 15% were male. On average, they were 25.20 ($SD = 5.31$) years old and had already completed 6.43 ($SD = 2.29$) semesters of their teaching degree. In this survey, the participants were asked to complete both a questionnaire on their perceptions of distance learning and one on their core self-evaluations.

2.2.2. Perception of Distance Learning Questionnaire

To evaluate perceptions of distance learning, we developed a 55-item questionnaire, covering the following evaluation aspects:

1. Successful teaching and learning: This subscale consisted of 17 items, covering relevant aspects relating to successful teaching and learning [32], e.g., encouragement of the learners to reflect on individual learning progress, reply to learners' questions, or fit between teaching formats and learning objectives. Each of these items should be rated twice. On the one hand, the teacher students were asked to give an absolute rating on a 4-point Likert scale (1 = *highly unsatisfactory* to 4 = *highly satisfactory*). On the other hand, they were asked to rate these aspects when comparing them to previous semesters of regular on-site learning (−1 = *inferior to on-site learning* to +1 = *superior to on-site learning*). Homogeneities of both subscales were $\alpha = 0.90$ (absolute rating) and $\alpha = 0.93$ (comparison to on-site learning) in our sample.
2. Attitude towards digital teaching and learning: This subscale consisted of 9 items, covering relevant aspects relating to the teacher students' view of e-learning, e.g., potential to learn more flexibly or reduction of effort for learners and teachers. These items should be rated each on a bipolar scale (1 = *strongly disagree* to 10 = *strongly agree*). Homogeneity of this subscale was $\alpha = 0.93$ in our sample.
3. Technical conditions: This subscale consisted of 6 items, covering the teacher students' view of relevant technology-related aspects of e-learning, e.g., usability, technical support, or accessibility of courses. These items should be rated each on a 5-point

Likert scale (1 = *very poor* to 5 = *very good*). Homogeneity of this subscale was $\alpha = 0.69$ in our sample.

4. Digital skills: This subscale consisted of 13 items, covering the teacher students' self-concept of digital skills [43], e.g., abilities to use e-learning platforms, protect own digital data, or reflect on own usage behavior. These items should be rated each on a 4-point Likert scale (1 = *strongly disagree* to 4 = *strongly agree*). The homogeneity of the subscale was $\alpha = 0.81$ in our sample.
5. Handicaps: This supplementary question related to 10 categories, representing potential handicaps of the teacher students during the first semester of distance learning, e.g., infection with COVID-19, increased psychological stress, or financial problems. For each of these handicaps the students were asked to state whether it applied to them or not, so a selection of several categories was possible for every participant.

2.2.3. Core Self-Evaluations Scale

Core self-evaluations represent a personality trait, comprising aspects of self-esteem, self-efficacy, locus of control, and neuroticism. Taken together, these aspects reflect peoples' fundamental view of their own person and confidence in their own abilities [93]. The Core Self Evaluations Scale (CSES) [94,95] consists of 12 items which should be rated each on a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). The CSES's objectivity, factorial structure, and validity are supported by previous findings [94–96]. Homogeneity of the scale was $\alpha = 0.84$ in our sample.

2.2.4. Statistical Methods

Our second minor research question (RQ3) referred to teacher students' perceptions of distance learning after COVID-19's outbreak, whereas RQ4 related to their core self-evaluations at that time. To answer these questions, we first calculated descriptive statistics, which were already sufficient to answer RQ3. Regarding RQ4, we additionally compared our teacher students' average CSES score to that of a reference sample ($N = 158$ young employees) from Germany [95], considering different sample sizes and variances by using a standardized effect size (Cohen's d). Finally, we carried out additional correlational analyses to explore how the different subscales relating to teacher students' perception towards distance learning correlated with each other as well as with the students' core self-evaluations. To this end, we first checked for distributional parameters of the variables considered. We found normal distributions in any case except for the number of handicaps. Accordingly, we calculated nonparametric Spearman correlations for the latter, whereas calculation of parametric Pearson correlations was appropriate in case of all other variables (see Section 3.2).

3. Results

3.1. Study 1

In study 1, we focused on the self-concept of professional knowledge (RQ1) and Big Five personality characteristics (RQ2) of biology teacher students who were surveyed before or after switching to distance learning. As comparable teaching subjects and semesters of study were already ensured inherently by sampling, we only tested for potential baseline differences regarding gender and age variables (see Section 2.1.4). Corresponding t- and χ^2-tests indicated neither differences regarding the groups' average age, $t(187.36) = 1.00$, $p = 0.36$, nor gender distribution, $\chi^2(3) = 3.28$, $p = 0.35$. Consequently, no covariates or interacting factors were included additionally in subsequent statistical analyses.

