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Subject teacher education as a prisoner of its own tradition

Experiments in mathematics and science to break out of the routine

Harry Silfverberg

Introduction

In Finland, mathematics, physics, chemistry and information technology are usually referred to as *mathematical subjects*. This chapter introduces four reforms concerning the subject teacher education programmes in the mathematical subjects carried out in the School of Education at the University of Tampere during the last two decades. Each of these reforms in their own way challenged the traditional ideas of what type of structure the subject teacher education programme should and could have, what contents it should have, and which institutions should be responsible for the

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administration of each sector of the education. In this chapter, my aim is to examine, as objectively as possible, the motives leading to the onset of these development projects, the basic ideas behind the projects and the life course of each project. Some of the projects are still ongoing, some of them have ended and others will end soon. However, one must remember that although projects end, many of their innovative background ideas continue their lives in some other form in the practices of the institution. As far as the completed projects are concerned, we also examine the reasons leading to the end of the projects despite having had quite a general agreement on the value and innovativeness of the experiments.

The contents of the curriculum for subject teacher education are checked and modified at intervals of two or three years, the purpose of which is to renew the entire curriculum of the teacher education unit. Nevertheless, from earlier curricula, one can notice that the basic structure of the curriculum has remained almost unchanged for a surprisingly long time. Subject teacher education has a strong tradition that seems to resist changes that may be too radical but perhaps changes that would be necessary and perhaps even *de rigueur*. For a long time, slightly more than one third of the pedagogic studies (60 ETCS) has consisted of basic studies in (general) education, about one third teaching practice, and the rest, i.e. slightly less than one third, consists of subject didactic studies. However, several different issues have created pressure to change subject teacher education – even quite radically – and especially in mathematical subjects. The pressure has targeted both reforming the structures of subject teacher education programmes and developing the contents of individual courses within the programme. The pressures for change have been caused, among other things, by the following issues:

First, throughout the 1990s, we were unable to obtain a sufficient number of students for the teacher training programmes in the mathematical subjects as they were recruited from our own university only. Each year, just a few students completed pedagogical studies to

qualify as subject teachers of mathematics, physics or chemistry. The same trend was also evident in other Finnish universities. Together with the department of mathematics, we decided that we needed to make the recruitment of prospective teachers in mathematics, physics and chemistry more attractive, one way or another. At the same time, there was an imbalance in the study modules for the mathematical subjects offered at the Tampere University of Technology (TUT) and the University of Tampere (UT). The students of mathematical subjects in UT completed all of their studies in physics and chemistry in TUT, the students at TUT, on the other hand, were only offered a few courses at UT. The negotiations between the universities concluded in an agreement which guaranteed that the students at TUT had the possibility to complete pedagogical studies in mathematical subjects at UT within an agreed quota.

Second, since the end of the 1990s, the comprehensive schools with both primary and lower secondary schools in them became increasingly common in Finland (cf. Rajakaltio 2011). According to Statistics Finland in 2018 a total of 2,234 comprehensive schools were in operation, 20 per cent of which were joint schools comprising grades 1 to 9. The comprehensive schools, comprising grades 1–9, are supervised by the same administration, and the core curriculum has been planned to ensure the students' transition from the primary school to the lower secondary school goes as smoothly as possible. One of the objectives of the unification is to enable as many teachers as possible to teach at both the primary and lower secondary levels, accoding to their expertise. The problem the Finnish teacher education system encounters here is the fact that our teacher education programmes do not usually qualify student teachers to teach in the entire comprehensive school. Primary teacher education programme qualifies graduates to work only as class teachers at the grades 1 through 6 and subject teacher education programmes qualify to teach at the grades 7 through 12 those subjects that the teacher has made 60 ECTS points or more. The purpose of the AIKAMA programme,

a new type of teacher education programme developed in the faculty, was to meet this challenge especially.

Third, according to several studies (e.g. Juuti et al. 2010; Merenluoto et al. 2003; Pehkonen 2011), the prospective primary school teachers' knowledge of mathematics during that time was insufficient. The weak competence in mathematics led to a situation where too few students specialized in mathematics. By developing the Didactical Mathematics study module (25 ECTS), together with the department of the mathematics at the University of Tampere, we tried to encourage prospective primary school teachers to choose mathematics as a minor subject in their degree. We also encouraged them to reconsider their attitudes according to which university level mathematics is insuperably difficult for them.

