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THE DAWN OF MATHEMATICS EDUCATION FOR GIRLS AT THE *HÖHERE MÄDCHENSCHULE* IN PRUSSIA IN THE EARLY 20TH CENTURY

Summary: This paper examines a famous reform of girls' secondary schools in Prussia in 1908 regarding mathematics education. The historical analysis focuses on the aims, new objectives, and methods of teaching algebra and geometry to girls in comparison with a comprehensive reform of mathematics education for boys, the Meran Reform (Ger. *Meraner Reform*) of 1905. Contemporary didactic approaches to the methodological design of mathematics education for girls are outlined and illustrated by examples.

Keywords: history of mathematics education, female education, secondary girls' schools, Meran Reform

In 1908, a pioneering school reform in Prussia reorganized higher education for girls in response to the demands of the women's movement at the time. For the first time, the subject of mathematics was introduced into the curriculum of girls' schools. At the *Höhere Mädchenschule* (a secondary school for middle-class girls), algebra and geometry were added to the standard arithmetic lessons. Previously, only elementary arithmetic up to commercial arithmetic had been taught, with the aim of enabling female students to solve given problems quickly and independently[1].

While the history of female education in general, and of secondary mathematics education for boys at the turn of the 19th and 20th c., has been extensively

[1] See *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, Verlag von Wilhelm Hertz, Berlin 1894, p. 472.

studied from various perspectives[2], there is a notable gap in research concerning mathematics education for girls[3]. This paper summarizes my current research on mathematics education in the upper grades of the ten-grade *Höhere Mädchenschule* in Prussia in the early 20th c. The recently published article, *Mathematics Education for Girls in Prussia 1890–1925*, is of great importance for this paper: it provides the historical context of the Prussian reform of girls' secondary schools and is often cited[4]. First, this reform is examined in light of the increasing demand for equal educational opportunities for both sexes. Further, it is explained which proposals of the influential Meran Reform of mathematics education for boys were incorporated into the new official Prussian curriculum for the *Höhere Mädchenschule*[5]. These two sections establish a historical framework for analyzing the didactic innovations of the new mathematics curriculum for girls[6]. Finally, contemporary approaches to the methodical design of mathematics lessons for girls will be illustrated by examples from textbooks newly published at that time[7]. The principle of intuition regarding functional thinking in algebra lessons will be demonstrated with examples.

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[2] See J.C. Albisetti, *Schooling German Girls and Women*, Princeton University Press, New Jersey 1988; H. Inhetveen, *Die Reform des gymnasialen Mathematikunterrichts zwischen 1890 und 1914*, Klinkhardt, Bad Heilbrunn 1976; M. Kraul, *Von der höheren Töchterschule zum Gymnasium. Mädchenbildung in Deutschland im 19. Jahrhundert*, [in:] *Der Weg an die Universität. Höhere Frauenstudien vom Mittelalter bis zum 20. Jahrhundert*, vol. 1, ed. by T. Maurer, Wallstein, Göttingen 2010, p. 169–190; K. Krüger, *Erziehung zum funktionalen Denken – zur Begriffsgeschichte eines didaktischen Prinzips*, vol. 1, Logos, Berlin 2000; K. Krüger, *Functional Thinking: The History of a Didactical Principle*, [in:] *The Legacy of Felix Klein*, vol. 1, ed. by H.-G. Weigand, W. McCallum, M. Menghini, M. Neubrand, G. Schubring, Springer Open, Cham 2019, p. 35–54; G. Schubring, *Der Aufbruch zum "funktionalen Denken". Geschichte des Mathematikunterrichts im Kaiserreich*, „NTM International Journal of History & Ethics of Natural Sciences, Technology & Medicine" 2007, vol. 15, no. 1, p. 1–17; B. Zymek, *Der Strukturwandel des Mädchenschulwesens in Preußen 1908–1941*, "Zeitschrift für Pädagogik" 1988, vol. 34, no. 2, p. 191–203.