3.1.1. Self-Concept of Professional Knowledge

MANOVA results indicated significant global differences between the two groups, $F(7, 387) = 6.58$, $p < 0.001$, $\eta_p^2 = 0.11$, $d_{Cohen} = 0.70$. Subsequent t-tests to check for differences on single dimensions of the biology teacher students' self-concept of professional knowledge (see Table 1) showed significantly lower scores of the group surveyed after switching to

distance learning on all subscales except TK. In this connection, the largest significant difference was related to the subscale of PCK, $t(355.49) = 5.44$, $p < 0.001$, $d_{Cohen} = 0.55$; the smallest significant difference was related to the subscale of CK, $t(393) = 2.27$, $p < 0.05$, $d_{Cohen} = 0.23$.

Table 1. Differences regarding the self-concept of professional knowledge between comparable groups of students before and after switching to distance learning.

Dimensions of Self-Concept of Professional Knowledge	Style of Learning	*n*	*M* [1]	*SD*	*t*-Test	d_{Cohen}
TK	on-site distance	201 194	4.28 4.31	1.21 1.03	$t(386.25) = 0.29$	
CK	on-site distance	201 194	4.63 4.43	0.82 0.93	$t(393) = 2.27$ *	0.23
PK	on-site distance	201 194	5.19 4.93	0.85 0.83	$t(393) = 3.10$ **	0.31
PCK	on-site distance	201 194	4.99 4.40	0.90 1.21	$t(355.49) = 5.44$ ***	0.55
TCK	on-site distance	201 194	4.56 3.90	1.16 1.35	$t(379.08) = 5.25$ ***	0.53
TPK	on-site distance	201 194	5.01 4.66	0.90 1.01	$t(393) = 3.62$ ***	0.36
TPCK	on-site distance	201 194	4.78 4.21	1.00 1.30	$t(363.82) = 4.83$ ***	0.49

Annotation. [1] Scale labeling: 1 = strongly disagree; 2 = disagree; 3 = partially disagree; 4 = neither disagree nor agree; 5 = partially agree; 6 = agree; 7 = strongly agree; TK = technological knowledge; CK = content knowledge; PK = pedagogical knowledge; PCK = pedagogical content knowledge; TCK = technological content knowledge; TPK = technological pedagogical knowledge; TPCK = technological pedagogical content knowledge; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

3.1.2. Big Five Personality Characteristics

MANOVA results indicated significant global differences between the two groups, $F(5, 388) = 7.65$, $p < 0.001$, $\eta_p^2 = 0.09$, $d_{Cohen} = 0.63$. Subsequent *t*-tests to check for differences on single Big Five dimensions (see Table 2) showed significantly higher scores of those students who were surveyed after switching to distance learning on the three subscales of openness to experience, agreeableness, and conscientiousness. In this connection, the largest significant difference was related to the subscale of openness to experience, $t(392) = 4.41$, $p < 0.001$, $d_{Cohen} = 0.44$; the smallest significant difference was related to the subscale of agreeableness, $t(393) = 2.64$, $p < 0.01$, $d_{Cohen} = 0.27$.

Although our sampling and baseline difference testing were sufficient in excluding significant influences of potentially confounding variables regarding the self-concept of professional knowledge (level of education, etc.), this procedure is not robust with respect to personality due to its dependence on several other influencing factors [97,98]. Since these numerous factors of peoples' personal biography could have hardly been captured in our study, we have chosen another approach to at least make a rough estimate of whether the significant differences on Big Five dimensions could actually have been caused by factors related to COVID-19's outbreak, or if they are rather an independent, general trend. To this end, we have created line diagrams, visualizing the scores on the three dimensions of openness to experience, agreeableness, and conscientiousness over the course of the four academic years of measurement (see Figures 3–5). These diagrams offer a comparable pattern for all three variables: before COVID-19's outbreak, the scores were basically stable (except agreeableness), then rose significantly in 2020 (COVID-19 outbreak) and, finally, slightly tended back towards their baseline value when the pandemic situation eased off due to vaccination campaigns in 2021.

Table 2. Differences regarding the Big Five dimensions of personality (NEO-FFI) [90] between comparable groups of students before and after switching to distance learning.

Big Five Dimensions	Style of Learning	*n*	*M* [1]	*SD*	*t*-Test	d_{Cohen}
Neuroticism	on-site	201	20.42	7.62	$t(393) = 1.65$	
	distance	194	21.69	7.98		
Extraversion	on-site	201	29.79	5.80	$t(384.91) = 0.45$	
	distance	194	30.09	6.48		
Openness to experience	on-site	201	28.62	5.85	$t(392) = 4.41$ ***	0.44
	distance	194	31.13	5.43		
Agreeableness	on-site	201	34.04	5.65	$t(393) = 2.64$ **	0.27
	distance	194	35.55	5.61		
Conscientiousness	on-site	201	32.63	6.13	$t(393) = 3.23$ **	0.33
	distance	194	34.68	6.19		

Annotation. [1] Cumulative scale values could basically range from a minimum 0 to a maximum 48; ** = $p < 0.01$; *** = $p < 0.001$.

