Developing by Key Competences Mathematics Education

Lifelong Learning Programme

Long-term activities for the development of educational system
Deliverable 8.4

The project members coordinate long-term activities for the development of educational systems and describe them in this paper. This paper has two main aims:

- **Theoretic aspects of long-term strategies for innovations in the educational system**

"KeyCoMath" aims to innovate mathematics education on a systematic level, e. g. changes are envisaged that reach the level of beliefs and attitudes of all agents involved (teachers, students, administrators, etc.). Therefore, in section 1, a theoretical framework is developed that gives suggestions how initiatives aiming at systemic changes of the educational system should be designed conceptually.

- **Description of specific long-term activities**

All partners have a certain impact on the development of the educational system in their countries and beyond. They are in regular contact with decision-makers in politics and the educational administration. Therefore, the European consortium can influence the development of educational systems and strengthen the development of key competences through mathematics education. This is one of the main long-term objectives of "KeyCoMath". Section 2 gives a description of long-term activities and their impact in this field.

1 Innovations in the Educational System

There are many efforts to innovate the educational system – on a regional, national and international level – aiming to change teaching and learning. In order to understand the structure of such initiatives, a short glance at theories of cybernetics and management theory is useful.

1.1 Innovations

The OECD defines an *innovation* as the implementation of a new or significantly improved product, process or method (OECD & Eurostat, 2005, p. 46). Thus an innovation requires both an *invention* and an *implementation* of the new idea.

In the educational system a lot of concepts, methods and tools have been developed for substantial improvements of teaching and learning. Yet for real innovations these promising theories and products have to be implemented in the educational system. Here implementation means a good deal more than diffusion or dissemination of material (papers, guidelines, software tools etc.).

Implementation should reach the real agents in the school system, i.e. the teachers and students, their thinking and their working. Changes in teachers' and students' notions of educational processes, in their attitudes towards mathematics and in their beliefs concerning teaching and learning at school are necessary. Hence, the crucial question is: How can substantial innovations in the complex system of mathematics education be initiated and maintained successfully? To get indications for answers, a short glance at complex systems in general is useful.

1.2 Complex Systems

In the theories of cybernetics, a system is called "complex", if it can potentially be in so many states that nobody can cognitively grasp all possible states of the system and all possible transitions between the states (Malik, 1992; Vester, 1999). Examples are the biosphere, a national park, the economic system, the mathematics education in Europe and even the mathematics education at a certain school. Complex systems usually are networks of multiple connected components. One cannot change a component without influencing the character of the entire system. Furthermore, real complex systems are in permanent exchange with their environment. Possibly this characterization of complex systems appear to be rather vague. Nevertheless, it is of considerable meaning. Regarding the opposite: If a system is not complex, someone can overview all possible states of the system and all transitions between the states. Therefore, this person should be able to steer the system as an omnipotent monarch leading it to "good" states. In contrast, complex systems do not allow this way of steering.

1.3 Steering of Complex Systems

The fundamental problem of humanity dealing with complex systems is how to manage the complexity, how to steer complex systems successfully and how to find ways to sound states.
With reference to theories of cybernetics, two dimensions of steering complex systems can be distinguished (Malik, 1992). The first one concerns the manner, the second one the target level of steering activities (Fig. 1).

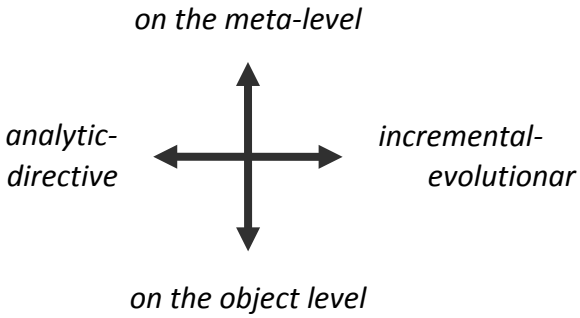

Fig. 1: Steering complex systems

The method of *analytic-directive* steering needs a controlling and a governing authority that defines objectives for the system and determines ways for reaching the aims. Authoritarian systems with strong hierarchies are founded on this principle. However, fundamental problems are caused just by the complexity of the system. In complex systems no one has the possibility to grasp all possible

