An Integrated Model of Digitalisation-Related Competencies in Teacher Education

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Abstract. This paper presents a model of digitalisation-related competencies for teacher education, developed by a working group on digitalisation in teacher education (WG DidL) at the University of Duisburg-Essen. Currently, there are various models available that outline the competencies teachers should develop for being equipped to work in a digital world. These approaches often mention various, widely applicable digitalisation-related competences that teachers are meant to acquire, or they are based on a limited or only implicit understanding of digitalisation. The aim of the presented model is to contribute to the discussion of how to best integrate existing models. It is based on an integrated understanding of digitalisation-related competencies that encompass teaching and learning with digital media, as well as learning about digitalisation as a subject matter in its own right. At the center of the model are generally formulated competency goals for teaching and learning, for professional engagement, and for reflective, critical-constructive teaching practice. The potential for achieving these goals is then illustrated by means of interdisciplinary and/or subject-specific examples. In this way, the model can also be applied to specific subject areas and to their teaching methodologies.

Keywords: Digitalisation-related competencies · Teacher education · Frameworks of digital competence · Reference models

1 Introduction: Background and Objectives

In order to systematically promote the implementation of digitalisation-related[1] competencies[2] in teacher education programmes at the University of Duisburg-Essen (UDE), there are numerous initiatives at the university, faculty, and institute levels. The working

[1] "Digital competencies" is the standard term used in most publications. Since competencies describe abilities and skills, which are not digital per se, the authors use "digitalisation-related competencies" instead.

[2] Competencies refer to the cognitive abilities and skills that individuals can learn in order to solve problems, as well as to the associated motivational, volitional, and social readiness to use such solutions successfully and responsibly in various situations [1].

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group on digitalisation in teacher education (WG DidL)[3] supports these initiatives and at the same time develops them further for teacher education courses and for interdisciplinary cooperation between all subject methodologies at the UDE. The WG was initiated in 2017 with the participation of representatives of several school types (primary, lower and upper secondary), subjects (Computer Science, German and *Sachunterricht*[4]), Educational Sciences, and the Center for Teacher Education (ZLB). The WG works in close cooperation with representatives of other school subjects and Educational Sciences, for example through Think Tanks. The aim of the WG is to prepare student teachers adequately for their future careers by fostering their media methodology, digitalisation and computer science-related competencies across all subjects and school types and implementing them in their respective curricula. As a first step, the WG developed an Integrated Model of Digitalisation-Related Competencies for Teacher Education (hereinafter referred to as the Integrated Model). This paper is based on the German publication of the model [2] and aims at making the ideas and concepts available to a wider audience and thereby to contribute to a larger international discussion.

Currently, in Germany, there are various models and descriptive matrixes available that outline the vision for the development of digitalisation-related competencies among teachers. An analysis of existing models has led to the identification of specific focus areas and, as a result, to the need to work on further developments with regard to an integrated model:

(1) Existing models for describing digitalisation-related competencies of teachers address various aspects:

a. The much-cited Technological Pedagogical Content Knowledge (TPACK) Model [3], for example, emphasises the need for teachers to acquire and appropriately link subject-specific competencies for their respective subjects (content), pedagogical competencies, and technological or digitalisation-related competencies in order to teach in an environment shaped by technology or digitalisation.
b. The Digital Competence Framework for Educators (DigCompEdu) [4] is a European framework model for describing digitalisation-related competencies of teachers. It refers to the Digital Competence Framework for Citizens (DigComp) [5], which defines general digitalisation-related competencies of citizens. The DigCompEdu [4] as well as the German framework for North Rhine-Westphalia (NRW) called "Teachers in the Digitalized World – Orientational Framework for Teacher Education and Teacher Training in North Rhine-Westphalia"[5] [6], focus more specifically on teaching in an environment characterised by digital media as well as on the professional commitment in this regard (own professional development, school development, etc.).

[3] For more information about the working group, see http://udue.de/didlag.

[4] *Sachunterricht* (Primary Social and Physical Science) is s subject taught in primary school that combines social science and natural (physical) science education.

[5] Hereafter abbreviated as Orientational Framework NRW. Given the federal structure in Germany, the Orientational Framework NRW [6] forms a relevant basis in the German state North Rhine-Westphalia.