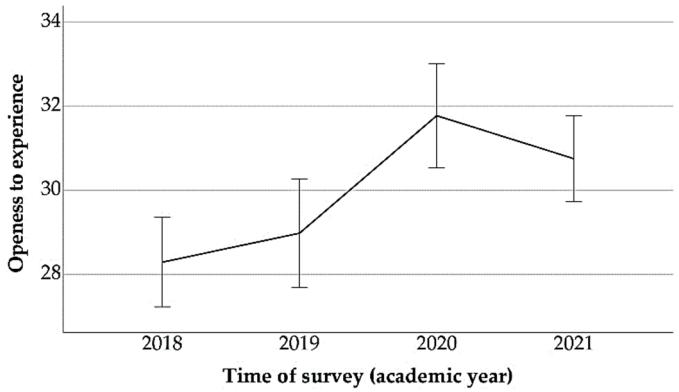


Figure 3. Openness to experience scores over the course of all four points of measurement of our repeated cross-sectional design.

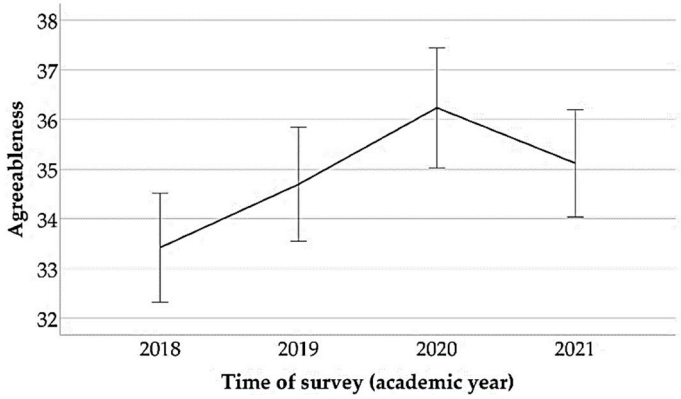


Figure 4. Agreeableness scores over the course of all four points of measurement of our repeated cross-sectional design.

3.2. Study 2

In study 2, we focused on teacher students' perceptions of distance learning (RQ3) as well as their core self-evaluations at the end of the first semester of distance learning (RQ4).

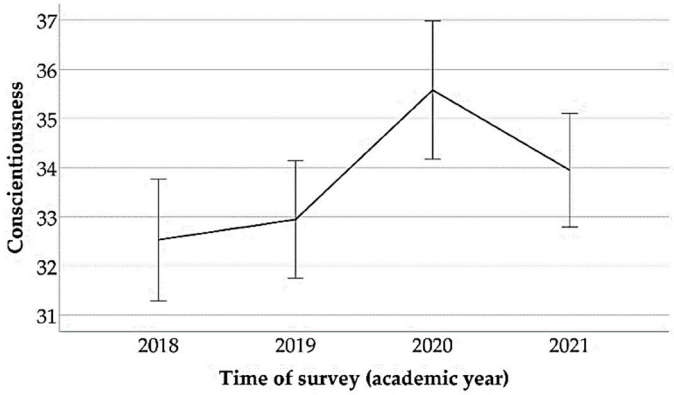


Figure 5. Conscientiousness scores over the course of all four points of measurement of our repeated cross-sectional design.

3.2.1. Perceptions of Distance Learning

On average, our sample of $N = 84$ teacher students rated relevant aspects relating to successful teaching and learning between slightly and somewhat satisfactory ($M = 2.50$, $SD = 0.54$). The aspect of "motivating the learners to continuously deal with a topic" was rated worst ($M = 2.23$, $SD = 0.81$); the aspect of "replying to learners' organizational matters" was rated best ($M = 2.85$, $SD = 0.87$). Furthermore, when the teacher students were asked to compare the first semester of distance learning with previous semesters of regular on-site learning, they rated it overall as inferior ($M = -0.35$, $SD = 0.46$; see Table 3).

Table 3. Means and standard deviations regarding the rating of relevant aspects relating to successful teaching and learning in the first semester of distance learning.

