Developing by **Key Competences Mathematics Education**

Lifelong Learning Programme

# Concepts for initial teacher education
# Deliverable 4.2

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# Key Competences for Lifelong Learning: Concepts for Initial Teacher Education

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## 1 Introduction

Initial teacher education is the first step putting a teacher's career on course (Terhart, 2004). Future teachers acquire professional knowledge as well as theoretical basic knowledge (e. g. in pedagogy and psychology) for the subsequent professional practice (Neuweg, 2004). They are learner and teacher at the same time; one might speak of a student's double role during the initial teacher education: "being supported in learning how to teach, and supporting pupils in how to learn." (Caena, 2014) To apply their newly acquired knowledge in practical classes will be a challenging task (Keller-Schneider & Hericks, 2011). This circumstance should usefully be reflected in the structuring of initial teacher education. As the parameters are set by the professional practice, it is mentally demanding to analyse, question and review theoretical concepts. The focus is set on the entity of a person, including their behaviors and attitudes, their knowledge and competences. (Caena, 2014) The development of competences not only plays an important role for the development of the pupils as future world citizens, but also for the teachers. Teacher students and teachers are required to gain competences and thus act as an inspiring example for their students. (OECD, 2011)

The project KeyCoMath tackles the challenge of implementing the "European Reference Framework of Key Competences" (see previous chapter) in mathematics education. The project develops means to put this Reference Framework into practice in school and to increase its impact on the educational system. Initial teacher education is the basis of future mathematics education. Thus, the partners implement didactical approaches for supporting key competences in initial teacher education. Teacher students should develop corresponding professional competences.

## 2 Didactical Approaches

The project activities in initial teacher education focus on the following six key competences and use specific didactical approaches to support them in mathematics education:

| Key Competence | Didactical Approach |
|---|---|
| Mathematical competence | KeyCoMath promotes pupils' active, exploratory learning in open and rich situations to deepen their ability of mathematical thinking. |
| Communication in the mother tongue | KeyCoMath closely intertwines doing mathematics and communicating with others orally or in written form. Pupils are encouraged to talk about mathematics, to discuss ideas, to write down thoughts and reflections, and to present results. |
| Digital competence | In KeyCoMath pupils work with learning environments that include digital media (e.g. spreadsheets, dynamic geometry, computer algebra). By working mathematically they should develop a confident, critical and reflective attitude towards ICT. |
| Learning to learn | KeyCoMath emphasizes pupils' self-regulated and autonomous learning. Thus, they develop abilities to manage their learning – both individually and in groups –, to evaluate their work, and to seek advice and support when appropriate. |
| Social competences | KeyCoMath fosters pupils' collaboration and communication. They do mathematics cooperatively, discuss ideas, present findings and have to understand different viewpoints to achieve mathematical results. |
| Sense of initiative | KeyCoMath strengthens exploratory, inquiry-based learning in mathematics. Pupils are encouraged to be creative, proactive, and to turn ideas into action. They develop abilities to plan, organize, and manage their work. |

## 3 Strategies for Initial Teacher Education

The universities participating in KeyCoMath implement the didactical approaches of the table in section 2 in initial teacher education. They arrange seminars and lectures where university students learn how to support pupils' key competences.

*Mathematical expertise*
Mathematical knowledge is a basic prerequisite for future mathematics teachers. Even if some elements of higher mathematics play no role in teachers' practices at work with pupils, some other elements still need to be included in teachers' education e.g. polynomials, analytic geometry, derivatives, integrals, lines and surfaces in space, etc. Nevertheless, one should look for connections and examples of the application of concepts whenever it is possible. Mathematics courses need to be set in such way that university students are able to gain an understanding of the role of school mathematics in contemporary mathematics science.
Furthermore, initial teacher education should enable teacher students to obtain a deeper understanding of basic elements of mathematics, such as the change between forms of representation or the appropriate use of the language of logic, e.g. words "and", "or", "if . . .then", "all", "some", etc.