Fourth, we also looked for a satisfactory solution to the problem of the main subject: At that time, the major subject in master's degrees at Finnish universities could (and still can), in fact, be either mathematics or educational sciences but not mathematics education. A solution to this problem was sought from two directions: First, we proposed that the faculty of education allow stronger emphasis on mathematics education in the optional part of the curricula in B.Ed. and M.Ed. degrees. The main subject would still be educational sciences. This gradual process to strengthen the status of mathematics education and research therein in our faculty eventually led to the establishment of the above-mentioned AIKAMA teacher education programme. The major subject of the nationally unique programme was education, and the compulsory minor subject was mathematics.

After the AIKAMA programme had been carried out for a few years interest among a group of Nordic researchers of mathematics education sparked. The group decided to start, as Nordic cooperation, a Master of Arts programme with the didactics of mathematics as its main subject. The Nordic Minister Council funded the planning of the project and in the year 2010 the Joint Nordic Master Programme on Didactics of Mathematics, NORDIMA was established in cooperation

with a consortium of five universities from Norway, Denmark, and Finland. Since the beginning of the planning of the programme, the teacher education unit of the Faculty of Education at the University of Tampere was one of the partners in the consortium. The Nordic Graduate School of Mathematics Education (NoGSME) served as a natural channel to further studies in the research of mathematics education.

Pedagogical studies for engineering students

Normally, the pedagogical studies in the Faculty of Education are organized in cooperation with the faculties of the University of Tampere, i.e. the faculties provide the major subject studies for secondary (and tertiary level) teachers. In addition to the faculties at the University of Tampere, the Tampere University of Technology, too, has offered an option (for about 20 years now) to engineering students to complete pedagogical studies as a minor subject in their MSc degree. The students' teaching practice is carried out at the University of Tampere teacher training school and in several other secondary and tertiary level institutions in the Tampere region, in cooperation with the Faculty of Education of the University of Tampere. The students have mathematics, physics, chemistry or computer science as their major subject in the Master of Science in Technology degree, which they study at the Tampere University of Technology. To get the qualification for the teacher's profession, they also have to include in their degree 60 ECTS credits of pedagogical studies offered by the Faculty of Education at the University of Tampere. To be attractive on the labour market, most students have one or more extra subject from the above-mentioned mathematical subjects as their minor subject(s). The rest of the degree consists of studies in technology. In recent years, the student quota for this programme has been set at 25.

So far, there has not been any formal evaluation of the programme, but the students compile a portfolio where they evaluate their professional growth during the pedagogical studies. The portfolios give valuable information on the students' professional growth and on their views concerning the parts of the programme which function well or perhaps not so well. On the basis of portfolios, almost all students have been considerably satisfied with the programme. No doubt, cooperation between the partners is the cornerstone of the success of the programme. On the one hand, the University of Tampere has developed the pedagogical studies module to meet the needs of engineering students. On the other hand, the Tampere University of Technology has developed the Master of Science in Technology degree to fulfil the needs of both the degree in engineering and the teaching qualification in mathematical subjects.

Most importantly, both parties of the programme have considered the cooperation advantageous to themselves. The programme has been popular and, consequently, it has been possible to recruit gifted students to study the STEM subjects, i.e. science, technology, engineering and mathematics. Graduates have been well employed. Educational institutions have willingly employed people who, in addition to the subject knowledge of pure mathematics and science, have the knowledge to apply these subjects in engineer sciences and other fields in society. The programme is unique in Finland.

Parallel to the traditional view that school subjects are taught separately, much attention has currently been given to the view that emphasises closer integration within subjects. Discussion about the STEM or SMET subjects (science, mathematics, engineering, technology) (Stohlmann, Moore & Roehrig 2012) began in the United States, but it is also widely spreading in the European discourses of subject teaching nowadays. The intention of this perspective is to connect science and mathematics, especially within the frame of engineering and technology. Looking back, from the beginning of

the project we tried to integrate SMETsubjects in teacher education, even though integration was not discussed to the extent it is discussed nowadays.