Aspects Relating to Successful Teaching and Learning	Absolute Rating [1]		Compared to On-Site Learning [2]	
	M	*SD*	*M*	*SD*
Motivation of the learners to continuously deal with a topic	2.23	0.81	−0.38	0.76
Interaction with other students on learning contents	2.24	1.04	−0.44	0.77
Monitoring of the learners' individual learning progress	2.29	0.87	−0.37	0.66
Communication of realistic learning goals	2.32	0.84	−0.38	0.68
Extent of the learning content [3]	2.32	0.88	−0.61	0.62
Encouragement of the learners to reflect on individual learning progress	2.36	0.85	−0.30	0.71
Encouragement of the learners to participate actively in courses	2.39	0.85	−0.39	0.76
Structuring and portioning of the learning content	2.39	0.89	−0.44	0.68
Communication of learning contents' practical relevance and usefulness	2.51	0.89	−0.31	0.60
Support of the learners in case of comprehension difficulties	2.51	0.94	−0.29	0.74
Level of complexity of the learning content	2.63	0.77	−0.30	0.62
Consideration of the learners' prior knowledge and experiences	2.63	0.82	−0.26	0.54
Fit between teaching formats used and learning objectives	2.64	0.69	−0.40	0.71
Promotion of learning progress (knowledge, interest, practical skills)	2.65	0.77	−0.25	0.67
Reply to learners' content-related questions	2.76	0.90	−0.23	0.72
Communication of organizational aspects (e.g., planned time flow)	2.77	0.94	−0.26	0.70
Reply to learners' organizational matters	2.85	0.87	−0.27	0.63

Annotation. $N = 84$ teacher students; [1] scale labeling: 1 = highly unsatisfactory; 2 = slightly satisfactory; 3 = somewhat satisfactory; 4 = highly satisfactory; [2] scale labeling: −1 = inferior to on-site learning; 0 = neither inferior nor superior to on-site learning; +1 = superior to on-site learning; [3] extent was rated excessive (adaptive specification item).

Regarding their attitude towards digital teaching and learning, the teacher students showed almost neutral scores on average ($M = 5.31$, $SD = 2.62$). The lowest agreement was found for the statement of "long-term effort reduction" ($M = 3.55$, $SD = 3.40$); the

highest agreement was found for the statement of "more flexibility in learning" (M = 7.04, SD = 3.30; see Table 4).

Table 4. Means and standard deviations regarding the attitude towards digital teaching and learning in the first semester of distance learning.

Aspects Relating to the Attitude Towards Digital Teaching and Learning	M [1]	SD
The integration of e-learning elements reduces the students' effort in the long term.	3.55	3.40
E-learning enables a better handling of heterogeneous groups of learners.	4.21	3.26
The use of e-learning has more advantages than disadvantages.	4.79	3.28
In the future, I would like to use more e-learning in my university studies.	5.14	3.71
The use of e-learning overall enriched my university studies.	5.14	3.37
The integration of e-learning elements reduces the lecturers' effort in the long term.	5.42	2.97
A targeted integration of e-learning can offer scopes for on-site learning and more personal support for every student.	5.60	3.35
I am happy with the opportunity to use e-learning in my university studies.	6.93	2.96
E-learning enables students to learn more flexibly.	7.04	3.30

Annotation. N = 84 teacher students; [1] bipolar scale ranging from 1 = strongly disagree to 10 = strongly agree.

Additionally, the teacher students rated the technical conditions of digital teaching and learning moderately (M = 3.10, SD = 0.70). "Accessibility of courses (e.g., for disabled students)" was rated worst (M = 1.87, SD = 1.12); "software equipment" was rated best (M = 3.73, SD = 0.92; see Table 5).

Furthermore, the teacher students rated their own digital skills as rather good on average (M = 3.03, SD = 0.41). The worst rated was their knowledge of legal regulations when dealing with digital media (M = 2.27, SD = 0.92); as best they rated their skills in using e-learning platforms (M = 3.80, SD = 0.40; see Table 6).

Table 5. Means and standard deviations regarding the technical conditions of digital teaching and learning in the first semester of distance learning.

Technical Conditions of Digital Teaching and Learning	M[1]	SD
Accessibility of courses (e.g., for disabled students)	1.87	1.12
Technical support	2.70	1.14
Effort to come to terms with	3.13	1.17
Usability (navigation, clear arrangement, etc.)	3.44	1.13
Available hardware equipment (PC, laptop, DSL router, microphone, etc.)	3.71	1.15
Available software equipment (e-learning platforms, video software, audio software, etc.)	3.73	0.92

Annotation. N = 84 teacher students; [1] scale labeling: 1 = very poor; 2 = rather poor; 3 = neutral; 4 = rather good; 5 = very good.

Finally, regarding potential handicaps, N = 66 (79%) out of overall N = 84 teacher students reported that they had to struggle with at least one, e.g., N = 49 (58%) reported increased psychological stress, followed by financial problems (N = 24, 29%), and technical difficulties when using e-learning (N = 21, 25%). An overview considering all categories of handicaps can be found in Table 7. Furthermore, of the N = 66 teacher students who stated that they had to struggle with handicaps, only N = 5 were convinced that these could be adequately compensated by special arrangements offered by the university. In contrast, N = 39 expressed doubts about this and N = 22 even stated that they definitely did not experience adequate compensation.

