GLOBALISATION THROUGH THE LENS OF HISTORY OF MATHEMATICS EDUCATION

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ABSTRACT

The emergence of nation states in the 19th century, the institutionalization of school systems and the corresponding teacher training led to the development of national education systems in the following centuries. These systems were shaped by various factors, including economic conditions, military activities, ideological paradigms, and cultural traditions. In the history of education, the internationalization of mathematics education is largely assumed progressive, which requires a critical examination. As we will show, these narratives can be questioned by investigating historical examples and the study of tensions between universal global trends and cultural-historical traditions.

1 *Different views on Internationalization and Globalization*

The history of mathematics education as a scientific discipline is much younger than the history of mathematics. Nevertheless, it is closely interwoven with the history of mathematics. Topics like the history of institutions, biographical histography, history of mathematical concepts can also be seen as parts of the history of mathematics and its methodologies can partly be used (Karp & Furinghetti, 2018, p.3). While the history of mathematics often focuses on the study of historical artefacts and sources and historical and cultural contextualizations are rather local and limited to short time intervals, research in the history of mathematics education is often related to long-term processes and their patterns. In particular, the study of recent history like the history of the New Math reforms show, that by analysing processes in the past the history of mathematics education can develop perspectives that allow the present to be seen as a continuation of cultural-historical processes and thus to explore meaningful critical analyses of currently existing social practices (Fleck, 1979, p. 20):

> "...whether we like it or not, we can't get rid of the past - with all its errors. It lives further in borrowed terms, in problem formulations, in school teaching, in everyday life, in language and in institutions. There is no Generatio spontanea of concepts. They are, so to speak, determined by their ancestors. The past is much more

> dangerous - or actually only than dangerous – if the bond with it remains unconscious and unknown."

This article focuses on phenomena, which are described as global in the educational policies of many countries. Recent examples of such global processes are output - and competence orientation, introduction of educational standards, central tests and global assessments, as well as economization, centralization, digitalization of education systems (e.g. Atweh et al., 2001, Atweh & Clarkson, 2002).

Globalization is often seen as a kind of internationalization of processes that take place locally more or less simultaneously and independently of one another, becoming more international through cooperation and then forming a global process through the large number of participating states. Thereby, a global network is formed and then identified with the process. This narrative enables the participating states to assume that the resulting global network serves as a political tool for solving local problems.

Critical positions on the assumed progressive character of global networks started to develop in the second half of the 20th century, especially with regard to the leadership and control claims made by "Western democracies" . As early as 1961, the OECD demanded (Graupe & Krautz, 2014, p. 2):

> "...with regard to developing countries, it would be 'nothing short of cutting a million people loose from a way of life that has constituted their living environment for hundreds or thousands of years. Everything achieved by these countries' schools and education until now has served social and religious aims, which have primarily allowed for resignation and spiritual comfort; things that completely go against any economic sense of progress. Changing these century-old approaches may, perhaps, be the most difficult yet also most important task for education to accomplish in developing countries."

A systematic study of the influence exerted on national educational systems in the context of colonialism and neocolonialism was in the second half of the last century initiated by concepts of critical pedagogy, critical psychology, critical mathematics education and the philosophy of mathematics.

Since the 1980s, representatives of ethnomathematics and critical mathematics education, like Freire, D'Ambrosio and Skovsmose, questioned the leadership and control claims of so-called "Developed Western democracies" over "developing countries". Their educational approaches take into account the social, cultural and historical conditions of "developing countries" and address the situation of disadvantaged population groups. From this perspective, though, an unintentional identification of North American, Western European and Asian educational systems takes place under the notion of "Western democracies". However, the latter are partly very different in terms of their cultural traditions (e.g. Kocka, 1987), the extent of economization, profit orientation and power structures. The educational approaches of socialist Eastern European and Asian states, although very successful in science and mathematics education, are rarely visible from the perspective of the global antagonism "Developed Western countries vs. developing countries".

