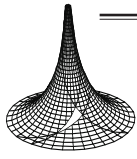

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Teaching
Mathematics and
Computer Science

Professional Competence in science education

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Abstract. The article begins with a brief introduction aimed at sensitizing the reader to the perception of a trend in Mathematics and Computer Science Education publications towards empirical studies. Contrary to the stated trend, the characterization of Professional Competence is intended to serve as the guiding concept for the paper. The role of Professional Competence is discussed in various areas incorporating context-relevant publications in consecutive chapters. The discussion starts with the area of material development, covering Educational Standards and ends with Didactic Principles.

Key words and phrases: professional competence, educational standards, didactic principles.

MSC Subject Classification: 97xxx, 94xxx.

Inventory

In recent years, there has been a clear trend towards empirical studies in Mathematics and Computer Science Education. Recent contributions from the representative Journal für Mathematik-Didaktik (Journal of Mathematics Education – Ufer et al., 2020; Gerdes et al., 2022; Hess & Smit, 2024), and a highly topical paper published by Springer Nature (Wang et al., 2024) serve as proof of the claim.

Characterization of Professional Competence

We place the concept of *Professional Competence* at the centre of our plea. We find the following definition of Professional Competence in the document "Output Orientation and Competence Formulation in the Bologna Process".

The term Professional Competence includes specialist knowledge and methods as well as their application (cognitive and functional competence dimension), which can be used and are required to cope with subject-specific tasks.

The expertise should be in line with the current state of research and is made up of two subareas:

(1) *Basic and Specialist Knowledge* from the respective subject area and the related scientific disciplines; and

(2) *General Education*, which makes it possible to integrate one's own field of expertise into a broader scientific and societal context. In order to deepen knowledge, a reflective knowledge and understanding of the most important theories, principles and methods of the subject is also required (Baumann & Benzing, 2013, p. 4).

Professional competence and teaching materials

In the section "Mathematical Knowledge for Teaching" (Ball & Bass, 2003), we find the following summary of the expertise required for the production of materials (Figure 1):

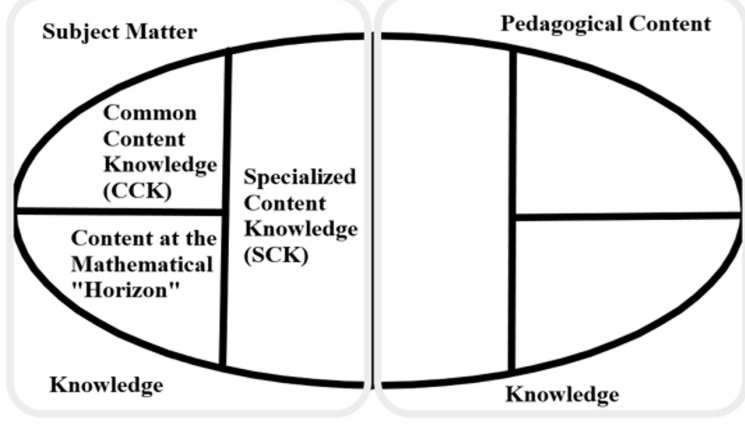

Figure 1. Required subject matters

In a recent publication *Connecting Mathematics and Mathematics Education – Collected Papers on Mathematics Education as a Design Science*, Erich Christian Wittmann (2021) notes in the context of designing materials for teaching that this process lies at the very heart of a teacher's *professional activities*.

Wittmann follows Christopher M. Clark's and Robert J. Yinger's publication *Three Studies of Teacher Planning* (1979), which describes mathematics education as a design science.

Ernst Griesel (1971) describes, in Volume 1 of his book *Die Neue Mathematik für Lehrer und Studenten* (i.e., 'The new mathematics for teachers and students'), mathematics education as the science of developing *practical materials*, too.

Practicability in this sense must not be understood as a mere reduction of material, as Rudolf Sträßer (2015) argues in his publication "Mathematikdidaktik – mehr als das Design praktikabler Kurse für den Mathematikunterricht – Eine Replik auf Erich C. Wittmann" (i.e., 'Mathematics Education – More than the design of practical courses for the mathematics teaching – A reply to Erich C. Wittmann').

The use of new media developing practical and meaningful materials to promote Professional Competence was pointed out by Christian Urff in 2014, in his dissertation *Digitale Lernmedien zur Förderung grundlegender mathematischer Kompetenzen* (i.e., 'Digital learning media to promote basic mathematical skills') at the Ludwigsburg University of Education.

> Mathematical competences are [...]
>
> - [...] regarded as an active construction process of the individuum, and
> - different representations play an important role on the way to the construction or internalisation of mathematical concepts.

Behaviourist, cognitivist and constructivist approaches – whereby Theories of Multimedia Learning (Mayer, 2005) or Cognitive Load Theory (Maresch, 2006) are taken into account – result in a typification of the learning software.