[3] See M. Strub, *"Das nachsichtslose Einprägenwollen hilft zu nichts". Vom Rechnen zur Mathematik in der höheren Mädchenbildung im 19. und frühen 20. Jahrhundert*, Dissertation, Universität Bremen 2008; G. Werth, *Neue Wege im Mathematikunterricht – Auf den Spuren Mathilde Vaertings*, vol. 1, Springer, Wiesbaden 2023.

[4] See K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*, "Journal of Mathematical Behavior" 2025, vol. 79, Article no. 101242.

[5] Ibidem.

[6] K. Krüger, *Aufbruch in die mathematische Bildung für Mädchen zu Beginn des 20. Jahrhunderts*, [in:] *Fallstudien zur Geschichte der Mathematikdidaktik*, ed. by A. Büchter, R. Bruder, R. Strässer, WTM-Verlag, Münster 2024 (Schriften zur Geschichte der Mathematik und ihrer Didaktik, vol. 13), p. 7–24.

[7] See K. Krüger, *Mathematikunterricht für Mädchen zu Beginn des 20. Jahrhunderts – ein Blick auf die elementare Algebra*, "Der Mathematikunterricht" 2024, vol. 70, no. 3, p. 3–18.

Reform of the *Höhere Mädchenschule* in Prussia

While the Prussian secondary school system for boys was reorganized and standardized in 1810 as part of an educational reform initiated by Wilhelm von Humboldt, girls' education remained outside the scope of state regulation[8]. One educational option available to middle-class girls was the mostly privately run *Höhere Mädchenschule*[9]. This institution was distinct from the *Volksschule*[10] in that it offered instruction beyond the elementary level. It perpetuated social segregation and offered subjects such as French and English.

The *Höhere Mädchenschule* primarily aimed to prepare girls for their roles as future wives and mothers. Consequently, mathematics instruction, such as geometry or algebra, was deemed unnecessary. This perspective began to shift with the emergence of the women's movement in the mid-19th c. Women's rights activists and female educators increasingly advocated for reforms in the girls' school system, demanding equal educational opportunities for both sexes. However, it was not until 1894 that the Prussian Ministry of Education issued the May Regulations (*Maibestimmungen*), a decree that regulated the girls' school system[11]. Girls from the middle class now had the option of attending a state-regulated school from elementary to secondary education over a period of nine years. The curriculum for the *Höhere Mädchenschule* still did not include a subject called 'mathematics' in girls' secondary education. Neither geometry nor algebra had to be taught, only elementary arithmetic (without variables): 'Algebraic arithmetic, even in its beginnings, is excluded'[12].

The May Regulations opened expanded professional fields for women appropriate to their social class, especially the teaching profession in the lower grades of the *Höhere Mädchenschule*. After graduation from the *Höhere Mädchenschule*, young women were offered vocational education at female teacher training seminars. However, the May Regulations did not include provisions for ad-

[8] See G. Schubring, *Mathematics Education in Germany*, [in:] *Handbook on the History of Mathematics Education*, vol. 1, ed. by A. Karp, G. Schubring, Springer, New York 2014, p. 241–255.

[9] The translation of *Höhere Mädchenschule* as girls' high school might be misleading, because the adjective 'höhere' ('higher' in English) referred only to the social status of the female students, not to the level of the education provided (K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*).

[10] During the 19th c. two practically disjoint systems of education were established – for the low classes and for middle classes. *Volksschule* was intended and limited for the lower classes and offered only basic studies in elementary arithmetic and geometry ('*Rechnen*' and '*Raumlehre*'; see G. Schubring, *Der Aufbruch zum "funktionalen Denken". Geschichte des Mathematikunterrichts im Kaiserreich*, p. 12)

[11] See K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*.