states of the system cognitively. Thus, the analytic-constructive approach postulates the availability of information about the system that cannot be reached in reality.
In contrast, *incremental-evolutionary* steering is based on the assumption that changes in complex systems result from natural growing and developing processes. The steering activities try to influence these systemic processes. They accept the fact that complex systems cannot be steered entirely in all details and they aim at incremental changes in promising directions. The focus on little steps is essential, since revolutionary changes can have unpredictable consequences, which may endanger the soundness or even the existence of the entire system.
The second dimension distinguishes between the object and the meta-level. The *object level* consists of all concrete objects of the system. In the school system, such objects are e. g. teachers, students, books, computers, buildings etc. Changes on the object level take place if new books are bought or if a new computer lab is fitted out. Of course, such changes are superficial without reaching the substantial structures of the system.
The *meta-level* comprehends e. g. organizational structures, social relationships, notions of the functions of the system etc. In the school system, e. g. notions of the nature of the different subjects and beliefs concerning teaching and learning (e. g. Pehkonen, Törner 1996) are included.

1.4 Innovations in Complex Systems

The pivotal question is: How can substantial innovations in the complex system "mathematics education" be initiated successfully? The theory of cybernetics gives useful approaches.
Attempts of analytic-directive steering will fail in the long term, since they ignore the complexity immanent in the system. Changes on the object level do not necessarily cause structural changes of the system. According to the theory of cybernetics, it is much more promising to initiate *incremental-evolutionary changes on the meta-level* (Fig. 2). They are in accord with the complexity of the system and do not endanger its existence. Nevertheless, they can cause substantial changes within the system by having effects on the meta-level, especially when they work cumulatively.

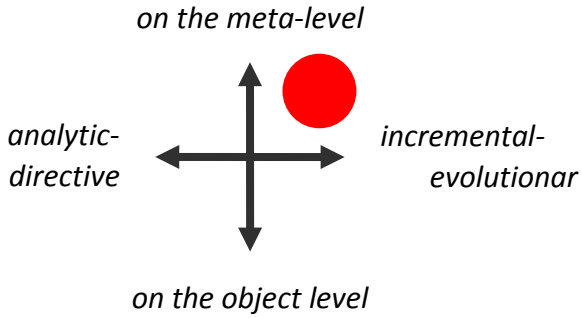

Fig. 2: Innovations in complex systems

This means that innovations in the educational system are most effective if they reach the meta-level of beliefs and attitudes of all agents involved. The following section 2 describes a spectrum of long-term activities that aim at such systemic effects of "KeyCoMath" on mathematics education.

2 Strategies for long-term impact of "KeyCoMath"

2.1 Long-term integration in pre-service teacher education

"KeyCoMath" brought together several universities, which are deeply involved in initial-service teacher education (see e. g. deliverable 8.2). Initial-service teacher education is a basis of professional development in the education system. The "KeyCoMath" teams from the participating universities will draw upon the didactical concepts and resources developed in "KeyCoMath" in their teaching at university. Moreover, the book and the electronic documents (deliverables 7.5 and 7.6) are valuable resources for further initial teacher education. They will also be distributed to other teacher educators, e. g. in the framework of other European projects or on international conferences.

Example:

- The Chair of Mathematics and Didactic of Mathematics of the University of Bayreuth, Germany, farms Bachelor, Master and PhD theses in the field of developing key competences out to students. That is a good opportunity to achieve long-term effects and to be able to continue this research beyond the end of "KeyCoMath".
  The chair holder Prof. Dr. Volker Ulm, who is coordinator of this European project, is leader of the Centre for Teacher Training of the University of Bayreuth and can thus contribute to increase the transfer of the successful results of "KeyCoMath".

