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Mirosława Sajka, Roman Rosiek

Enhancing functional thinking from primary to upper secondary school according to "FunThink" project

In August 2020, a project called "Enhancing functional thinking from primary to upper secondary school" (ID: KA203-2ACBA170) with the acronym "FunThink" won funding under the "Erasmus+ KA2 – Cooperation for innovation and exchange of good practices" competition in the category "KA203 – Strategic partnerships for higher education".

Eight universities are involved in the project. The applicant and coordinating institution is the Pedagogical University of Ludwigsburg (Pädagogische Hochschule Ludwigsburg, Germany), and the core partners, aside from the Pedagogical University of Cracow, include: Pavel Jozef Šafárik University in Košice (Univerzita Pavla Jozefa Šafárik v Košiciach, Slovakia), University of Cyprus, University of Applied Sciences iPabo in Amsterdam (Hogeschool iPabo, Stichting IPABO, Netherlands), University of Utrecht (Universiteit Utrechtu, Netherlands) and two German cooperating institutions: Universities of Koblenz-Landau and Osnabrück (Universität Koblenz-Landau, Universität Osnabrück).

Within the discipline of mathematics, function can be considered as a basic concept. However, functional thinking, which can be expressed e.g. by the use of functions to model phenomena, thinking using relationships, or analysing dependencies and changes, is also needed when considering various problems from other disciplines and fields. It is required, for example, when modeling physical phenomena (e.g., falling, projection, thermal phenomena) as well as an important part of other natural sciences, geography, social sciences, etc. Functional thinking is also needed in a person's professional life (e.g., related to science, economics, medicine, or psychology), and is crucial in everyday life. It is used, for example, for modeling and understanding the spread of a virus such as COVID-19 or for monitoring the repayment of a bank loan.

Unfortunately, there is a great deal of mathematics education research and empirical evidence stating that functional thinking causes students great difficulty at all levels of mathematical learning. This, in turn, can have significant consequences, can give rise to further failure at school, and can negatively impact one's social and professional life in the future.

Therefore, the main goal of the described project is to improve functional thinking in a transnational perspective, based on specific and complementary competences of the involved partners.

Each of the institutions cooperating within the project, particularly the members of the project team, will bring with them their specialist knowledge and long-term experience regarding the support of students through effective teaching methods, education of future mathematics teachers, and the professional development of active mathematics teachers. Although the project partners generally focus on different types of schools, have different educational systems and curricula in their countries, as well as different cultural backgrounds, they share a common vision which states that the teaching of mathematics can be significantly improved by strengthening functional thinking at all levels of education – from primary through secondary school to the training of pre-service teachers. During the preparatory phase of the project, it was unanimously agreed that effective planning of the teaching-learning process, as well as adequate initial and in-service training for teachers and pre-service teachers were of key importance in this area. One of the main goals of the project regarding its first intellectual output was to design and produce new, modern, versatile, and activity-rich learning environments that can be implemented in mathematics teaching from elementary to secondary school (and even university) to support the students' functional thinking.

The planned innovative learning environments will be created with four simultaneous assumptions:

1) They will all implement the idea of inquiry-based education,
2) They will combine methods of learning with digital tools in a new way,
3) The learning process will be based on the idea of "embodiment",
4) They will take into account diverse situatedness.

Using modern digital technologies, we plan to combine the analysis of real world situations and elements of teaching through inquiry. It is assumed that embodiment should be an important contribution to the development of learning and the formation of functional thinking. As recent research has shown, mathematics lessons should engage the different senses of students (especially movement, activities) in order to enhance the process of discovery and make knowledge more durable. That is why embodiment and situatedness are one of the main tenets of the project.

It is worth noting that all of these elements have been the subject of many empirical studies and detailed research regarding education, some of which have partially demonstrated benefits in teaching functions, but they have never been comprehensively linked. Such a coherent concept of teaching functions will be developed alongside comprehensive teacher guides in the form of a multifaceted learning trajectory, i.e., reinforcing function thinking in a coherent and continuous way, linking different stages of education, thus connecting the teaching of different classes of functions and different aspects of the concept, which so far are often taught in an isolated way. A significant element visible e.g. in the Polish education system is the lack of synchronization in the scope of curricular content between physics and mathematics. It is the physics teacher who first introduces content related to functions by analysing graphs and formulas of functions in their lessons,

e.g. kinematics. Due to the lack of synchronization between subjects, it is mainly during physics lessons where students encounter many difficulties related to the analysis and reading data from graphs or describing phenomena, e.g. motion, by using functions.

Therefore, there are a number of important steps to be done as part of the project before the work of creating learning environments takes place.

First, there will be a thorough analysis of the available literature and research on the subject, a review of the latest publications regarding state-of-the-art research from the best sources on functional thinking education.

The next stage will consist of a detailed analysis of the domestic situations in the countries of all project partners, done in order to identify the different learning trajectories and then develop the most effective and optimal educational model.

The subsequent stage will consist of in-depth interviews with experts in the field of mathematics and physics teacher education, mathematics and physics teachers, active researchers in mathematics and physics, and stakeholders. The main purpose of the interviews is to define the term "functional thinking", to acquire and systematize knowledge about the difficulties, and to analyse the potential expectations of the teacher community in terms of teaching aids, training, and possible modifications of curricula. After these preliminary steps are made, the work will transition into development, optimization, and revision of training materials – examples of learning environments during mathematics lessons at all levels of education. For this purpose, a series of international meetings will be scheduled for the purpose of discussion and mutual exchange of experiences.

Another goal of the project and its second intellectual output is to develop an appropriate course for in-service and pre-service teachers which will prepare them for effectively enhancing functional thinking in their students by using the developed learning environments. The courses will be taught by specialists based on the developed and validated teaching materials. Specially prepared recordings of classroom lessons, showing a range of more and less effective implementations of the learning environments, will provide for additional training material and encourage reflection, professional analysis, and an exchange of conclusions among course participants regarding the development of their students' functional thinking, which is an important prerequisite for their professional success in the future. The developed learning environments prepared for students as well as the courses for pre-service and in-service teachers will take into account and combine the different cultural and curricular requirements of the partners, thus providing high transfer potential. To increase the number of beneficiaries of the project, another objective, and its third intellectual output, is the launch of an open, educational, interactive, multilingual digital platform equipped with the products of the project. The integrated user forum will enable teachers, teacher educators, and researchers to engage in international interactions, exchange ideas and experiences, analyse practices, and learn from each other in regard to functional thinking and more.

The results of the project and its corresponding empirical evaluation showing its effectiveness will be presented in six languages: English, German, Dutch, Polish, Slovak, and Greek. With the worldwide availability of the digital platform, we

expect a wide and sustained implementation of the project solutions at school and university level, impacting mathematics education across Europe. In particular, the digital platform will provide mathematics teachers from across Europe and beyond with extensive support in implementing our innovative course as part of local teaching courses. Furthermore, regular transnational project meetings and jointly developed dissemination events will disseminate the project solutions and support their widespread use in European countries and beyond. The implementation of the described objectives is planned for the period from September 2020 to August 2023.

We hope that having fun while learning about functions, as shown in "Fun-Think", the abbreviated name of the project, and the joy resulting from the effective development of functional thinking will become a reality for students at different stages of mathematical education, pre-service and in-service teachers of mathematics, and the researchers in mathematics and physics education who are involved in this project.

Institute of Mathematics
Pedagogical University of Krakow
e-mail: miroslawa.sajka@up.krakow.pl

Institute of Physics,
Pedagogical University of Krakow
e-mail: roman.rosiek@up.krakow.pl