Establishment of the AIKAMA master programme and the Joint Nordic Master Programme in Didactics of Mathematics, NORDIMA

Having mathematics as a compulsory minor subject and focusing studies in the major subject on mathematics education, the AIKAMA subject teacher's master programme started in 2002 and finished in 2016. From the very beginning, it attempted to meet the needs of society and teachers specialising in teaching at comprehensive schools. The objective of this programme was not only to provide students with expertise in their own subjects and teaching but also to work as educational specialists in comprehensive schools.

In the programme, the main subject was education, and the students who graduated from it received a master's degree in education. The studies in mathematics required of the subject teacher in the comprehensive school formed the compulsory minor subject in the students' degree. Depending on the students' choice of minor subject(s) and those offered in the master's degrees, the programme rendered qualifications to work either as a primary school teacher or as a subject teacher in the comprehensive school, or even in upper secondary school.

The main advantages we expected from this type of programme were the following:

1. Emphasis is on the entire comprehensive school;
2. Appropriately selected advanced studies in the main subject (education) bring added value to the pedagogical studies required of subject teachers;

3. The duration of the teacher education (usually about five years) gives extra time to the students to develop their identity as teachers as compared to the established way of carrying out the pedagogical studies for subject teachers in one or two years;
4. The programme application process is economic as it is arranged in connection with the already existing application process in primary school teacher education.
5. The programme makes it possible to get double qualification, i.e. the qualification of a primary school teacher and that of a subject teacher. (cf. also Kohonen 2005).

During the ten years when new students were accepted into to the programme, it became very popular. In the last few years, when it was still possible to apply to the programme, the number of applicants exceeded the admission quota by more than 15 times. One doctoral dissertation (Portaankorva-Koivisto 2010) was completed in association with the project. Portaankorva-Koivisto conducted a narrative study on the AIKAMA students' professional growth processes in becoming mathematics teachers. In her thesis for Master of Education, Pääkkönen (2012) carried out the overall evaluation of the programme. According to Pääkkönen, the teachers who had graduated from the AIKAMA programme and already worked as teachers were mainly satisfied with the education in the AIKAMA programme. However, some teachers had experienced that their colleagues had found it strange that the mathematics teachers had graduated as Masters of Education instead of Masters of Science.

The Joint Nordic Master Programme in Didactics of Mathematics, NORDIMA, was established in the Faculty of Education in the spring of 2010 in cooperation with a consortium of five partner universities from three Nordic countries: Norway, Denmark, and Finland. The partners in the project include the University of Agder, Kristiansand; the Danish School of Education; Aarhus University, Campus København; the University of Copenhagen, København;

Åbo Akademi University, Vasa; and the University of Tampere, Tampere. In the beginning, the programme was partly funded by the Nordic Council of Ministers and the agreement was made for the years 2010–2016. The University of Agder in Kristiansand, Norway is the main partner of the University of Tampere. The first year of the studies is carried out in the University of Tampere, the second year in the University of Agder. If the first year of studies is carried out in Agder and the second in Tampere, the studies taken at the University of Tampere are determined according to a personal study plan.

The purpose of the programme was to gain the following benefits:

1. The Nordic master programme in the didactics of mathematics will through the use of combined expertise and opportunities create Nordic synergy in an area of research where most of the environments are small and vulnerable.
2. The Nordic master programme in the didactics of mathematics will be built on high-quality research and run by teachers and supervisors who are active researchers in mathematics education.
3. A common Nordic solution for a master programme will offer the entire Nordic educational system with experts in mathematics education and will be unique in the Nordic countries.

The programme consisted of 120 ECTS. The bulk of the courses consisted of the didactics of mathematics, but to some extent other types of courses could be included, for example, in mathematics or science education, depending on the previous studies of the individual student. In any case, the master's degree rendered qualifications in the area of mathematics education. It was suggested that some courses be core courses and compulsory, but most courses were optional. The board of the Nordic master's programme was responsible for accepting students, coordinating the application process, maintaining the quality of the programme, ensuring that

individual students did not take overlapping courses and that the combination of courses guaranteed a high-quality master's degree.

The purpose of the master's programme was to

- facilitate Nordic and European labour market mobility,
- make postgraduate studies possible both in Finnish and Nordic graduate schools (NoGSME) within this field,
- improve competitiveness in the labour market, and
- offer excellent basic education, for example, to the university-level posts at the teacher training schools or in the departments of teacher education.

Completing the NORDIMA master's programme, students obtained a double degree. This meant that they received a diploma from each university – Master of Education from the University of Tampere and Master of Science in the Didactics of Mathematics from the University of Agder.