Another view, which ascribes enormous importance to the phenomenon of globalization as a key concept for understanding "the transition of human society into the third millennium" but sees globalization without historical contexts and cultural and social common references, was formulated in the 1990s (Waters, 1995, p.1). Here globalization is seen as "a concept which refers both to the compression of the world and the intensification of consciousness of the world as a whole" or as "a social process in which the constraints of geography on social and cultural arrangements recede and in which people become increasingly aware that they are receding". In mathematics education, such global trends are e.g. convergence of school mathematics and mathematics education curricula around the world, similarity in research questions or epistemological positions such as constructivism. This kind of actions without actors are often associated with "forces that are impersonal and beyond the control and intentions of any individual or groups of individuals" (cf. Atweh et al., 2001, p. 79, Atweh & Clarkson, 2002).

In other words, globalization in this case is not considered to be related to the solution of economic and social issues but to slogans, such as container terms with arbitrarily postulated meaning created by the network itself. For example, "virtual reality, information society, digital natives", which are related to visions, utopias without restrictions in terms of space and time and therefore without a past. Since the beginning of the millennium, there have been numerous efforts, particularly by critical mathematics education, to systematically study educational and socioeconomic phenomena occurring worldwide (see e.g. Atweh et al., 2001, Atweh et al. 2007).

We will approach the phenomenon of globalization and its conceptualization from the perspective of the history of mathematics education. Depending on the context, internationalization and globalization can be defined differently. However, internationalization processes are traditionally seen as having a bottom-up dynamic, starting from local, culturally and historically anchored problems. Internationalization here means above all the adaptation of functioning local “best practices” to other local, like national or cultural-historical conditions; in other words, cross-country dissemination based on local needs. In contrast to this, a system-theoretically oriented, structural approach may see internationalization as growing numbers of connections in international networks; according to this understanding, any activity that involves a cross-country collaboration contributes to the internationalization of the activities of the partners (Henry et al., 2013). For example, from a system-theoretic perspective, publications in “international journals” increase the “international visibility” of the author(s); support of collaboration and division of labour are rather not in the focus.

We will follow the first cultural-historical interpretation of internationalization. In this understanding, we see globalization as a contrasting top-down movement whose motives no longer need to be justified locally in cultural-historical or socioeconomic terms. We will use historical examples from the German history of mathematics education to sharpen our understanding of the differences between internationalization and globalization.

2 German History of Mathematics Education in the Context of Internationalization and Globalization

2.1 Germany as a Case Study

One might ask why the history of teaching reforms in Germany can be illuminating for phenomena related to internationalization and globalization. As we will see, Germany's history of mathematics education is of particular interest from several perspectives.

During two centuries, Germany had various socioeconomic systems and thus different views of humanity, educational paradigms and educational systems: an Imperial Empire (German Empire after the Franco-Prussian War), the Weimar Republic, the fascist Nazi Germany, 4 occupation zones, West German capitalist social market economy, East German socialist society and German neoliberal imperialism. German history therefore offers the opportunity to examine internationalization and globalization processes in different social contexts. We will restrict our study to three international reforms; the reform of geometry teaching Newer Geometry in the 19th century, the Meraner Reform and the New (or Modern) Math Movement in the 20th century. All three aimed at the modernization of upper secondary mathematics teaching. The restriction to the teaching of geometry does not represent a real restriction here, since the changes in the teaching of school geometry were essential for all three reforms (Weiss, 2022). The consideration of Germany as a case study is also interesting in connection with internationally known protagonists of international associations for the promotion of mathematics education. German mathematicians such as Felix Klein, Walter Lietzmann and later Heinrich Behnke and Georg Steiner played a significant role in the formation, development and management of organizations supporting the foundation of ICMI as well as in the reforms of geometry teaching (Tobies, 2021, Schubring, 2019, Tobies, 2024).

Finally, yet importantly, the development of the German educational system was strongly influenced by supranational movements such as the Enlightenment, the development of dual higher education careers, reform pedagogy and a culture of accompanying instruction and oral examination by the mathematics teacher that is characteristic of the German-speaking educational models and differs from the Anglo-Saxon model.