A model specifically tailored to the requirements of teacher education should integrate the aforementioned aspects in a suitable manner, and at the same time establish explicit, exemplary links to the content of the various subjects and their competency requirements, as well as outline associated classroom practices, pedagogies and appropriate teaching approaches. The authors consider this to be indispensable for the presentation of the subject-specific aspects of digitalisation-related competencies in teacher education programmes. They also view this to be necessary for the coordination between the different subject areas, for implementing these competencies in the respective curricula, and for communicating them within the framework of the subject-specific content and subject teaching methodology areas of teacher education programmes.

(2) Existing models for describing digitalisation-related competencies of teachers are often based on a limited or implicit understanding of these competencies: Some of the existing models, such as DigComp [5] and the German *KMK* strategy called "Educational in the Digital World" [7][6], outline digitalisation-related competencies of learners and put a special emphasis on teaching and learning with digital media. These models neglect to address digitalisation as a subject matter in its own right: analysis, design, reflection on technological and media structures and digital systems as well as their socio-cultural impact. When specifying the digitalisation-related competencies to be acquired by teachers, reference is made to the competencies to be acquired by learners. DigCompEdu [4], for example, refers to DigComp [5]. In some cases, for example, in the Orientational Framework NRW [6], the relevant competencies are not specified in any detail. This means that – as with the learner-related competencies – the understanding of digitalisation-related competencies has a one-sided emphasis, or it is not clear which aspects of digitalisation are to be used as a basis for acquiring teaching-related or other professional competencies.

The Integrated Model presented in this paper therefore integrates selected aspects of various models and descriptive matrixes into one model (see Sects. 2, 3, 4) and is explicitly based on an integrated understanding of digitalisation-related competencies.

The models considered were integrated in terms of their structural elements and explicit competency goals. In Sect. 2 the structural elements of the existing models under consideration for the integration are specified; in Sect. 3 their integration and the resulting structural model are described. Section 4 presents the result of the integration of the competency goals, which also includes their implementation and instantiation in practice from a transdisciplinary, interdisciplinary and subject-specific perspective. Section 5 gives an insight into the implementation of the model in university teacher training at the UDE.

[6] The competency descriptions contained in the KMK strategy [7] are based on the ones defined in the DigComp [5]. KMK stands for *Kultusministerkonferenz*. It is the "Standing Conference of the Ministers of Education and Cultural Affairs". The KMK strategy [7] serves as a reference framework for the development of national concepts for teacher education in various states in Germany.

2 Theoretical Basis of the Integrated Model

The core concern of the model is to bring together existing models and related discourses into an integrated model. The components of the integration are explained in the next section.

The Revised TPACK Model [8] was chosen as the structural basis, which is a further development of the original TPACK Model [3]. It describes content, pedagogy and technology as overlapping core knowledge areas for teaching in a technology-driven environment. Relevant knowledge categories for teachers are derived from the respective intersections. In the Revised TPACK Model [8] the knowledge that learners bring into the classroom is also specified, as well as the context of classroom practice and teaching methods, which, although already identified as relevant in TPACK [3], is now more nuanced (interpersonal/intrapersonal, cultural/institutional as well as physical/technological contexts are specified).

The aim of the Integrated Model is not to re-describe content-specific or teaching methodology knowledge as applicable to teacher education without a closer reference to digitalisation, because these areas of knowledge can already be found in the original TPACK Model [3]. To see how these are implemented, reference is made, for example, to the common requirements of the federal states for the subject-specific and educational requirements in teacher education programmes [9, 10].

Since the concern of the Integrated Model is to specify digitalisation-related competencies of teachers, some basic decisions are outlined below:

1. The area of technological knowledge, including its internal structuring, is taken as a basis from the TPACK Model [3], since digitalisation is assigned to this area. Due to the intersections of the technological knowledge domain with the content knowledge and the pedagogical knowledge domains in the original TPACK Model [3], the following four subdomains of teachers' technological knowledge can be identified, all of which are relevant for a model of digitalisation-related competency of teachers:

   a. Technological Knowledge, (TK) in the TPACK Model [3],
   b. Technological Content Knowledge (TCK),
   c. Technological Pedagogical Knowledge (TPK),
   d. Technological Pedagogical Content Knowledge (TPACK).
2. The knowledge areas in the TPACK Model [3] are interpreted as competency areas by the authors following the current competency orientation. The re-interpretation of the knowledge areas as competency areas is done on the basis of the TPACK structural model. The authors do not want to equate competencies with knowledge. Rather, this re-interpretation implies the transfer of knowledge elements into matching competency goals.
3. Since this article is about teachers' digitalisation-related and not technological competencies, the above-mentioned subdivision of technological knowledge in the TPACK Model [3] into sub-areas (see point 1.) including the re-interpretation of knowledge areas as competency areas (see point 2.) is taken as a basis. However, as a further step, the term "technological" is replaced with "digitalisation-related". This is in no way intended to imply that these terms should be used synonymously, only that all of the knowledge or – as interpreted here as – competency areas

defined by the TPACK Model [3] can be applied analogously to the digitalisation discussion. This idea is inspired by the DPaCK Model [11] (Fig. 1).

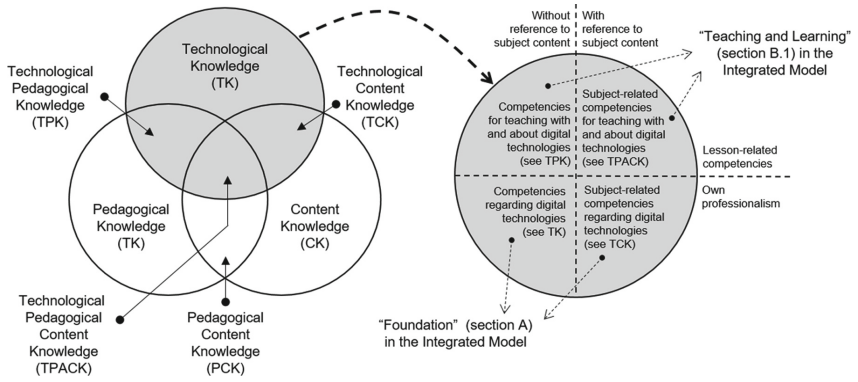

Fig. 1. Excerpt from the development of the integrated model of digitalisation-related competencies for teacher education (own representation[7] including [3])

4. Since the context categories defined in the Revised TPACK Model [8] can also be applied analogously to the digitalisation discussion, they are included in the integrated model

In addition, the Integrated Model uses relevant components from other models already mentioned (see Sect. 1):

5. DigCompEdu [4], the *KMK* strategy [7] as well as the Orientational Framework NRW [5] essentially specify teaching and learning with digital media in a subject area and beyond (included in the TPACK Model [3] as TPK and TPACK, see above). They are reified for these areas in the Integrated Model. However, an integrated understanding of digitalisation-related competencies requires an expansion of this competency area to include teaching about digitalisation as a subject (see Fig. 2, subsection B.1).
6. Furthermore, both the DigCompEdu [4] and the Orientational Framework NRW [6] describe the professional engagement of teachers with regard to digitalisation, e.g. in the areas of school development, cooperation, or professional development. This aspect is integrated as a separate area of competency (see Fig. 2, subsection B.2).
7. In order to reify the digitalisation-related basis for teaching processes and professional engagement, the Frankfurt Triangle on "Education in the Digitally Networked World" [12] is used. This model integrates perspectives from information technology, computer science education, media studies and media education. It differentiates between technological and media structures and functions, social and cultural impacts, and interaction (user options, social practices, identity construction), each of which is to be developed through analysis, reflection, and design (see Fig. 2, competency are A). The Frankfurt Triangle [12] is interpreted here as a

[7] This is a translation of a figure used in the German paper, see [2], p. 47.

meta-model over various existing models with the intention of integrating the competencies and concepts of, for example, computer science education (e.g. [13]) contained in the *KMK* strategy [7]. In this respect, it is considered by the authors to be suitable for addressing the need for further development identified in Sect. 1. By leaning on this model, the authors intent to stress that digitalisation-related teaching and learning practices must focus on both the use of digital technologies as a medium and digitalisation as a subject of instruction. The same applies to professional engagement, such as school development or one's own continuing education, which must also take both aspects into account.