Development of the Didactic Mathematics study module

When the Didactic Mathematics study module was executed in its most extensive form (25 ECTS), it consisted of five university-level mathematics courses. The courses addressed geometry, algebra and number theory, analysis, and mathematical and pedagogical problem solving. The contents of the module were planned in the cooperation with the departments of teacher education and mathematics. The number of participants in the courses varied between 20–45. Most of the students were prospective teachers who will teach at the primary or secondary level in comprehensive education.

The basic problem in the developing process of Didactic Mathematics was to characterise what is meant by the so-called

didactization of university-level mathematics courses. Our attempt to understand the aims and demands of the didactization in the context of university pedagogy guided us to identify four parallel components of didactization: (1) *contentual didactization*, (2) *technological didactization*, (3) *methodological didactization*, and (4) *developmental didactization*. (Poranen & Silfverberg 2011.)

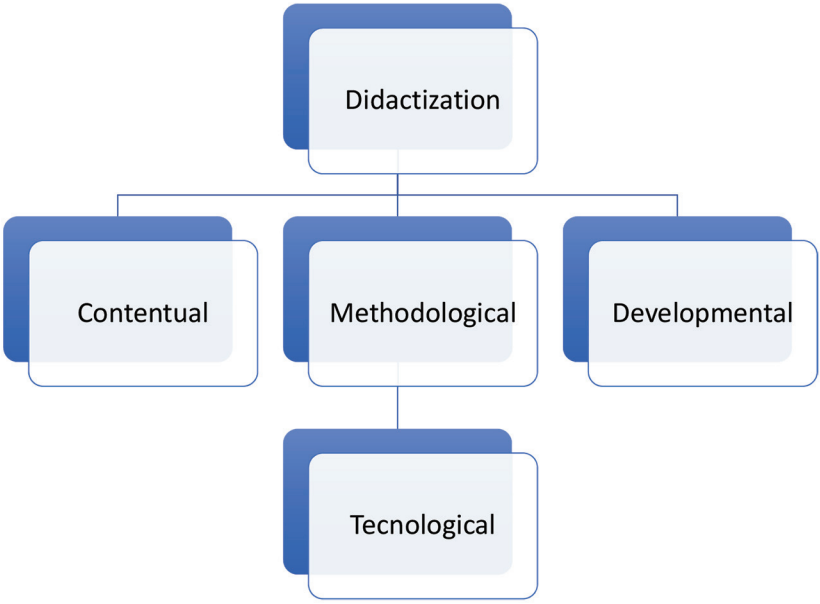

Figure 1. The components of the didactization process

Contentual didactization closely corresponds what Ball and Bass (2000; 2003) have called mathematics for teaching. It describes the mathematical content, the fact that it is important for teachers to successfully manage the mathematical issues that come up in their professional practice in school. By the term, we have attempted to emphasise the links between the contents of school mathematics and university mathematics, and clarify some conceptual continuums in the curriculum which begin from the elementary or secondary mathematics and continue to the basic courses of the university

mathematics and perhaps even further. In the didactization process of the courses, we especially utilised the ideas presented by Ball & Bass (2000), Abramovich & Brouwer (2003) and Stylianides & Stylianides (2010). We also used the so-called *didactical proficiency examinations*, in addition to more traditional evaluation methods, where students in small groups at the school level were asked to find ways to introduce some of the theme(s) that we had had in our university-level course, e.g. the group concept, Euler totient function, etc. In those tasks, in particular, the students were expected to take into account both the *mathematical and pedagogical spaces* described in Stylianides & Stylianides (2010).

By methodological didactization, we mean attempts to use in the university level courses teaching methods that strengthen the prospective teachers' professional skills, as much as possible, to apply similar approaches in teaching school mathematics, especially collaborative working and inquiry-based learning. During the courses, we discussed, for instance, what concepts such as mathematical truth, argumentation, proof and defining may mean at different school levels for a teacher and for a student. We also encouraged our students to reflect on how their own mathematical thinking was changing or was expected to change at the university and how they thought they could develop their own students' mathematical thinking at school. Technological didactization can be considered a special case in methodological didactization. By the frequent use of technological tools like symbolic calculators, Geogebra, Maples, applications in Internet, etc. and through discussions on the pedagogical advantages and disadvantages of the use of these tools we made an effort to broaden prospective teachers' pedagogical content knowledge (PCK) towards more inclusive techno-pedagogical content knowledge (TPACK) (Mishra & Koehler 2006).