[12] See *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1894, p. 47.

vanced qualifications equivalent to those available to male secondary students. Graduates of the *Höhere Mädchenschule* were not granted the general university entrance qualification that was granted to boys through the *Abitur* examination.

Following the 1900 Prussian reform of boys' secondary education – which enabled students at all types of nine-grade secondary schools (*Gymnasium*, *Realgymnasium*, and *Oberrealschule*) to obtain a general university entrance qualification[13] – there was an increasing demand for the admission of women to universities. Since mathematics was a main subject in boys' secondary schools and was examined in the *Abitur*, educators discussed including it in girls' schools to achieve equal education opportunities.

Several years later, in 1908, the Prussian Ministry of Education implemented a pioneering reform of girls' education through a decree known as the August Regulations (*Augustbestimmungen*). At the core of this reform was the restructuring of the *Höhere Mädchenschule*, which was redesigned to provide a ten-year course of study. This course began with three years of elementary instruction (*Vorklassen*)[14] and was followed by seven years of secondary education in the middle and upper grades (see Fig. 1). In addition to the *Höhere Mädchenschule*, the so-called *Studienanstalten* were introduced. This novel educational institution provided girls with a state-recognized path to the *Abitur* examination, which enabled them to attend university. After grade IV, *Höhere Mädchenschulen* were allowed to offer a transition to one of three different courses, each corresponding to the three types of nine-year secondary schools for boys mentioned above. As with the May Regulations before, a female teacher training seminar was affiliated with the *Höhere Mädchenschule* (see Fig. 1).

Under the August Regulations, mathematics instruction (beyond arithmetic) became a required component of the curriculum in the upper grades (IV to I) at the *Höhere Mädchenschule*. This requirement was introduced because mathematics was part of the *Abitur* examination for boys and was therefore implemented to ensure equal educational opportunities for girls.

Fig. 2 shows a photograph of a mathematics class at a female teacher training seminar in Karlsruhe, where students are collaboratively solving a fractional

[13] See K. Krüger, *Erziehung zum funktionalen Denken – zur Begriffsgeschichte eines didaktischen Prinzips*.

[14] In these so-called *Vorklassen*, primary schooling for girls in the middle-class was separated from the *Volksschule*. After World War I, the German Empire became a republic (known as the Weimar Republic). Its new constitution provided that the secondary school system had to be based on a common primary school. In 1920 a law called Reichsschulgesetz 'abolished the social segregation between a primary school system for the lower classes and a secondary school system with separate preparatory schooling for the higher classes and established a consecutive system of primary school for all' (G. Schubring, *Mathematics Education in Germany*, p. 249–250).