3 Structure and Components of the Integrated Model

The Integrated Model describes basic prerequisites as well as institutional and instructional aspects of teachers' digitalisation-related competencies. The metaphor of a house was used for the presentation of the model in order to express, on the one hand, that all considerations of digitalisation-related teaching and learning (B.1) and professional engagement (B.2) of teachers must be based on one common foundation (an integrated understanding of digitalisation (A)). On the other hand, the metaphor is meant to illustrate that any critical-constructive reflection (C) on the overall process is to be placed over and above the aforementioned components, like a roof would be placed over a house. The inner core of the house is represented by the promotion of subject-specific and digitalisation-related competencies of learners – all surrounding aspects are aligned with these (see Fig. 2).

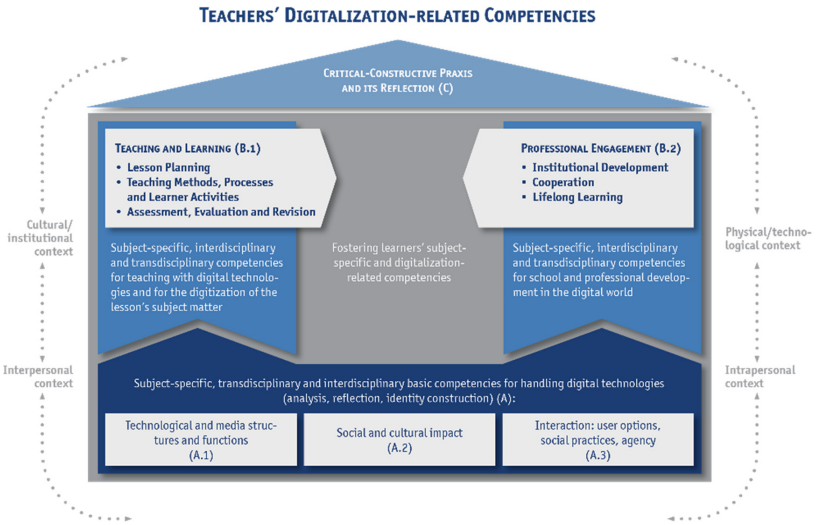

Fig. 2. Integrated Model of Digitalisation-Related Competencies for Teacher Education (own representation[8] including elements from [3, 4, 8, 12])

[8] This is a translation of the German model, see [2], p. 49.

The foundation of the house, **competency area (A)**, comprises the knowledge areas TK and TCK of the Revised TPACK Model [8] (see above). The interdisciplinary and transdisciplinary basic competencies are specified in subsections A.1, A.2 and A.3 of the Frankfurt Triangle [12]. **Subsection A.1** combines information technology and media structures and functions and thus focuses on a fundamental understanding of digital technologies and specific digital artifacts as well as the ability to participate in shaping them. **Subsection A.2** focuses on how objects of the digitalised world interact with and impact social and cultural aspects (and vice versa) and thus addresses diverse phenomena and change processes that occur in connection with digitalisation. Finally, **subsection A.3** focuses on aspects of the functional application of digital systems and media, their integration into social practices (such as teaching processes), and related aspects of identity formation. According to the subsections A1, A2 and A3 of the model, teachers and other professionals have digitalisation-related competency when they are able to analyse, reflect on, and to a certain extent help create or shape objects or phenomena of the digitalised world (e.g., data privacy, social media, virtual labs, smart home systems, self-driving vehicles) or when they are able to reconstruct them as relevant in school settings. Since the aforementioned explanations are closely connected with related subject-specific aspects (knowledge area TCK in the TPACK Model [3]), the areas TK and TCK have been combined here to form a common foundation (A).

Competency area B is subdivided into **Teaching and Learning (B.1)** and **Professional Engagement (B.2).** Competency area B is based on the DigCompEdu [4]. Since within teacher education the DigCompEdu [4] forms the counterpart of the DigComp [5], the authors consider it appropriate to lean on this model. In the DigCompEdu [4], the area of teaching and learning is divided into several separate subareas of competency: the corresponding areas are referred to as digital resources, evaluation, learner orientation, and the fostering of learners' digital competencies. In the model presented here, redundancies were identified, removed, and related competency goals combined. In the process, greater emphasis was placed on digitalisation-related subject-specific teaching and learning.

Subsection B.1 specifies the areas TPK and TPACK in the Revised-TPACK-Model [8]. Included here are competencies that relate to teaching with and about digital technologies in the respective subjects (TPACK). In addition, related interdisciplinary and transdisciplinary competencies (TPK) are also included. The area TPK includes transdisciplinary media and computer technology education aspects, for example when subject-integrated teaching and learning questions are addressed, such as algorithms or data processing, according to the *KMK* strategy [7] or the Media Competence Framework NRW [14]. In accordance with the understanding of digitalisation outlined in area A, area B.1 explicitly integrates teaching and learning with digital media and establishes the examination of digitalisation as a subject of instruction.