Developmental didactization refers to attempts to bring out historical developments which some of the concepts addressed during the course have had in the progress of mathematics as a

science. Secondly, we examined psychological learning trajectories for some basic mathematical concepts beginning from the early and naïve conceptions which preschool or primary school teachers may use in their teaching to more exact concepts introduced in lower and upper secondary school mathematics and, finally, becoming ennobled to precisely defined concepts in university mathematics. The development of number sense and number concept, the development of geometrical thinking and pupils' common interpretations of the nature of the basic geometrical concepts for instance on different van Hiele levels, the different conceptions of the *limit, derivative* and *integral* concepts, etc. all offer good examples if this type of analysis.

One necessity we especially have to take into account is that after passing the pedagogically oriented courses in Didactic Mathematics, students will continue to study the 'normal, non-didactizated' courses in university mathematics. That forms a kind of counter force to the goal of the didactization process. Students have two types of challenges. In the short run, they will continue their studies with the more demanding courses in university mathematics and ought to be well prepared to enter into a more demanding level in their mathematical thinking. However, in the longer run, they will also qualify as mathematics teachers in the primary or secondary school.

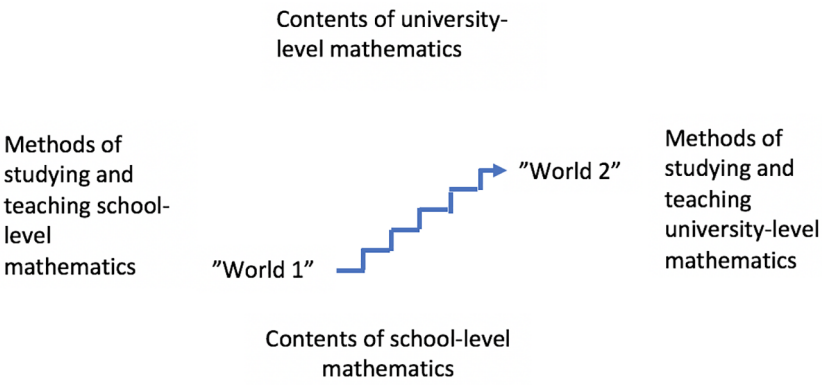

Figure 2. The essence of didactization

Therefore, in the more demanding courses, students should learn to put themselves in schoolchildren's position and, from this perspective consider their pedagogical choices and their own learning processes in different mathematical tasks. Figure 2 illustrates the steps we want our students to be gradually able to climb.

Selecting suitable mathematical tasks that help in didactizing the courses and teaching has a central role in the process. Stylianides & Stylianides (2010) call such tasks *pedagogy-related mathematics tasks* (P-R mathematics tasks). These tasks are intended to provoke activity that can support the development of mathematical knowledge for teaching (Mft) as Ball and Bass (2000; 2003) call such mathematical knowledge. Also, the essential part of our development process of Didactic Mathematics has been producing P-R mathematics tasks which emphasise the learning trajectories from elementary-level to university-level mathematics and strengthen students' learning to adopt skills such as abstraction, defining and argumentation. Examples of the pedagogy-related (P-R) mathematical tasks used in our courses can be found, for instance, in the articles written by Poranen and Haukkanen (2012), Poranen and Silfverberg (2011), Silfverberg and Joutsenlahti (2014) and Silfverberg (2004; 2012).

The development of the didactization of courses was based on the continual discussions between teachers, the feedback gathered from students and on the reported experiences from the projects that have had a similar type of didactization attempts guiding their actions. As an outcome of the development project, we have renewed the curricula and the teaching approaches of the courses to include better-built bridges between school and university mathematics and between basic and more advanced university mathematics.

On the life course of the projects and the conclusions

With the projects mentioned above, we challenged many traditions in subject teacher education and many common beliefs of how these studies should be organised. The challenged traditions were, among other things, the following:

1. The subject teacher education is based on the clear division of labour of the faculties where the so-called subject faculty takes care of the teaching of the subject to be taught and the faculty of education takes care of the pedagogic studies.
2. The main subject in the future master's degree for teaching mathematics is mathematics, physics or chemistry, and correspondingly the main subject of the primary school teachers' degree is educational science.
3. The studies of prospective teachers of mathematics lead to a Master of Philosophy degree.