Table 6. Means and standard deviations regarding the teacher students' digital skills in the first semester of distance learning.

Digital Skills	M^1	*SD*
I can describe and comply with legal regulations (copyright, license agreements, etc.) when using digital information.	2.27	0.92
I can describe quality characteristics for rating digital information.	2.64	0.83
I can take measures to protect my digital data.	2.65	0.86
I feel able to advise or guide other students in the use of e-learning.	2.85	0.74
I critically reflect on my own usage behavior of digital media (media types and content, duration, and locations, etc.).	2.99	0.77
I can describe forms of online cooperation.	3.04	0.69
I can edit videos and images.	3.07	0.92
I know digital sources for researching expert information.	3.10	0.79
I can manage files digitally (e.g., using network drives or cloud storage).	3.11	0.79
I can describe several functions of typical Web 2.0 tools (e.g., social networks, blogs, wikis, forums).	3.12	0.65
I can identify potential problems and opportunities in online communication.	3.15	0.63
I can use MS Office applications (word processing, spreadsheets, presentations, etc.).	3.60	0.54
I can use e-learning platforms related to my courses (e.g., join a forum discussion, download materials, upload files, contact other students).	3.80	0.40

Annotation. N = 84 teacher students; [1] scale labeling: 1 = strongly disagree; 2 = rather disagree; 3 = rather agree; 4 = strongly agree.

3.2.2. Core Self-Evaluations

The students achieved an average CSES score of 3.53 (SD = 0.56), indicating a neutral to slightly positive rating of themselves and their confidence in their own abilities [93,95,99]. Compared to a German reference sample (N = 158 young employees), achieving a CSES average score of 3.88 (SD = 0.55) [95], however, the rating of our teacher students deviates significantly and with a medium effect size of $d_{\text{Cohen}} = 0.63$.

Table 7. Number of reported handicaps in the first semester of distance learning.

Handicaps [1,2]	*n*	%
Increased psychological stress	49	58
Financial problems	24	29
Technical problems when using e-learning	21	25
Childcare	12	14
Care for relatives	7	8
Severely at risk of COVID-19	5	6
Quarantine order	5	6
Chronic illness or disability	2	2
Infection with COVID-19	0	0
Other	9	11

Annotation. N = 84 teacher students; [1] a selection of several categories was possible; [2] handicaps do not only refer to distance learning but include all kinds of impairment of successful learning (e.g., anxiety, isolation, absence of student assistants for disabled students, etc.).

3.2.3. Additional Correlational Analyses

Regarding the rating of aspects relating to successful teaching and learning, the correlation analyses show the highest relation to the attitude towards digital teaching and learning ($r = 0.66$, $p < 0.001$), which is, on the other hand, moderately related to technical conditions ($r = 0.41$, $p < 0.001$) and the number of handicaps ($r = -0.39$, $p < 0.001$). The closest association with the students' core self-evaluations was found for digital skills ($r = 0.43$, $p < 0.001$). An overview of the correlational results considering all variables can be found in Table 8.

Table 8. Correlations between the different subscales relating to teacher students' perceptions of distance learning and core self-evaluation scores.

Variables	1	2	3	4	5	6
1 Aspects relating to successful teaching and learning	—					
2 Technical conditions	0.40 ***	—				
3 Digital skills	0.17	0.07	—			
4 Attitude towards digital teaching and learning	0.66 ***	0.41 ***	0.17	—		
5 Number of handicaps [1]	−0.38 ***	−0.38 ***	−0.19	−0.39 ***	—	
6 Core self-evaluations	0.32 **	0.34 **	0.43 ***	0.25 *	−0.35 **	—

Annotation. $N = 84$ teacher students; [1] since the number of handicaps was not normally distributed, Spearman correlations (instead of Pearson) are reported for this variable; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

4. Discussion

The results of study 1 (see Section 3.1) show significant differences on almost every dimension of the teacher students' self-concept of professional knowledge with lower scores for the group surveyed after switching to distance learning. Additionally, the two groups scored differently on three Big Five dimensions: openness to experiences, agreeableness, and conscientiousness. The results of study 2 (see Section 3.2) show that the aspects relating to successful teaching and learning were rated only between slightly and somewhat satisfactory in the first semester of distance learning. Furthermore, the teacher students rated these aspects as inferior to on-site learning, although they showed an almost neutral (i.e., no negative) attitude towards digital teaching and learning, which turned out to be highly positively correlated with their rating of aspects relating to successful teaching and learning. Beyond that, the teacher students reported handicaps in various areas, accompanied by a significant decrease of their core self-evaluations when comparing them to a reference sample [95].