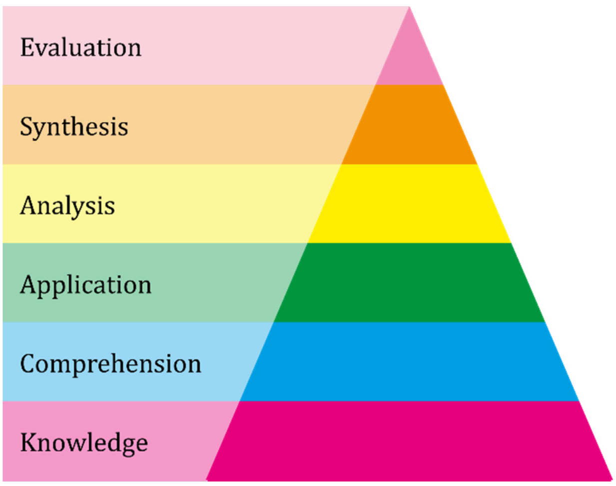
*Experiencing mathematical processes*
In initial teacher education, attention should always be paid to ensure that university students gain (more) experience to do mathematics in the form of observation, comparison, experiments, attempt, analysis, analogy, generalization, synthesis, induction, and deduction.

*Theoretical background*
In seminars and lectures, university students are acquainted with general ideas and theories of teaching and learning, they are made familiar with the didactic concepts for supporting key competences and they discuss and reflect on educational processes.

*Subject-matter didactic competences*
In addition to introduction to mathematics theory, student teachers need to know the entire subject matter of school mathematics as well as the didactic transformation of it. This means that in accordance to the goals of mathematics education, teachers need to deeply understand the topics of school mathematics, such as sets, measures and measurement, arithmetic, algebra, geometry, functions, probability etc. These topics are spirally developed throughout the grade levels. For this reason, it is very important for future teachers to know how to transform the content from these fields of mathematics into forms that are appropriate for learning in particular pupils' age levels.

*Learning/assessment scenarios as a tool for professional development*
To bridge the gap between theory and practice, the university students learn by doing: They apply the general concepts to specific situations of mathematics education and design corresponding "learning/assessment scenarios". These "scenarios" should support pupils in working according to the didactical concepts depicted in the table in section 2 and thus, to develop a variety of key competences. Furthermore, they should provide feedback for the teacher and the learner on deficiencies and proficiency with respect to the key competences aimed at.

*Taxonomy of Educational Objectives*
To develop such suitable tasks for "learning/assessment scenarios" is a challenge not only for teacher students, but also for teachers. It is very important for them to become aware of the degree of task difficulty. One classification scheme for categorising types of questions is provided by Benjamin Bloom with his taxonomy (see e.g. Alford, Herbert, Frangenheim 2006).




These categories can be described in the following way:

- *Knowledge:* Recalling information, discovering, observing, listing, locating, naming

- *Comprehension:* Understanding, translating, summarising, demonstrating, discussing
- *Application:* Using and applying knowledge, using problem solving methods, manipulating, designing, experimenting
- *Analysis:* Identifying and analysing patterns, organising ideas, recognizing trends
- *Synthesis:* Using old concepts to create new ideas, designing and inventing, composing, imagining, inferring, modifying, predicting, combining
- *Evaluation:* Assessing theories, comparing ideas, evaluating outcomes, solving, judging, recommending, rating

With the aid of this taxonomy, teacher students can reflect their prepared “learning/assessment scenario”: Which level of task is it? Is it the intended one? How can the tasks be rephrased to target a higher or lower requirement?

*Corresponding methodical concepts*
For the practical realization of “learning/assessment scenarios” in class, methodological approaches are essential as well. Thus, in university courses e.g. the teaching principle “I-You-We”, developed by Peter Gallin und Urs Ruf, is imparted (Gallin, Ruf 2014). It is an ideal entry design for cooperative learning: After a phase of individual analysis, the pupils exchange their view with a partner. In the plenary the results will be presented and reflected.