2.2 Long-term integration in in-service teacher education

In-service teacher education is an essential element of all activities aiming at incremental-evolutionary developments in the complex system of mathematics education (see section 1). Thus, most of the "KeyCoMath" partners are intensively engaged in in-service teacher education (see e. g. deliverable 8.3). They will continue their activities after the funding period of "KeyCoMath", since substantial effects on mathematics education as a whole need time and can only be expected in the long term. Of course, all experiences and results of "KeyCoMath" are a valuable basis for these further activities and the "KeyCoMath" products like the electronic documents and the book (deliverables 7.5 and 7.6) will be integrated in these dissemination processes.

Example:

- The German Department of Education in South Tyrol institutionalises a long termed in-service education project. These courses include various parts of reflection, of experiences in the own class, working out and refining assignments and assessments in groups. The first approach for primary school teachers starts in 2016 and lasts until 2018.

2.3 Network of Schools

In the framework of "KeyCoMath", networks of schools were established for teacher education offers. These networks will continue to exist after the end of the project – on a personal level and on an institutional level. They form structures for further professional development.

Examples:

- The Swiss project partners established a "KeyCoMath" network of teachers, multipliers and schools. It will maintain the activities and disseminate new achievements in the development of key competences and innovative methods in mathematics education even after the funding period of "KeyCoMath".

2.4 Development of learning environments

The learning environments developed in the framework of "KeyCoMath" have several functions: On the one hand, they are resources for direct use in class. On the other hand, they are tools for initial-service and in-service teacher education to transport didactic ideas. Finally, teachers develop their professional competence by creating, testing and reflecting such learning environments on their own. This concept and strategy of developing mathematics education on system level, by working with concrete learning environments, has proven to be successful in "KeyCoMath" and will be used in future.

Example:

- The Institute of Instructional and School Development of the University of Klagenfurt implement the concept of key competences in various nation-wide in-service teacher education programmes (e. g. IMST, PFL mathematics, PROFIL, etc.). There, teachers, teacher educators and other contributors to the field of education are supported in their professional development, in putting innovative instructional projects into practice and providing support in terms of content, organization and finances. The development of learning environments will continue to play a key role.
- The organisation of regular meetings with math teachers to develop learning environments, tasks, criteria for evaluating assessments by the German Department of Education in South Tyrol, Italy, is maintained in the future.

2.5 Establishment of multipliers-concepts

Reaching a large number of teachers with an innovative content, such as the development of key competences or inquiry-based learning (IBL), in face-to-face professional development courses is accomplished by using a pyramid model: Engaged teachers or researchers are trained to become multipliers, who then go on to train other teachers. This pyramid model has proven efficient and effective within various contexts and projects (e. g. Sinus project in Germany, EU project PRIMAS, cf. also Rocard, et al., 2007) and is as well a part of "KeyCoMath" activities.

Example:

- The Chair of Mathematics and Didactic of Mathematics at the University of Bayreuth, Germany, developed a practice-based multipliers concept for an urban network of primary schools with the aim to develop mathematics education and to support pupils' competences. The idea is implemented on a local scale and addresses primary school teachers of a city. 28 primary schools are taking part in this face-to-face professional development.
- The Bulgarian Academy of Sciences appoints so-called "regional inspectorates" in mathematics, informatics and IT and trains them in several courses, particular for the inspectors in these fields. More than 15 regional inspectorates of the Bulgarian Academy of Sciences are in action.

- The German Department of Education in South Tyrol, Italy, is currently developing and implementing a "consultants' training", where multipliers for school development will be trained with the aim to extend mathematics education and to adapt competences.

2.6 Cooperation with decision-makers in school administration and politics

The members of the project consortium of "KeyCoMath" are in regular contact with decision-makers in school administration and politics in their countries. These contacts are an important means to disseminate the results and experiences of "KeyCoMath" with respect to key competences in school and the corresponding didactic concepts.

Example:

- Not only because of this implemented multiplier concept the University of Bayreuth has a close cooperation with the Government of Swabia and the local school board of Augsburg. This affiliation will also be used to inform these authorities on the project and its results.