4.1. Study 1

Our major research question (RQ1) referred to potential differences regarding biology teacher students' self-concept of professional knowledge before and after switching to distance learning. RQ1 can be answered quite clearly, as our results show significant differences on six out of seven dimensions of the TPACK model [38], reflecting a disadvantage of the group surveyed in times of distance learning (see Section 3.1.1). Taking into account our previous theoretical considerations (see Section 1), two explanations for these results suggest themselves: on the one hand, the lower ratings could reflect an actual deficit in knowledge acquisition during distance learning. This explanation would be in line with those empirical findings that have now clearly shown that the unprepared switch to distance learning has been problematic for the learning success of school and university students due to limited opportunities of communication, technical difficulties and/or a lack of abilities regarding self-regulated learning [15,57,58,82,100,101]. On the other hand, the lower scores of the group surveyed after switching to distance learning could also be attributed to difficulties in validly rating their own abilities, caused by diminishment of the social dimension of comparison that is decisive for the development of a stable and realistic academic self-concept [23,24]. Social distancing and distance learning limit the possibilities for personal interaction, communication, and group formation as well as the continuous maintenance of such social processes dramatically [102]. The argument that reducing the opportunities for social comparison complicates the development of a stable self-concept of abilities [23,24] emphasizes the dependence of such a self-assessment on the respective context of reference [103–105]. While a social context of reference includes interaction and comparisons of one's own academic achievement to that of peers in the same field, an individual context of reference refers to comparisons of one's own current to one's own previous achievement [106]. The assessments of those teacher students who were surveyed after switching to distance learning will therefore have largely been determined by such

intraindividual comparisons. When following Tesser's [107] theory of self-evaluation maintenance as well as the empirical results of Elsholz [108], it seems possible that these self-reference-based assessments could even represent a kind of overestimation of one's own abilities compared to assessments that would have been expected under conditions including valid social comparisons. In other words, it seems possible that our participants' self-concept of professional knowledge has actually been even lesser pronounced than reported.

Our first minor research question (RQ2) focused on potential group differences on the Big Five dimensions of personality that may suggest any clarification regarding RQ1. Indeed, the significantly higher openness to experience, agreeableness, and conscientiousness scores of the group surveyed after switching to distance learning provide useful insights in this regard (see Section 3.1.2). In previous empirical studies, conscientiousness and openness to experience in particular were repeatedly considered to be helpful regarding successful studying [109–115]. Higher scores on these dimensions could therefore be interpreted as indicators of a positive psychosocial adaptation that the group surveyed after switching to distance learning performed to constructively cope with the new demands and strains on behalf of their teacher training [109–115]. This possibility would be consistent with our finding that the respective scores tended towards lower values again as the pandemic situation eased off in 2021 (see Figures 3–5). The adaptability of personality structures, which are actually assumed to be stable [7,9,10], was explored by Cook [116], for example. She was able to collect empirical evidence that people must be able to (volitionally) realize different characteristics on a trait to be able to meet different or changing requirements [116]. In line with these considerations, our findings clearly point to the opposite of resignation or a phlegmatic attitude on the part of the teacher students, who apparently tried to cooperate, to engage with the new situation of distance learning, and to organize their learning conscientiously [90,91]. From this point of view, however, it seems even more worrying that the respective teacher students showed such a significantly weaker self-concept of professional knowledge (see Section 3.1.1).

4.2. Study 2

Our second minor research question (RQ3) referred to teacher students' perceptions of distance learning, considering several evaluation aspects rated at the end of the first semester of distance learning. On average, relevant aspects relating to successful teaching and learning were rated only between slightly and somewhat satisfactory as well as inferior to on-site learning (see Section 3.2.1). This finding can be seen to be in line with the weaker self-concept of professional knowledge of the other group of teacher students in study 1 (see Section 3.1.1). While aspects related to replies to students' organizational and content-related questions as well as communication about organizational matters scored comparatively better, those aspects that were closely related to university teachers' didactic approaches and peer interaction were rated particularly worse. This result conforms to previous empirical findings (see Section 1), which have already identified these aspects as particularly problematic for the learning success of school students during times of distance learning [16,66,69,70,72]. In comparison to previous semesters of regular on-site learning, it is noticeable that the extent, structure, and portioning of the learning content was rated worst by our sample, which is also reflected in the teacher students' attitude towards digital teaching and learning when they stated expectations of a high workload from digital teaching and learning in the long term. This perception can hardly be explained by a lack of digital skills on the part of the students, as they rated them as rather good on average and, furthermore, overall showed no negative attitude-related biases towards digital teaching and learning (see Section 3.2.1). Thus, the result may rather indicate that distance learning requires a fundamentally different didactic approach to regular on-site learning [117,118], which should be considered when designing lessons (see Sections 1.1 and 1.2). In this context, technical conditions (rated only as moderate) and accessibility of courses (rated as inadequate) could do with improving as well, to enable all students to