*Experiences in practice in school*
Whenever possible, these activities are related to practical courses in school where the university students work with pupils.

*Reflection in teams*
All participants present, discuss and reflect their “learning/assessment scenarios” with corresponding pedagogical and didactical ideas as well as their experiences from the work in school cooperatively in university courses.

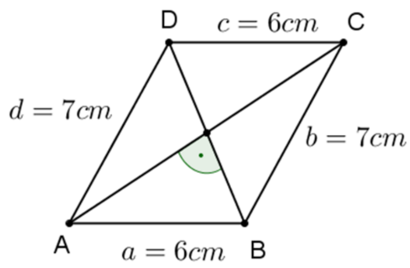
*Refinement of materials*
Finally, after all discussions and reflections, the "learning/assessment scenarios” are refined by the students on the basis of all experiences. Good learning/assessment scenarios that match the quality standards of KeyCoMath are published on the project website and/or in further publications. It is motivating for the students to know that their work is embedded in a European project and that their products are published on an international level.

# 4 Examples

The following examples illustrate the idea of discussing and reflecting tasks with respect to Blooms taxonomy.

## 4.1 Knowledge, comprehension – understanding, discussing

*Decide if the geometric shape, which is shown below, is a rhomboid. Explain your answer.*

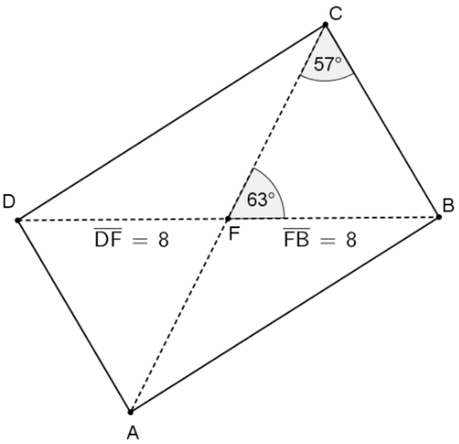



In this exercise, the pupils are intentionally given a visual representation of a non-existent geometric figure. Their task is to make a decision based on presented properties whether the presented figure is a rhomboid. The pupils are to apply the basic knowledge of diagonals and lengths of rhomboid’s sides. Using the transfer of what has been learned and considering what they already know, based on this already existent mental representation, they should compare the presented nonverbal element to the incorrect data and discover the reason for non-existence of the figure. The correct answer is the discovery that the figure cannot be a rhomboid with the given lengths of the sides, since the diagonals bisect each other at a right angle.

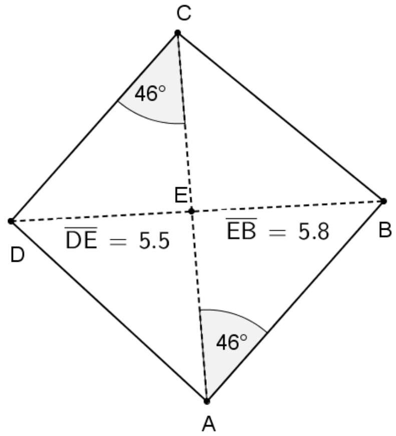
## 4.2 Comprehension, application – understanding, applying knowledge

*Decide and write down what kind of geometric object is in the picture below. (Square, triangle, rhombus, rhomboid, rectangle, tetrahedron, parallelogram, trapezium.)*

*a)*




*b)*




This exercise presents two visual representations of a quadrangle to the pupils. Pupils have to decide what kinds of quadrangles are in the picture. Stated visual representations are a rhomboid and a trapezium whose shapes are more evocative of a rectangle and a square. The pupils have to consider all of the important properties of these visual representations and compare them to their created mental representations of a rectangle and a square. This is where incorrect mental representations – based only on shapes of geometrical figures and not on characteristic properties like sizes of inner angles, diagonals bisecting each other, opposite sides being parallel – can become evident.