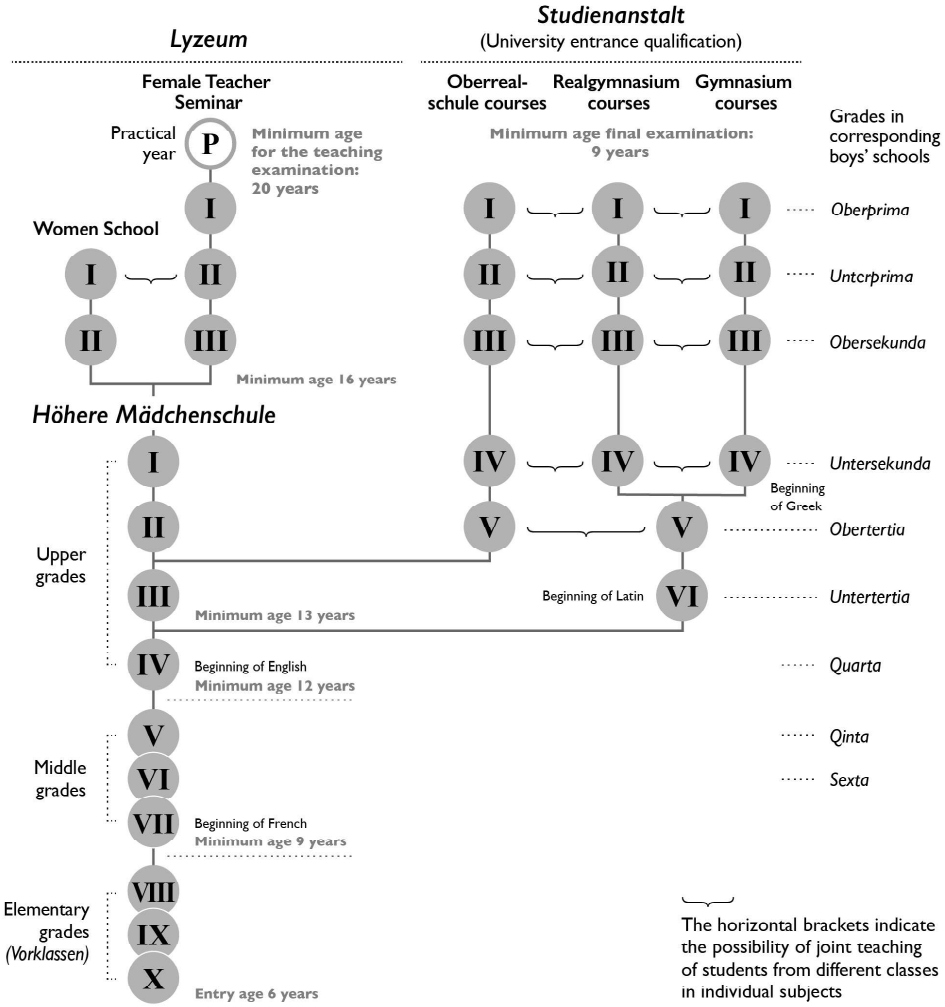

Fig. 1. *Höhere Mädchenschule* and *Studienanstalten*.

Source: K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*, "Journal of Mathematical Behavior" 2025, vol. 79, Art. 101242, p. 5; based on *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, J.G. Cotta'sche Buchhandlung Nachfolger, Berlin 1908, p. 717.

equation written on the blackboard[15]. Future female teachers had to be trained to teach the new subject of mathematics.

The long-standing absence of mathematics teaching beyond elementary arithmetic in the *Höhere Mädchenschule* was also rooted in a widespread societal preju-

[15] Baden was ahead of Prussia in the education of girls, see M. Strub, "*Das nachsichtslose Einprägenwollen hilft zu nichts". Vom Rechnen zur Mathematik in der höheren Mädchenbildung im 19. und frühen 20. Jahrhundert*, p. 180)

Fig. 2. Mathematics education at the female teacher training seminar *Prinzessin Wilhemstift*, Karlsruhe, 1911.

Photograph: Stadtarchiv Karlsruhe, 7/Nl Oeser 252.

dice. In contemporary debates preceding the 1908 reform about the introduction of mathematics education for girls, their mathematical capabilities were denied, particularly regarding logical reasoning[16]. This was an assertion made despite the absence of evidence. In addition, girls' interest in the newly introduced subject of mathematics was dismissed, often based on prior experiences with the teaching of arithmetic in the *Höhere Mädchenschule*. Conversely, educators with experience in teaching mathematics to girls contended that they were indeed capable of mastering the subject[17]. However, the question remained of how to teach mathematics to girls. In light of the historical context outlined above, this question became a central topic of discussion in educational circles following the Meran Reform of 1905, which restructured mathematics education in boys' secondary schools[18].

Influence of the Meran Reform on mathematics education at *Höhere Mädchenschule*

The Meran Reform led to a significant modernization of mathematics education for boys. It was initiated and organized by the renowned mathematician Felix Klein[19]. Major curricular changes were proposed, emphasizing the concept

[16] See Ibidem, p. 182–184.

[17] See Ibidem, p. 188.

[18] See Ibidem, p. 192 ff.