learn successfully. To ensure such inclusivity, however, it is also necessary to adequately compensate for existing handicaps of learners, but this aspect was rated as inadequate as well in the first semester of distance learning. Far more than half of the surveyed teacher students reported increased psychological stress, financial problems and/or technical problems related to e-learning (see Section 3.2.1). This finding is in line with those of other studies that have already identified almost the same factors as impediments regarding the learning success of university students during the pandemic situation [16,67,69,70,72,119].

Our third minor research question (RQ4) focused on the teacher students' core self-evaluations at the end of the first semester of distance learning. While Big Five traits have a primarily descriptive focus on personal characteristics [86,88], core self-evaluations are more evaluative by including personal experiences of success and an internal locus of control when dealing with tasks [94]. Since core-self evaluations are positively related to relevant outcome variables of satisfaction and performance in professional contexts [93,95,120,121], it seems alarming that this trait is significantly less pronounced in our sample than in the reference sample of Stumpp et al. [95] (see Section 3.2.2). Such reduced confidence in being able to successfully cope with professional demands can have a negative effect on professional performance and motivation both in the short and in the long term [32,120]. Whether our result is actually an effect of distance learning cannot be clarified on the basis of our design. However, a study of Ritchie et al. [122], who found a large negative effect especially of lockdowns on self-efficacy expectations in the general population, at least suggests that our samples' comparatively low core self-evaluation scores could be associated with the pandemic situation in a similar manner.

Additionally, our further exploratory correlational analyses showed that aspects relating to successful teaching and learning were rated more positively, the more positive the teacher students' attitude towards digital teaching and learning and their rating of technical conditions were. On the other hand, a more positive rating of technical conditions is further associated with a more positive attitude towards digital teaching and learning. Finally, the number of handicaps the students had to struggle with was solely negatively correlated with all other variables, i.e., an increasing number of handicaps went hand in hand with more negatively/lower ratings of aspects relating to successful teaching and learning, technical conditions, own digital skills, and core self-evaluations. On the other hand, higher core self-evaluation scores were closest associated with better digital skills, which is hardly surprising as the core self-evaluations primarily include confidence in one's own abilities and digital skills were the only skill-related construct assessed.

4.3. Summary

In summary, the following overall picture can be drawn from our single findings: study 1 shows that the switch to distance learning goes hand in hand with lower scores on almost every dimension of teacher students' self-concept of professional knowledge, although, in parallel, their scores on the Big Five dimensions of openness to experiences, agreeableness, and conscientiousness increased significantly (see Section 3.1), indicating overall a certain degree of compliance with the new situation [90,91,123]. Additionally, study 2 shows that relevant aspects relating to successful teaching and learning of the first semester of distance learning were rated as rather unsatisfactory and inferior to on-site learning by teacher students, although they did not show any attitude-related bias towards digital teaching and learning and rated their digital skills and technical conditions as rather good. On the other hand, it became clear that the teacher students experienced difficulties and disadvantages in various areas (e.g., financial problems, childcare), which can severely affect successful university studies [72,124]. Finally, these difficulties were accompanied by a significant decrease of the teacher students' core self-evaluations when comparing them to a reference sample [95], indicating a less positive view of their own person and less confidence in their own abilities [93,95,99] (see Section 3.2).

Although conclusions about causes and effects do not seem reasonable against the background of our research design, the considerable decreases on dimensions of the teacher

students' self-concept of professional knowledge found in study 1 seem converging towards the rather negative ratings of relevant aspects relating to successful teaching and learning, the comparably large number of handicaps, and the only moderate confidence in their own abilities at the end of the first semester of distance learning found in study 2.

4.4. Practical Implications and Recommendations

Our major research question-related findings refer to the approach of self-enhancement [24,25] and the REM [26–28]. Therefore, they suggest potentially far-reaching practical implications, as these research traditions constantly show medium to strong reciprocal relationships between the self-concept of abilities and academic achievement [24,25,29,30]. Given this, it seems obvious to assume that the weaker self-concept of professional knowledge of the group surveyed after switching to distance learning could actually be related to poorer academic achievement among the aspiring teachers. Considering the REM, on the one hand, the development of a self-reinforcing downward spiral on the part of the teacher students seems possible, since a weaker self-concept of abilities usually leads to poorer achievement and, in turn, poor achievement could lead to an even weaker self-concept of abilities, and so on [24,25,29,30]. On the other hand, considering the chain of effects between teacher training, teachers' professional competence, and learning success of school students, it seems possible that such competence lags on part of the aspiring teachers could have a negative impact on the learning success of their future school students [31,32], who are already struggling with learning lags due to the pandemic anyway [14–17]. It therefore seems essential to recognize and correct potential competence lags on the part of teacher students in sufficient time to enable them both to successfully complete their own teacher training and to successfully teach their future school students, avoiding further disadvantage for them.