  In Franconia, a new initiative from the Bavarian state ministry of education is implemented under the slogan "in the region, from the region, for the region". The University of Bayreuth, schools, local authorities and commercial enterprises are currently working together with the aim to improve education in the field. The Chair of Mathematics and Didactics of Mathematics helps to establish a special mathematical education center for all types of schools, called "KeyCoMath". The idea of "KeyCoMath" to develop key competences in mathematics education also contributes to the conception and implementation of this new local mathematical education centre.

  Now, the University of Bayreuth is very active in the so called "quality offensive teacher training" by the Federal Government and the Federal States in all of Germany. Concepts to improve teacher training in consideration of developing key competences are developed and proposals are written.
- The Bulgarian Academy of Sciences works closely with the national Ministry of Education and Science in this regard. The idea of IBL with emphasis on the key competences development has been promoted with the result that the Ministry already supports a number of events (conferences, seminars, PD courses) for teacher in mathematics. The Ministry borrows and facilitates prioritized educational strategies from the Bulgarian "KeyCoMath" team and will continue its involvement also in the future.

2.7 Cooperation with developers of schoolbooks

Some members of the "KeyCoMath" consortium are involved in the development of schoolbooks or related to publishing houses for teaching and learning media. This provides a channel to bring results of "KeyCoMath", especially didactic concepts for teaching and learning, into practice in school.

Examples:

- A new mathematical schoolbook for primary schools called "Zahlenzauber" was written by a member of the University of Bayreuth.
- The members of Mathematic Education at the Department of Education of the University of Cyprus are in the process of developing new material for the new curriculum K-12 such as schoolbooks and applets.

2.8 Cooperation with developers of standards and curricula

Some of the partners of "KeyCoMath" are strongly involved in the development of standards and curricula for mathematics education in their country. Thus, the experiences of "KeyCoMath" and the notions of teaching and learning for the development of key competences in this project are a strong basis for the work on standards and curricula.

Examples:

- Prof. Dr. Volker Ulm from the University of Bayreuth, Germany, works on curricula for mathematics education in cooperation with the Bavarian State Institute for School Quality and Educational Research.
- The University of Cyprus is deeply involved in the development of the Cyprian curriculum in mathematics.
- The Institute of Instructional and School Development of the University of Klagenfurt as Austrian Educational Competence Centre integrates key competences in the formulation of standards and curricula in Austria.
- The German Department of Education in South Tyrol, Italy, is directly responsible for the development of the legal framework concerning mathematics education and the adaptation of the curricula in the "Autonomous Province of Bolzano".

2.9 Activities with pupils

"KeyCoMath" finally aims at pupils' competences. Although the focus of the project activities was put on teachers' professional development, some partners of the consortium worked directly with pupils. Such activities will be continued to ensure substantial effects in the educational system.

Example:

- The Bulgarian "KeyCoMath" team regularly arranges a competition for school students that work on projects of their own and acquire knowledge by investigating theoretically and experimentally (by means of available dynamical software such as Geonext, GeoGebra, Cabri, etc.) certain topics in mathematics and informatics. The competition will consist of two *Sessions* and a *Summer Camp*. At the two *Sessions* (in January and April) the school students were able to present and share the advancement in their work on the projects in the presence of a scientific jury. The authors of best projects (and their supervisors) will be invited (with support of related expenses) to a *Summer camp*. At the *Summer camp* lectures will be delivered by specialists from the Bulgarian Academy of Sciences and from different universities in the country. A seminar for teachers with focus on supervising students' projects will also take place.
- The Faculty of Education of the University of South Bohemia with its university students regularly organize mathematical camps for pupils. During their holidays, pupils can take part in mathematical activities like geocaching, puzzling, paper folding etc.
- School Rottenschwil, the "KeyCoMath" project partner from Switzerland, is a state school comprising a kindergarten and a primary school. On the one hand, School Rottenschwil offers specific support for low-achieving pupils and for children with special needs. On the other hand, it is a competence center for supporting gifted and

high-achieving pupils. In lessons, didactic concepts of "KeyCoMath" are put into practice.