[19] See H. Inhetveen, *Die Reform des gymnasialen Mathematikunterrichts zwischen 1890 und 1914*; K. Krüger, *Erziehung zum funktionalen Denken – zur Begriffsgeschichte eines didaktischen Prinzips*; G. Schubring, *Der Aufbruch zum "funktionalen Denken". Geschichte des Mathematikunterrichts im Kaiserreich*.

of function and incorporating differential and integral calculus into secondary education. The main goals were to promote a 'habit of functional thinking' and to strengthen spatial intuition[20]. Since that time, functional thinking has assumed a fundamental role in mathematics education in Germany[21].

These reform ideas were developed by a teaching commission appointed by the Society of German Natural Scientists and Physicians (*Gesellschaft Deutscher Naturforscher und Ärzte: GDNÄ*) and specified in a mathematics curriculum for the *Gymnasium*. This curriculum, called the Meran Proposals (*Meraner Vorschläge*), was initially piloted at selected secondary schools for boys. It became part of the official Prussian curriculum in 1925[22].

Prior to this, consensus proposals of the Meran Reform had already been integrated into the mathematics curricula of the newly organized secondary girls' schools in Prussia in 1908. A statement by the teaching commission of the GDNÄ, presented at an annual conference in Stuttgart in 1906, contributed to this. In their so-called Stuttgart Proposals (*Stuttgarter Vorschläge*), the members of the commission advocated for the introduction of mathematics instruction (beyond elementary arithmetic) at the *Höhere Mädchenschule*. They requested the implementation of mathematical content comparable to that taught in *Realschulen* – a type of middle school for boys – but recommended that the methods be adapted to align with perceived gender differences. '[A] distinction should be made in the selection and manner of presentation of the subject matter on account of the different dispositions of the two sexes'[23]. Emphasis was placed on the 'cultivation of intuition' and a less rigid approach to mathematical proof. Mathematical relationships deemed self-evident were not required to be proven[24]. Regarding functional thinking, the variation in wording compared to the Meran Proposals is noticeable[25]: the 'habituation to the functional linking of mutually dependent relationships [...] will guarantee that the mental training to be brought about remains in constant contact with the real world of appearances'[26]. In middle grades,

[20] A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, vol. 1, Teubner, Leipzig 1908, p. 104.

[21] See, e.g., H.-J. Vollrath, *Funktionales Denken*, "Journal für Mathematikdidaktik" 1989, vol. 10, no. 1, p. 3–37.

[22] See *Richtlinien für die Lehrpläne der höheren Schulen Preußens. Band 1: Grundsätzliches und Methodisches. Teil 2: Lehraufgaben*, ed. by H. Richert, Weidmannsche Buchhandlung, Berlin 1925.

[23] A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, p. 194. The translations of the quotations in this article are primarily from K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*, or were made by the author.

[24] A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, p. 196.

[25] K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*.

[26] A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, p. 199.

functional thinking should be intuitive and later developed into a conscious 'act of thinking'. For boys, the 'education in the habit of functional thinking' was explicitly required[27].

Gustav Noodt and Frieda Kundt, both experienced teachers at *Höhere Mädchenschulen* in Berlin[28], also argued for the introduction of mathematics education at around the same time in the journal "Frauenbildung" [Women's Education]. Noodt addressed the crucial question of how to foster interest in mathematics instruction at the *Höhere Mädchenschule*. He suspected that 'the lack of interest in a subject is certainly largely due to the method by which it is taught'[29]. In his view, the Meran Proposals were well suited to arouse and maintain girls' interest in the newly introduced subject of mathematics[30]. Kundt also regarded the Meran Proposals as a basis for mathematics instruction at the *Höhere Mädchenschule*. In a lecture delivered to the German Association of Female Teachers (*Allgemeiner Deutscher Lehrerinnenverein*), she emphasized the significance of providing girls with access to mathematical education. Like the Meran reformers, Kundt used formal and material education arguments and emphasized the contribution of mathematical education as a 'counterweight to a too one-sided education which would lead to a strong development of the emotional life'[31]. On this basis, she formulated the following aims of mathematical education at *Höhere Mädchenschule*:

> Mathematical education generally aimed to train the mind in logical thinking, to strengthen spatial visualization, and as far as possible, to give female students an insight into the significance of mathematics for contemporary culture.[32]

Mathematics education at *Höhere Mädchenschule* since 1908

According to the August Regulations, mathematics was added to the subject of 'Reckoning' (*Rechnen* in the sense of elementary arithmetic) in the new curriculum of the *Höhere Mädchenschule* in Prussia. The general teaching aim of the extended subject closely mirrored that of the boys' secondary schools[33].

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[27] Ibidem, p. 104.

[28] K. Krüger, *Mathematikunterricht für Mädchen zu Beginn des 20. Jahrhunderts – ein Blick auf die elementare Algebra*.

[29] G. Noodt, *Wie ist auf den höheren Mädchenschulen das Interesse für den mathematischen Unterricht zu wecken?*, "Frauenbildung" 1906, vol. 5, no. 5, p. 255.

[30] G. Noodt, *Wie lassen sich die Meraner Vorschläge über die Reform des mathematischen Unterrichtes für den algebraischen Unterricht an den Lyzeen verwerten?*, "Frauenbildung" 1906, vol. 6, no. 5, p. 303–314.

[31] F. Kundt, *Der mathematische Unterricht auf der zehnklassigen höheren Mädchenschule*, "Frauenbildung" 1907, vol. 6, no. 4, p. 154.

[32] Ibidem, p. 155.

[33] See *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, J.G. Cotta'sche Buchhandlung Nachfolger, Berlin 1901, p. 526.

> The purpose of teaching reckoning and mathematics is to give the students confidence and skill in reckoning and a knowledge of elementary mathematics based on a clear understanding. It should also help students to develop logical thinking and a concise and accurate way of expressing themselves.[34]

The distinction in wording is in the emphasis: boys were expected to focus on understanding the mathematical theorems to be developed, and girls were encouraged to understand the mathematical procedures.

Contrary to the original plan, 'Reckoning and Mathematics' – despite being designated a core subject[35] – was allocated only three hours per week at the *Höhere Mädchenschule* instead of the intended four[36]. A comparison with the mathematics curriculum of the corresponding male middle school, the *Realschule*, with four to five hours per week, shows that insufficient time was allocated for the intended mathematics curriculum at the *Höhere Mädchenschule*[37].

According to the curriculum specifications of the August Regulations, arithmetic[38] up to squaring and root extraction, and algebra up to quadratic equations with one unknown, were to be covered from grade IV. For the teaching of geometry, the objectives were 'plane geometry to the point of being able to calculate the circumference and area of a circle' and 'calculating the surface area and volume of simple solids'[39]. Table 1 presents a more detailed overview of the topics covered in the curriculum for the upper grades IV to I (which corresponds to contemporary grades 7–10). Graphical representations of functions are explicitly listed in grade II and were therefore compulsory much earlier than in boys' secondary schools. However, the concepts of powers and roots, logarithms, similarity, and trigonometry were not provided in the curriculum for the *Höhere Mädchenschule*.

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[34] See *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, J.G. Cotta'sche Buchhandlung Nachfolger, Berlin 1908, p. 952.

[35] Ibidem, p. 1001.

[36] M. Strub, "*Das nachsichtslose Einprägenwollen hilft zu nichts". Vom Rechnen zur Mathematik in der höheren Mädchenbildung im 19. und frühen 20. Jahrhundert*, p. 219.

[37] J. Schröder, *Die neuzeitliche Entwicklung des mathematischen Unterrichts an den höheren Mädchenschulen Deutschlands insbesondere Norddeutschlands*, Teubner, Leipzig 1913 (IMUK-Abhandlungen, vol. 1/5), p. 55; A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, p. 186.