Thus, we encourage other university teachers involved in teacher training to evaluate both their teacher students' achievement and self-concept of professional knowledge to quantify whether there are significant deviations from relevant reference samples or curricula specifications. The second step would be to compensate for potentially identified competence lags by offering specific additional university courses. Regardless of whether these offers are based on distance or on-site learning, implementation of consistent learning objectives, motivational didactic approaches (e.g., classroom discussions), feedback including formative evaluation and self-assessments of the students, clear communication about the learning content and its relevance, and scaffolding should be implemented, following Hattie's [32] metanalytical results. The definite goal of such measures is not only to compensate for competence lags, but also to consolidate a positive self-evaluation and self-efficacy of the aspiring teachers.

4.5. Limitations and Prospects for Future Research

Even though our results provide substantial clarification, they need to be evaluated in the light of the studies' limitations.

1. Study 1 was not based on a longitudinal design that would be necessary to validly determine changes over time. Therefore, the results must be interpreted with caution in this regard, although resulting impairment of internal validity could be reduced by (1) comparability of the cohorts on relevant potentially confounding variables regarding the TPACK dimensions [38] and (2) visual inspection of the line diagrams that visualize the NEO-FFI scores [90] over the course of the four academic years considered (see Sections 2.1.1 and 3.1).
2. Professional knowledge was not assessed directly (i.e., objective performance measure) in study 1. Instead, we decided to assess the teacher students' self-concept of knowledge (see Section 2.1.2), aiming at subsequently drawing conclusions about their factual performance. The reason for this was our intention to keep the burden on participants as low as possible. Nevertheless, we do not assume that this approach significantly affected internal validity of our conclusions, since self-concept of abilities

and academic achievement are usually moderately to highly correlated [24,25,29,30], so it can be assumed that self-assessment is a valid indicator of academic achievement. Nevertheless, in future studies, it would be desirable to assess objective performance parameters additionally, since such an approach would probably allow for more accurate identification of specific starting points of corrective interventions.

3. Regardless of the optimal statistical power of 0.80 of our statistical analyses within study 2, we surveyed a comparatively small sample of $N = 84$ teacher students of only one German university (see Section 2.2.1), which undoubtedly limits the generalizability of our results. Furthermore, study 2 was based on only one cross-sectional measure. Accordingly, although we were able to realize our intention to get a valid overview regarding the evaluation of the first semester of distance learning, no further conclusions can be drawn with respect to development of variables over time.
4. With respect to the different samples of both studies, it should finally be noted that although study 2 provides useful initial suggestions regarding the interpretation of the results from study 1, the respective participants can only be compared to a limited extent, since the teacher students in study 2, on average, had already completed one additional year of university teacher training and were partly enrolled in different teaching subjects (see Section 2.2.1).

Finally, regarding future research, it seems essential to carry out studies of comparable focus at other universities soon to gain a broad and valid insight into the current skills level and potential pandemic-associated competence lags on the part of teacher students. If our results could be replicated in other contexts and probably across different teaching subjects (i.e., others than biology), the educational policy-related question would arise as to which comprehensive and well-timed compensatory measures could be taken before the teacher students will have finished teacher training.

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Institutional Review Board Statement: In accordance with local legislation and institutional requirements, an ethics board approval was not required for this study on human participants. In Germany, as stated by the German Research Association (DFG) [125], the present survey did not require the approval of an ethics committee, because the research did not pose any threats or risks to the respondents, and it was not associated with high physical or emotional stress. Nevertheless, it is understood that we strictly followed all ethical guidelines as well as the Declaration of Helsinki [126,127] to ensure that none of the participants was subjected to harm in any way [128]. Before taking part in our survey, all participants were informed about its objectives, absolute voluntariness of participation, possibility of dropping out of participation at any time, guaranteed protection of data privacy (collection of only anonymized data), possibility of requesting data cancellation at any time, no-risk character of study participation, and contact information in case of any questions or problems. Furthermore, the respondents were explicitly given the opportunity to leave answers blank (study 1) or checking the statement "I do not want provide any information on this" (study 2). Data storage meets current European data protection regulations [129].

Informed Consent Statement: All subjects declared their informed consent before they participated in our surveys.

Data Availability Statement: The data presented in this study are available on request from V.D.E.W.

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