2.10 Conference contributions and scientific papers

The members of the scientific institutions involved in "KeyCoMath" regularly give talks at scientific conferences and publish papers on a national and an international level. The results and experiences from "KeyCoMath" will be a valuable basis for such further scientific activities in the field of mathematics education.

Example:

- The Bulgarian Academy of Sciences has a leading position in MASSEE, the Mathematical Society of South-Eastern Europe. Meetings of this society with reports of this partner will be very important for valorisation processes on an international level in South-Eastern Europe.
- The University of Bergen regularly publishes articles, which seizes the ideas and results of "KeyCoMath" in the journal "Tangenten", which is a national, Norwegian periodical for dissemination and discussion of ideas and research in mathematics education. Articles from "Tangenten" (in Norwegian / Danish language) are often used in teacher education, also at other universities and university colleges in Norway. In the Danish journal "MONA", which can be seen as a parallel to "Tangenten", similar articles are published as well.

2.11 Further cooperation of the partners of the "KeyCoMath" consortium

The "KeyCoMath" project brought together eight partners from eight European countries. The common work during the two years created an atmosphere of confidence and appreciation. This is the basis of further collaboration of institutions and persons that would not have come together without "KeyCoMath". On this basis further developmental work in the educational system in Europe is planned.

Example:

- The partners "University of Bayreuth" and "University of South Bohemia" are part of a common project funded by means of the European Regional Development Fund (ERDF). It will extend the cooperation in the framework of "KeyCoMath" to more subjects (Natural Sciences, Mathematics and Languages). Teachers in the common border region of Bavaria and the Czech Republic should develop professional competences to deal with the diversity within classes in school in adequate ways. This further cooperation is the basis of a long-term valorisation. It is clear that the results of "KeyCoMath" influence the new project.
- The University of Cyprus made an application for a further European project called "Mathematics Under-Achievement" within the framework of "Erasmus+, Key Action 2, Strategic partnerships in the field of education, training and youth" among others with the University of Bayreuth as project partner. This claim was rejected, but emphasizes the will to exploit the project results in further activities.

2.12 Links with other projects in the field of education

The partners of the "KeyCoMath" consortium will be involved in research and development projects concerning mathematics education in the future. They will exploit the results of "KeyCoMath" (especially the didactic concepts and resources for developing key competences by mathematics education) in their work in other projects.

Example:

- The University of Bayreuth will be funded with 3.3 million EUR by the German government in a project called "Diversity in School and University" (2016 – 2019). Teachers and teacher students should develop professional competences to use the diversity in class productively for pupils' learning. For this purpose, strategies from KeyCoMath for initial and in-service teacher education will be used and transferred to other subjects.

2.13 Availability of results

To ensure that the results of "KeyCoMath" can be exploited in the long term, the resources produced in the project are available freely in different ways.

Examples:

- The book and electronic documents (deliverables 7.5 and 7.6) have been given to university libraries.
- Two publications, which are available in printed and digital form, have an International Standard Book Number (ISBN) and can be ordered for free from the University of Bayreuth.

  Karin Höller, Volker Ulm (Hrsg.): *Aufgaben für kompetenzorientierten Mathematikunterricht*, ISBN 978-3-00-045898-9

  Carolin Gehring, Volker Ulm (Ed.): *Developing Key Competences by Mathematics Education*, ISBN 978-3-00-051067-0
- The book and the resources on the CD are available on the „KeyCoMath“ website (http://www.keycomath.eu/→KeyCoMath Book)
- Teaching and learning resources developed in "KeyCoMath" are also available on the "KeyCoMath" website.

2.14 Web links

To ensure awareness of "KeyCoMath" in the long term, there are links to the "KeyCoMath" website from several other websites (deliverable 7.7).

Examples:

- Information about "KeyCoMath" has been published on the Scientix platform: http://www.scientix.eu/web/guest/projects

As shown above, there are strategies on many different levels to disseminate and exploit the results of "KeyCoMath" in order to initiate and maintain systemic evolutionary changes in the complex system of mathematics education in Europe.

Literature

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