### 4.3 Analysis, synthesis – combination, organisation of ideas

*Draw and name a geometric shape with the following properties:*
*It is a geometric shape, whose opposite sides are parallel and congruent. Consecutive angles are different, but they are supplementary. Opposite angles are congruent. The diagonals of this shape bisect each other.*

In this exercise pupils are presented with a list of geometrical properties, based on which the pupils are to sketch a visual model corresponding to a geometric object that meets given conditions. The pupils are to use basic properties of a quadrangle concerning its inner angles, diagonals, and opposite sides. In this case of transfer of what has been learned, the pupils should create a correct mental representation of a geometrical object they have in mind and then express it visually. The correct solution is a sketch of a rhombus or a rhomboid.

## 5 Concrete examples for initial teacher education

At project meetings, the partners exchanged experiences from initial teacher education and gave recommendations for mathematics courses at university.

*Lectures*
For example, the University of Bergen, Norway, uses the didactic concept “learning by teaching” in lectures. In each session, two university students have to prepare a contribution to the lecture. These two students present an aspect of the lecture for about 20 minutes. This forms an integral part of the lecture.

*Tutorials*
Implementing a tutor system appears to be a good way to downsize big university lectures. In groups of about 20 people, the students

- work mathematically on their level and gain experiences when working mathematically, they experience mathematics as a process of experience, exploration, discussion, documentation, presentation,
- reflect on activities, build a bridge to general aims and standards, extract general ideas of mathematics education, formulate general didactic ideas,
- apply these general didactic ideas to specific topics on pupils’ level, construct learning environments for pupils according to the general didactic concepts.

The academics or tutors have the possibility to make video analyses and to stimulate the development of students’ ideas.

### *Seminars*

Academics have a wide creative leeway to organize their seminars. For developing key competences, it is helpful for students to experience learning scenarios by themselves already at university. Their fellow students could take a pupil's position and test these assignments.

As an option, a new mathematical topic with a difficulty level between school and university mathematics can be approached. In the first step, the university students bring a phenomenon into question and clarify it and in the second step, they transfer it into practical classes ("What do I do in the classroom?"). In this manner, a bridge between theory and practice can be built.

A further example of a practically oriented seminar can be seen at the University of Bergen, Norway. Here, video material with real class situations is often used to be analysed.

### *Practical studies*

Insights and initial professional experience make good sense in every respect and there is a variety of implementations.

The German and Czech project partners e.g. have the same procedure for their teacher students. At the beginning of their teacher training, university students visit classrooms as (guest) observers. Advanced teacher students complete a university-related internship at a school during one university term. It is very valuable in order to combine practical studies in school with seminars at university. In these seminars, teaching at school can be planned and prepared cooperatively, learning/assessment scenarios can be designed in a process of common discussion and all experiences from the lessons in school can be discussed and reflected with fellow students, the teachers at school and the university lecturer. These reflections and processes are crucial for developing the students' beliefs in mathematics and mathematics education.

The situation is different in South Tyrol, Italy. After their professional studies, students continue to study at university (1.5 days per week) extra-occupationally, whilst working as teachers at school.

### *Other activities*

Teacher students of the University of South Bohemia regularly organize mathematical camps for pupils under the direction of members of the Faculty of Education. During their holidays, pupils can take part in mathematical activities such as geocaching, puzzling, paper folding etc. All of these activities are planned and supervised by university students. On the one hand, this is a good possibility for students to stay in contact with pupils and to get an impression of pupils' way of working and thinking. On the other hand, university students get the chance to try themselves out as learning guides and to test their self-prepared learning materials.

Summing up: All these efforts mainly aim to change and develop the teacher students' attitudes and beliefs towards mathematics education and their role in teaching and learning processes.

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