2.2 German Enlightenment

To this day, the spirit of the Enlightenment permeates the German education system, especially the university law. The idea of man's emergence from his self-incurred immaturity is expressed in fundamentals of the German education system, like trust in the professionalism of the teacher and the orientation towards maturity autonomy, emancipation, responsibility, self-realization, and self-determination from teacher and student. Further ideas of the Enlightenment that were integrated into the German higher education system in the 19th century were and are the unity of research and teaching, as well as the freedom to choose the teaching methods. The symbiosis of autonomy with Verstaatlichung (nationalization) and of Zweckfreiheit (uncommitted research) with purpose oriented practices (e.g. Tenorth, 2017) was only in this millennium replaced by the dominance of third-party funded research.

Another characteristic of the German education system is the civil servant status of professors and teachers, which entails high social prestige and security on the one hand and loyalty to the state on the other. Since the academization at the beginning of the 19th century, teacher education for secondary schools in Germany has been at a high academic level. For career promotion teachers are expected to participate in committees for school development and development of curricula, as well as in the development of textbooks and methodologies and publications in corresponding journals.

2.3 German Dual Education and Reform Pedagogy

Another key factor in the development of mathematics education in Germany was the creation of a higher education path, dual to the classical Humboldtian *Gymnasium*, through the establishment of new school types; the *Oberrealschule* and the *Realgymnasium*. The qualifications at these schools were given the same status as those of classical *Gymnasium*s at the beginning of the 20th century; their curricula were particularly well coordinated with further scientific or engineering studies. Ideas adopted from the Enlightenment and rooted in elementary education such as knowledge does not come from books but from dealing with objects in nature and in the world and the concept of experimental learning (cf. Schubring, 2019) led to methodologies that were oriented towards the cognitive abilities and interests of the child (Fröbel, Pestalozzi, Herbart) and work-based education (Kerschensteiner, Ostrich).

2.4 Guided Instruction and Process Orientation as a German Teaching Tradition

Trust in the teacher was not only shown by the social status of the civil servant and the representation of an office, but also in the complete responsibility for assessing the learning success of the students. The tests and examinations were almost always created by the teacher themselves and were intended to serve more as diagnostics and feedback than as a selection tool, with the focus being on learning progress under accompanying guidance. (Lietzmann, 1926, p. 207):

> "That examinations, where examinee and examiner know each other, are the norm in our country seems to me to be an essential advantage of our school system. Where, as in France or in England, both parts are alien to each other or even - if they are limited to written exams - do not even come across each other, the exam itself is more difficult. Still, it doesn't lead to higher performance on average, despite a sometimes unworthy exam drill."

Access to studying mathematics, technology or natural sciences at university was not via entrance examinations. Examinations were preferably oral and were taken by the teacher who had also taught the class; this social practices were changed only in this Millennium.

3 Newer Geometry as a (bottom-up) Internationalization Process

The development of the teaching reform Newer Geometry, which took place in Germany in the second half of the 19th century, illustrates particularly effectively the importance of cultural-historical circumstances for the development of a reform movement from below. “Newer geometry” meant the disciplines that established themselves in the 19th century as Descriptive geometry (Monge), Geometry of position (Carnot, von Staudt), Geometric constructions (Steiner), Projective properties (Poncelet), Barycentric coordinates (Möbius), Linear algebra, algebra (Graßmann, Plücker), Analytical geometry (Gergonne) as well as the reform of the strict school geometry teaching by Euclid’s Elements. A uniform description of German educational policy is difficult, since educational policy in Germany is a federal matter.

Due to the professionalization and academisation of teacher education at the beginning of the 19th century, mathematics *Gymnasium* teachers were familiar with projective geometry and other non-Euclidean approaches through their university studies. Using descriptive geometry as an example, Barbin et al. (2019) show the spread of these ideas in some European countries and the close connection between the development of descriptive geometry and the development of curricula and teaching methods for the newly founded polytechnic schools and technical universities. In most federal states of Germany at the beginning of the 20th century, important aspects of projective geometry were anchored in the curricula and textbooks of secondary schools. This rapid inclusion of higher mathematics in secondary school curricula was due both to the nature of the subject and to the high qualifications of the teachers, who had partly worked on these non-Euclidean geometries in their dissertations and were themselves involved in the reform of the “strictly by Euclid’s elements” style of geometry teaching (Simon, 1906, p. 5):

> “If one takes a look at elementary geometry in the 19th century, it is particularly important to note how the major currents of science also emerge in elementary geometry.”