The teacher education programme offered to engineering students retains structures 1 and 2 but leads to the Master of Science (Technology) degree instead of Master of Philosophy degree (3). The AIKAMA education challenged especially the 2nd tradition. One could qualify as a mathematics teacher with education as a main subject also. The development of the Didactic Mathematics study module required a shift in focus, from the traditional point of view of storing the division of labour to more intensive cooperation between the departments. In all of the projects described, we, of course, made sure that they were in accordance with valid legislation. However, over the course of the years, we noticed that many parties outside the projects were still strongly committed to traditions 1–3 in their thinking and consequently reacted to our solutions quite critically.

After the growing pains, the teacher education programme for engineering students has proven to be a vital and socially

important part of the local and national supply of teacher education possibilities. When the programme began, its attractiveness was doubted. Nevertheless, in the last few years, the student quota reserved for it has become full without problems. The programme has a clear profile, and it produces teachers who are well employed in the teaching profession. The integration of the universities and along with it, their intensifying cooperation will make this teacher education programme an even more natural of the teacher education options. Then, it is perhaps possible, better than before, also to utilise the synergic advantages with the teacher training in vocational education.

The fate of the AIKAMA and NORDIMA projects has, instead, been their gradual shutdown. The main reason for this relates to the strategic decision of the university to make the master programmes into wider aggregates than before and to finish the programmes with a minimal number of students. When the faculty carried out these strategic decisions, such things as the innovativeness of the individual programme, the good feedback from students or the programmes, the justifiable significance regarding the educational policy were not sufficient grounds to deviate from the general strategy of the entire university. When it was decided to terminate the AIKAMA programme, the NORDIMA programme also lost its significance at the same time, at least partly because its main recruiting base – which, in any case, was too narrow - disappeared.

The fact of the matter is that the AIKAMA subject teacher education programme, in which education was the major subject, suffered from a sort of identity problem during its entire life course. Many of those teachers who had themselves completed the traditional subject teacher education or otherwise had committed to its background thoughts were not able to accept the fact that AIKAMA primarily aimed at offering students strong expertise in educational sciences and, in addition, to proficiency in mathematics that was qualifying and sufficient for teaching mathematics at the comprehensive school

and upper secondary school levels. Those who strongly criticized the programme argued that just the opposite should be essential in subject teacher education, i.e. a good knowledge of mathematics and sufficient professional skills in pedagogy. The education ended up in the crossfire for both ideological and labour union political reasons. On the one hand, the representatives from primary school teacher education considered the programme a subject teacher education programme and did not permit it in their own "territory", and on the other hand, the subject teachers shunned it because of its emphasis on the educational sciences and not on the mathematics itself.

At the pedagogic level, an attempt was made by the Didactic Mathematics study module to strengthen the compatibility of teaching university mathematics courses with the objectives of teacher education in the AIKAMA programme and, at the same time, to persuade students in primary school teacher education to choose the mathematics as a minor subject in their bachelor and master's degrees from the outset. The reduced resources in the department of mathematics and the Faculty of Education have depleted possibilities to offer Didactic Mathematics courses. At the same time, the ending of the AIKAMA programme has essentially reduced the need for the courses profiled in this way.

My view is that there are parties responsible for teacher education at the university who often protect their own interests and ideological views trying to retain existing old structures, even if the change in the educational structures within the society would clearly require changes both in the structures and the contents of the teacher education. Subject teacher education, especially, has been in a subordinate position, both locally and nationally, in the field of the entire teacher education, which has made its developing efforts difficult. Having and maintaining subject teacher education is generally admitted and considered extremely important for the university and its subject departments. However, the development of subject teacher education has not been seen as an important goal for the community, because

the education has fulfilled its task in its current form also, at least satisfactorily. The projects which I introduced above have made attempts to reform subject teacher education to better respond to the challenges of the changing Finnish basic education. The challenge to bring subject teacher education and primary school teacher education closer to each other exists. Fortunately, the thoughts behind these attempts were allowed to lead their free life for some time and some of them even stayed alive. Unfortunately, however, in the more general process of change in higher education, subject teacher education in many respects had to settle down and to return to a role of a prisoner of its own tradition.

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