Subsection B.2, which includes aspects of institutional development, cooperation with colleagues and persons beyond school, and one's own lifelong learning, is outlined in the DigCompEdu [4] and in the NRW Orientational Framework [6]. In the Revised TPACK Model [8], this area is specified only in the surrounding context, which focuses on framework conditions for digitalisation-related teacher practice. Due

to the practical relevance of such a framework, the context from the Revised TPACK Model [8] was included in the Integrated Model.

The institutional and cultural context as well as the network of actors involved in the process of teaching and learning (interpersonal context) influence teachers' practice. However, this scope of influence is not to be regarded as fundamentally unchangeable. Therefore, the competency areas of development (such as institutional development or collaboration) are specified. This also applies to the intrapersonal context, which includes teachers' own digitalisation-related attitudes, beliefs and competencies, which should be continuously developed through ongoing training. The physical/technological context, which refers to the systems and types of equipment available for teaching, can also be improved and adapted through appropriate media pedagogical and IT competencies, with the responsible persons ensuring that such equipment is improved and adapted in appropriate ways for the respective schools. As such, the various context categories describe relevant framework conditions for digitalisation-related teacher practice. The subsection B.2 focuses on the development of teachers' skills within these context categories as well as on their ability to co-shape them.

In **competency area C** (in the overarching roof of the model), practice is particularly emphasised once again: Within the framework of critical-constructive practice, the view should be directed not only to the overall system, which means in particular teaching-related and other professional practice of teachers at the respective school and its environment as well as the network of actors working in it. Personal involvement in and commitment to the overall system should be emphasised as well. Due to the importance of reflexivity (e.g. [15, 16]), the roof of the model expresses those competency goals that are aimed at reflection and the readiness to appreciate digitalisation for teaching and learning, school development, and one's own professionalisation.

Competency areas B and **C** are explained in detail in Sect. 4. For **competency area A**, it was decided not to specify it further here. Instead, the authors refer to the Frankfurt Triangle [12] as an interdisciplinary coordination basis. Since the Frankfurt Triangle [12] as a meta-model aims to encompass aspects of teaching and learning with and via digital technology as well as ITC education for all, reference is made to existing models for more detail, such as the *KMK* strategy [7], the NRW Media Competency Framework [14] and models of Computer Science education for all (e.g. [13]).

4 The Competency Areas and Competency Goals in Detail

The **competency areas B** and **C**, which form **the core of the Integrated Model**, are specified in the form of generally formulated competency goals. The basis for the specification of these general competency goals was an analysis of goals stipulated in already published models for education in the digitalised world, with an explicit focus on teachers' competencies: DigCompEdu [4], Orientational Framework NRW [6], the position paper "Fachliche Bildung in der digitalen Welt" [Professional education in the digital world] [17]. In addition, the *KMK* strategy [7] was used as a reference point for defining the competencies to be developed by learners that teachers, in turn, must have at a minimum. The considerations underlying the structure of the Integrated Model outlined above (see Sects. 2 and 3) thus formed a parallel, closely associated step for

defining competency goals, the result of which is exemplified by some extracts from the appendix of the workshop paper [2], as shown below (see Fig. 3).

The final formulation in the Integrated Model is based on the work done by the WG DidL on various preliminary models (e.g. [18]) as well as on feedback that the WG received in exchanges with colleagues representing various other subjects and disciplines at the UDE.

The **general competency goals** are differentiated on a case-by-case basis from an interdisciplinary, transdisciplinary and/or subject-specific perspective.[9] The **interdisciplinary and transdisciplinary formulations** are based on Educational Science (especially Media Education) and, in part, on Computer Science, while the **subject-specific formulations** (initially) cover the subjects Computer Science, German and *Sachunterricht* (the three subjects represented in the WG DidL) in the German version of the model [2]; the planning of expansion through the inclusion of other subject methodologies is under way.