The inclusion of new methods, such as the use of models, reflections as a change of perspective between spatial and planar geometry, the paradigmatic reference to conic sections and a task-led, action-oriented concept development is impressively demonstrated in the three-part textbook from Henrici and Treutlein. The great width of the work of Peter Treutlein was characteristic for many protagonists of the Newer geometry and later the Meraner reform: in addition to teaching at school, it included administrative work as director of a *Realgymnasium* and later a *Reformgymnasium*, curriculum development and development of textbooks and methodologies (see also Weiss, 2019).

4 The Meraner Reform as a (bottom-up) Internationalization process

The Meraner or Klein's Reform as an international teaching reform is often equated with international efforts to modernize mathematics teaching and the resulting introduction of differential and integral calculus and analytical geometry in the upper secondary school. However, Felix Klein's reform efforts in Germany can also be seen as an extension of the Newer geometry reform to and as a compromise solution to the contradictions of the dual education system, which became particularly apparent in the anti-mathematical movement.

The anti-mathematical movement developed from concrete problems that had arisen from a strongly theory-oriented teaching of mathematics at technical colleges and universities, which was often measured against the rigour of theoretical mathematics (Hensel et al., 1989, p.53):

> "Nevertheless, it was usually not sufficiently taken into account that the contradictions between theory and practice had been amplified because the theoretical-mathematical treatment of some technical science disciplines - measured against their level of development - was one-sidedly overemphasized, while the experimental validation of the theoretical framework was only insufficiently developed."

On the one hand, Germany's theoretical orientated engineering education enjoyed high recognition worldwide, but on the other hand, the World Exhibition in 1893 had also shown the advantages of pragmatic, mathematically less well-founded approaches like the American. A first result of the broad discussions that followed, which had already begun in the 1870s and were continued broadly and intensively after the World Exhibition, was the introduction of laboratory teaching. This, however, raised the question of which content should be replaced by the new subject. The question was polemicized whether mathematics at technical universities is a *Hilfswissenschaft* (auxiliary science) or a *grundlegende Wissenschaft* (basic science). The answer to this question was also linked to the place and importance of the basic and special mathematical lectures given by mathematicians with chairs at the technical universities (Hensel, 1987, pp. 253). The introductory courses to differential and integral calculus, as well as to descriptive and analytical geometry, developed and taught at the technical universities and poly-technical schools formed a solid empirical basis for the related discussions about the possibilities to teach these subjects at *Realgymnasien* and *Oberrealschulen*. The introduction of differential and integral calculus and analytical geometry into upper secondary teaching was therefore not an abstract modernisation of mathematics education. It was, rather a result of compromises reached in long discussions to divide the proportions of mathematical education between secondary schools and technical colleges and universities, while maintaining and expanding the desired close relationships between pure and applied mathematics. There was also an interest in ensuring that theoretically inclined engineers had possibilities to receive a well-grounded education in mathematics and science at technical colleges. The strong personal and content-related relationship between the Newer Geometry reform and the Meraner Reform is evident in Felix Klein's efforts to dissolve the anti-mathematical movement, as well as his ideas on functional thinking. In his concept development of a function and his introductions to calculus, geometrical transformations and geometrical approaches and relations are fundamental. The influences of the reform "Newer geometry" on the Meraner Reform are also visible in the methodology of Walter Lietzmann, Klein's close cooperator in the Meraner Reform. Another example that shows the strong personal and content-related connections and continuities between the teaching reform Newer Geometry and Klein's reform is Georg Wolff. Klein sent Wolff to England and France in 1913 and 1914 to study mathematics and physics education in these countries and to prepare reports on behalf of the IMUK (see also Schubring, 2019). As also Walter Lietzmann, Georg Wolf worked as a teacher in an Oberrealschule. In his lecture "Teaching of Geometry in Germany" at the annual meeting of the British Mathematical Association (1937), he classifies the achievements of the reform of geometry teaching and links them to the goals of the Meraner Reform (Wolff, 1937):

> "The Merano course of study aimed at promoting those parts of mathematics that have to do with number, and thus by means of the function-concept arithmetic, al-

> gebra, analysis, and analytic geometry were unified in a single whole. This unification proved to be very useful and purposeful."