[38] Arithmetic meant not only the teaching of operations with natural or rational numbers but also with 'general numbers' (variables) as a scientific completion to the preceding reckoning lessons at the elementary level (W. Lietzmann, *Methodik des mathematischen Unterrichts. Band 2: Didaktik der einzelnen Unterrichtsgebiete*, vol. 1, Quelle und Meyer, Leipzig 1919, p. 255).

[39] *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 952.

Table 1. Themes in arithmetic, algebra and geometry at *Höhere Mädchenschule* in the upper grades IV to I.

Grade IV. Addition, subtraction, and multiplication with general numbers. Positive and negative numbers. Simple equations of the first degree with one unknown. Exercises in numeracy, subsequent to the mathematical subject matter, here and in all subsequent classes. Introduction to planimetry through multiple exercises with a ruler, a scale, a protractor, and a compass, recording the results in the form of explanations and theorems. The most important properties of the triangle.
Grade III. Division and fractions with general numbers. Decomposition into factors. Equations of the first degree, especially encased (*eingekleidete*) equations. Extension of the theory of triangles. Triangle constructions with the use of auxiliary triangles and geometric loci. Theory of parallelograms and trapezoids.
Grade II. Linear equations with two unknowns. Graphical representation of linear functions. The simplest theorems in the theory of proportions. The theory of circles. Equality of rectilinear figures (the Pythagorean theorem); measurement of rectilinear figures.
Grade I. Extracting the square root from certain numbers. Simple second-degree equations with one unknown; graphical solutions of quadratic equations. Proportionality of lines. Equality of side ratios for triangles that coincide at two angles. Regular polygons. Measuring the circumference and area of a circle. Calculating the volume and surface area of simple solids.

Source: *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 958–960.

While the themes depicted in Table 1 were closely aligned with the corresponding Prussian curricula for boys' secondary schools, the influence of the Meran Reform ideas is more evident in the methodological remarks in the girls' curricula[40]. These remarks contain concrete information regarding the specific design of mathematics lessons for girls. From today's perspective, some of the methodological remarks discussed below are didactic approaches that are remarkably innovative compared to conventional mathematics instruction for boys at the time[41].

Methodological remarks on algebra and geometry instruction for girls

According to the Stuttgart Proposals (see the section "Influence of the Meran Reform on Mathematics Education at the *Höhere Mädchenschule*"), the August

[40] K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*.

[41] See K. Krüger, *Aufbruch in die mathematische Bildung für Mädchen zu Beginn des 20. Jahrhunderts*, p. 15.

Regulations emphasized the principle of intuition (*Anschauung*) in the sense of visualizing the subject matter[42]. The consistent use of graphic representations is required when introducing algebraic expressions and negative numbers, and when solving equations[43]. 'With such graphic representations, [female] students gradually familiarize themselves with the concept of function' and become accustomed to functional thinking[44]. The methodological remarks directly followed the Meran Proposals, which recommended the graphical solution of equations in each school year beginning with grade 9 (*Obertertia* corresponding to grade II)[45]. Particular attention was paid to solving equations in a comprehensible way. Female students should not carry out the individual transformations mechanically, but with understanding.

Geometry instruction for girls should begin with a propedeutic course that is intuitive, as was provided in the Prussian curricula for boys' secondary schools and in the Meran Proposals[46]:

> The first geometric instruction should be inductive. The students should be introduced to geometrical intuitions and to the use of ruler and compass by means of extensive drawing exercises in which the whole class should participate; the knowledge acquired should be expressed in the form of explanations or theorems [...]. The mechanical learning of definitions is to be avoided.[47]