The formulations are not to be understood as subordinate competency goals. They are rather examples that illustrate how the general competency goals can be interpreted from a transdisciplinary, interdisciplinary, and/or subject-specific perspective. Figure 3 shows how the three competency areas, namely **Teaching and Learning (B.1)**, **Professional Engagement (B.2)** and **Critical-Constructive Praxis and its Reflection (C)**, could be operationalised from a transdisciplinary, interdisciplinary and/or subject-specific perspective.

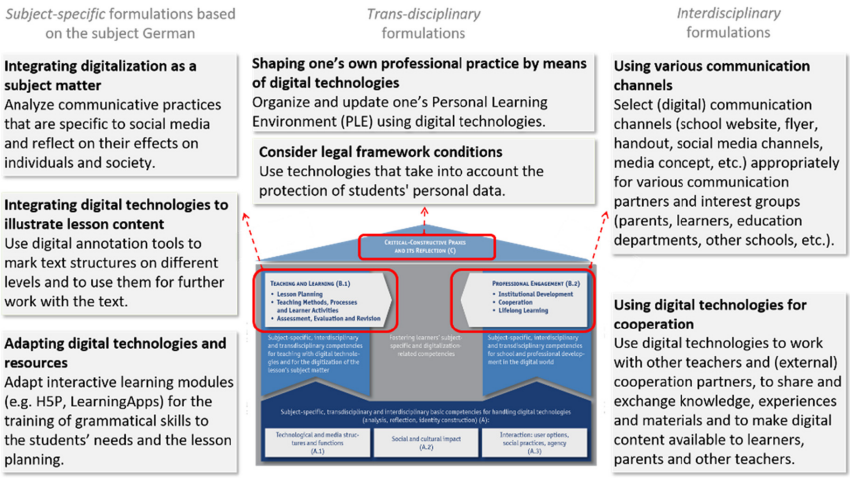

Fig. 3. Examples of how the Integrated Model could be operationalised in selected competency areas (own representation including elements from [2–4, 8, 12])

[9] Subject-specific formulations refer to observable and definable characteristics of teaching and learning in a specific subject. Interdisciplinary formulations refer analogously to a group of subjects or to teaching and learning in all subjects. Trans-disciplinary formulations go beyond teaching and refer, for example, to school development, communication or exchange with colleagues or parents, and the development of one's own digitalisation-related competencies.

The transdisciplinary, interdisciplinary and/or subject-specific formulations represent a distinction from, and at the same time a further development of the models and description matrixes mentioned in Sect. 1. The group of authors sees this as an important building block for the implementation of the fostering of digitalisation-related competencies in teacher education, as the examples serve as a guide for the practical implementation of the listed competency goals. In addition, this takes into account the fact that digitalisation-related teaching and learning should, above all, be formulated from a subject-specific perspective [17]. The examples are to be read on a case-by-case basis either as suggestions for possible implementation in university teacher training, in the classroom or as formulation sketches for the competencies to be taught.

5 Implementation and Conclusion

In this paper existing models and descriptive frameworks of teachers' digitalisation-related competencies were analysed. By focusing on specific parts of these approaches, the need for further development with regard to a model specifically tailored to the requirements of teacher education was identified. On this basis, an Integrated Model of digitalisation-related competencies for teacher education was developed.

The model can be used as a basis for research projects and teacher education. At the UDE, the model served as framework for an "Interdisciplinary Lecture on 'Education in the Digital World'". The lecture was designed and organised by the WG DidL for all teacher students at the UDE and piloted in summer 2021. The lecture aims to foster students' basic digitalisation-related competencies. Based on the proposed Integrated Model, members of the WG, representatives of Educational Sciences and representatives of various school subjects (e.g. physics, language studies, physical education) at the UDE presented trans-disciplinary or subject-specific and practice-oriented examples for digitalisation-related teaching and learning in the classroom. All contributions were aligned with the Integrated Model and represented different parts of the "house". The model is also used as a theoretical basis for several research projects, such as an online-survey on subject-specific digitalisation-related competencies among teacher students in the subject *Sachunterricht* at the UDE. The results of the survey are used to better adapt subject-specific teacher training to the requirements of the students. Furthermore, the model forms the structural basis for a good practice pool, that is currently being planned by the WG. The pool opens up opportunities for exchange among teachers at the UDE and is intended to provide impulses for the design of 'good teaching' in the field of teacher training.

In conclusion, the model synthesises existing models and is intended to contribute towards the discussion about the definition and curricular anchoring of digitalisation-related competency goals.

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