Wolff describes the development of geometry teaching within the framework of the Meraner Reform as a "quiet" reform, the goals of which are self-concreted through the consistent application of the principle of functional relations. The concept of functional thinking, which is at the heart of the Meraner Reform, succeeds in unifying the various geometric theories that had previously been taught separately.

In the Meraner Reform, the application-oriented approaches, which are closely linked to physical and engineering contexts, as well as the ideas of reform pedagogy are valued, taken up and further developed by the proponents of Klein's ideas.

5 The New Math Reform as a (top-down) Globalization Process

1.1 5.1 West German New Math Reform

The great importance of substantiated mathematical knowledge and conceptual understanding of natural sciences and engineering technology for economic competition among industrial nations remained unchanged after the Second World War. In the post-war years, West Germany benefited from the Marshall plan and the high level of education and training of technician, scientists and engineers in the Weimar Republic.

Adapting the ideas of the Meraner Reform to the new conditions, given by the rapid development of applied mathematics and the greater specialization of engineering sciences, would have been an obvious impetus for reform efforts on the grounds of economic needs. Another social challenge arose from the political supported work immigration of the 50s and thus greater heterogeneity in the classroom. Above all, however, a critical debate should have taken place about the appropriation, ideologization and misuse of mathematics education for racial theories and character training during the Nazi regime (Hamel, 1933, p.307):

> "But far more important is the educational value that follows from the connection between mathematics and the Third Reich. The basic attitude of both is the heroic. [...] Both demand service: mathematics the service of truth, sincerity, accuracy. [...] Both are anti-materialistic. [...] Both want order and discipline, both fight chaos and arbitrariness."

However, a fundamental debate failed to materialize, partly due to the lack of denazification of the West German education system.

At the end of the 1950s, university mathematicians in several European countries called for a modernisation of the 'backward mathematics education', demanding an algebraization of geometry teaching and an orientation towards axiomatic set theory, which had already been implemented by Bourbaki in higher mathematics since the 1920s. Although in Germany van der Waerden's Modern Algebra was already in its 5th edition in 1955, nevertheless, modern algebra in the sense of Bourbakism only began to gain acceptance at German universities from the early 1950s. Algebra instruction was, incoherent and out of date in the Bourbaki sense, depending on the lecturer and location. Therefore, a reform aiming at the set theoretical foundation and algebraization of geometry should have started with teacher education (Weiss, 2023).

Central figures of the New Math teaching reform were Heinrich Behnke and his former assistant, Georg Steiner. Heinrich Behnke was a member of the ICMI Executive Committee from 1952-the year the ICMI was restored-until 1966, and served as its president from 1955 to 1958. Since the 1930s, Behnke had continuously campaigned for the close connection between university and higher education. He saw the university's task as providing teachers with a broad, well-founded mathematical education and maintaining relationships through conferences, training courses and encouraging publications in subject didactics (Hartmann, 2008). Neither Behnke nor any other university mathematician from Germany took part in the meeting, which was supposed to shape the movement for modernisation as an international project: the Royaumont seminar in 1959. Heinrich Behnke took part in the ICMI seminar in Aarhus, where well-known mathematicians presented their ideas for a Bourbaki-inspired geometry concept development. In his opening lecture he tried to place the planned reform movement in the tradition of Klein's ideas, citing Klein (Behnke et al., 1960, p.15):

> "My [Klein's] interest from my time in Bonn ...was to understand the mutual relationship between the opposing mathematical schools and to encompass their contradictions through a unified overall conception. From this perspective, how much he would have won over to Bourbakism today! For it was precisely this unified conception of mathematics, which the French have been striving for with such success for about two decades now, that was always Klein's main goal."

And on the next page somehow contradicting, Behnke continues:

> “Klein believes that the axiomatic representation necessarily leads to "purism”, the shielding of one part of mathematics from the other. But here he was radically wrong. The Bourbakism of our day is axiomatic, but it connects the individual parts together again. Yes, that is its initial motive. All of mathematics is based on a few parent structures, namely: 1. Algebraic structures, 2. Order structures, 3. Topological structures.”