Professional Competence in the context of Educational Standards

Educational Standards in Austria and Germany draw our attention to Professional Competences. Alongside the development of meaningful materials, the focus lies on key skills of Professional Competence such as the adaptability to

changes in the educational system or the ability to recognize and promote competencies of students as described in the ability dimension of competency models from mathematics and computer science.

From the publication "Bildungsstandards und Aufgabenkultur im Mathematikunterricht" (i.e., 'Educational standards and task culture in mathematics teaching') by Karl Fuchs and Christian Kraler (2020), we take out the following different items of the ability dimension of the Competence Models for mathematics of Austria.

The ability dimension formulates the action competencies that students should acquire through mathematics instruction. Although the list of action competencies in lower and upper secondary schools has the same teaching objective 'in mind', there are still some differences in the formulations by [...]
[...] Allgemeinbildende Höhere Schule (AHS) (General Secondary School, or GSS):

- Representing,
- Modelling,
- Calculating,
- Operating,
- Interpreting,
- Arguing,
- Justifying;

[...] Berufsbildende Höhere Schule (BHS) (Vocational Upper Secondary School, or VUSS):

- Modelling and Transferring,
- Operating and Technology Use,
- Interpreting and Documenting,
- Arguing and Communicating.

In March 2016, the Society for Informatics in Germany (Gesellschaft für Informatik) drafted the following model of Computer Science Education Standards for the upper secondary level (2016), the so-called *Dagstuhl Declaration* ("Dagstuhl-Erklärung. Bildung in der digitalen vernetzten Welt", 2016). Its ability dimension was described by the following items:

- Modelling and Interpreting,
- Justification and Evaluation,

- Structuring and Networking,
- Communicating and Cooperating,
- Representing and Interpreting.

In the context of Educational Standards, Ewald Terhart (2011), in his publication "Lehrerberuf und Professionalität. Gewandeltes Begriffsverständnis – neue Herausforderungen" (i.e., 'Teaching profession and professionalism, changed understanding of terms – New challenges'), refers to a *New Professionalism*.

On page 212, Terhart illustrates the New Professionalism in the following table:

		Dimension Knowledge about the education system	
		"knowledgerich" Many information about the system, closely linked with the teachers' work.	**"knowledgepoor"** The education system knows little about itself.
Type of regulation	Central Regulation / Standardization	***Knowledge-based standardization***	***Educators as mediators of curricula***
	Professional action on site	***Educators as responsible "knowledge workers"***	***Instructors as 'lone warriors'***

Table 1. Dimensions of New Professionalism

Didactic Principles from the perspective of Professional Competence

We will initiate the considerations in this chapter with another dimension of *professionalism*, namely teaching ability. Didactic Principles play an essential role in the *Meaning – Making* of the following forms of instruction:

- *Meaning – Creation* through application or career orientation (Zachenhuber, 2024).
- *Meaning – Creation* through the integration of technology particularly Artificial Intelligence (Schachl, 2024; Biehler et al., 2024).
- *Meaning – Creation* through teaching using the Genetic Method (Fuchs & Landerer, 2021, p. 113).
- *Meaning – Creation* through structuring according to Fundamental Ideas, Basic Concepts (Bruner, 1966; vom Hofe & Roth, 2023; Fuchs, 2025, p. 24ff).

- *Meaning – Making* in the context of Educational Standards (compare with Professional Competence in the context of Educational Standards).

In 2017, Anne Niermann pointed out that the *personality paradigm* was central (2017). The prevailing opinion was that there are operationalizable traits of successful teachers, and that these personal qualities are responsible for good teaching and good school performance.

With regard to the Professional Knowledge of teachers, Anne Niermann additionally discusses [...]

- [...] the *Genetic Principle* as *Didactical Principle* including Historical Genesis (History of Mathematics) as well as a Psychologically-Oriented Genesis (Development of Individuals): Contemporary and meaningful mathematics teaching that aims for a better understanding of our world as well as the understanding that applications can contribute both to the emergence of new mathematical ideas and to the understanding of existing ones.

- [...] the context of *Task Constructions. Multiple Forms of Representations* (Fuchs & Landerer, 2021, p. 74ff) should be inherent in the construction process.

- [...] the *Operational Principle*: Action-oriented learning plays an important role in instructions in Mathematics and Computer Science. In particular, digital media are significant for current and future education.

- [...] the *Spiral Principle*: Content should be addressed at different times at various levels of difficulty.

Conclusion

Professional Competence is a fundamental element in numerous areas of Mathematics and Computer Science Education. The topics addressed in the paper are the development of materials for teaching, the area of Educational Standards, and finally the connections with Didactic Principles.

The Professional Competence as a common thread of the contribution serves two aspects. It justifies the treatment of various topics and also acts as an umbrella term for all sections of this contribution.

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