Although teachers were unprepared for a set-theory-based, axiomatic approach to teaching of geometry, and the axiomatic-deductive method contradicted established reform pedagogical principles, the axiomatic set theory was nevertheless integrated into the curriculum in 1968 through a top-down decision by *Kultusminister Konferenz* (Conference of Federal Ministers of Education), despite significant opposition from teachers (Weiss, 2023). An important change that also took place with the top-down reform, strengthened by trends in international networks, was the new self-determination of mathematics education as a scientific discipline. This involved a division of mathematics educators into school practitioners, dealing with the development of teaching materials and teacher training, and the visionary new mathematics didactics elite, who were increasingly occupied with self-reflection, establishing their own methods and research questions, and distancing themselves from unscientific approaches. The traditional theoretical conceptualization and contextualizations of current developments, as well as traditional activities of mathematics educators like editing and adaptation of teaching materials, were no longer seen as scientific work and research (Weiss, 2024). In the 1980s, the structural and set theoretical approaches of the New Math Reform were completely withdrawn. One of the new global trends that were now followed was Realistic Mathematics Education (RME). However, it was not linked to the application orientation of the Meraner Reform and its close interplay between mathematics and physics education.

5.2 East German New Math Reform

In East Germany, the reform New Math encountered different conditions than in West Germany. The German Democratic Republic (DDR) was not an official member of the International Commission on Mathematical Instruction (ICMI), the organization behind the International Congress on Mathematical Education (ICME). This was primarily because ICMI operated under the International Mathematical Union (IMU), of which the DDR was not a recognized member due to Cold War-era political divisions (Furinghetti & Giacardi, 2023). As a result of the war and the denazification carried out in East Germany, there was a shortage of 40,000 teachers (Bruder, 2024), who were trained as *Neulehrer* (new teachers) in short accompanying courses after World War II. In contrast to the Western Occupation Zones, the unified school was introduced in the Soviet Occupation Zone, consisting of an 8-year, later 10-year polytechnic elementary school and a 4-year-high school (Sträßer et al., 2023). The philosophical basis of the educational principles, the teaching design and the educational policy was historical dialectical materialism. The principles of the Meraner Reform were compatible with these teaching principles; work-based education, a paradigmatic inductive development of concepts and a close integration of mathematics teaching with the natural sciences, especially physics teaching. These guiding principles formed as well a foundation upon which mathematics education in East Germany developed. Due to the initial lack of well-trained teachers and the great heterogeneity of the students in a unified school system, the emphasis was on practicing and understanding examples that were paradigmatic for the subjects. Research into mathematics education was state-controlled and institutionalized and, like teacher training, was strongly oriented towards school practice. In contrast to the constructivist approaches prevalent in West Germany, pedagogical approaches in mathematics education were inspired by Soviet activity theory research (Bruder, 2024). Also, due to the traditional proximity to the ideas of the Meraner Reform, the efforts to modernize geometry teaching concentrated on linking the concept of geometric representation with the concept of function and thus a uniform presentation of the school subjects geometry, algebra and analysis. The initially planned, consistent foundation of geometry on the concept of mapping proved to be impractical and was only implemented as a possible background theory. The concept of geometrical transformations found its way into the curricula primarily through the construction of congruence mappings and their compositions and their use in geometric proofs of triangle geometry. However, a consistent connection between the geometric concept of transformation and the concept of function could not be demonstrated in the students' understanding (Filler, 2016). However, this was partially successful in mathematical and physical contexts. Although the educational system in East Germany was centrally organized, there were no drastic reorientations or breaks with cultural-historical traditions, due to the New Math movement. Some of the introduced notions, related to set theory, were kept until the reunification, in particular in the context of inequalities, transformations and functions.

6 Conclusions

History of reforms of geometry teaching enables a better understanding of the differences between bottom-up problem-oriented culturally rooted internationalization processes and global networks. The West German top- down New Math Reform was not motivated through practical experiences of schoolteachers. Methods such as axiomatic-deductive concept development and programmed learning had no foundations in the existing social practices of teachers and students. It seems also, that the reformers were more motivated by belonging to global networks than by practical local problems. German history in both West and East Germany also shows that profiling in global networks is often linked to ignorance or the lack of appreciation of one's own cultural-historical traditions.

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