The above-mentioned principle of intuition was used as a heuristic tool to gain geometric knowledge inductively[48]: '[T]he heuristic method of teaching should be used extensively, in which the theorem appears as the result of an investigation'[49]. By emphasizing the heuristic method, the Prussian girls' school curriculum went beyond the recommendations set forth in the Meran Proposals[50]. In accordance with the Stuttgart Proposals, geometric theorems that can be verified through intuitive understanding should not require formal proof. Rather, the emphasis

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[42] See M. Grenzer, *Zur Einführung von Mathematikunterricht an höheren Mädchenschulen in Preußen. Eine vergleichende Analyse zweier Schulbücher in Bezug auf die Regularien für den geometrischen Unterricht*, Wiss. Hausarbeit im Rahmen der Ersten Staatsprüfung für das Lehramt an Gymnasien im Fach Mathematik, TU Darmstadt 2024, p. 39.

[43] *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 955.

[44] Ibidem, p. 956.

[45] A. Gutzmer, *Die Tätigkeit der Unterrichtskommission der Gesellschaft Deutscher Naturforscher und Ärzte. Gesamtbericht*, p. 109.

[46] K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*, section 4.2.

[47] *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 955.

[48] See M. Grenzer, *Zur Einführung von Mathematikunterricht an höheren Mädchenschulen in Preußen. Eine vergleichende Analyse zweier Schulbücher in Bezug auf die Regularien für den geometrischen Unterricht*, p. 39.

[49] *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 955.

[50] K. Krüger, G. Werth, *Mathematics Education for Girls in Prussia 1890–1925*, section 4.2.

should be on exploration and theorem finding[51]. However, a gradual transition to strict logical reasoning was recommended. A deductive-formal course, such as was common in geometry lessons at boys' secondary schools, is therefore only recommended to a limited extent for girls – in line with the Meran Proposals: 'Experiments with deductive proofs should only be carried out once the [female – K.K.] students have developed an understanding of them in the course of the lesson'[52].

Finally, the education of girls in functional thinking was required not only in algebra but also in geometry: '[E]very opportunity should be taken, even in cases other than those already mentioned, to introduce students to this type of mathematical thinking to facilitate understanding, arouse interest and deepen understanding'[53].

Graphic representation of functions in algebra lessons for girls

An analysis of two new girls' textbooks on arithmetic and algebra, published by the reformist teachers Frieda Kundt and Gustav Noodt, showed how they implemented the methodological guidelines of the August Regulations. They both used the principle of intuition (outlined in the previous section) in explanations, tasks, and illustrations on the following topics: the introduction to algebra, the graphical representation of functions, and the treatment of linear equations with one variable[54]. In this final section, examples of these two protagonists will be presented, which not only illustrate their implementation of the principle of intuition regarding the graphic representation of functions, but also their commitment to motivating and comprehension-oriented mathematics education for girls[55].

Following the Meran Reform, Noodt explained how girls could become familiar with functional thinking. He suggested developing a 'sense' for functional relationships. This should not only be done in mathematics lessons.

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[51] From today's perspective a recognized didactic approach is proposed as to how the problem may be countered, that students often do not recognize or understand why a mathematical proof is necessary (H. N. Jahnke, D. Sommerhoff, S. Ufer, *Argumentieren, Begründen und Beweisen*, [in:] *Handbuch der Mathematikdidaktik*, vol. 2, ed. by R. Bruder, A. Büchter, H. Gasteiger, B. Schmidt-Thieme, H.-G. Weigand, Springer, Berlin 2023, p. 385 f.).

[52] *Zentralblatt für die gesamte Unterrichtsverwaltung in Preußen*, 1908, p. 955.

[53] Ibidem, p. 957.

[54] B. Zaitsev, *Eine Analyse von Schulbüchern zur elementaren Algebra für höhere Mädchenschulen in Preußen zu Beginn des 20. Jahrhunderts*, Wiss. Hausarbeit im Rahmen der Ersten Staatsprüfung für das Lehramt an Gymnasien im Fach Mathematik, TU Darmstadt 2004.

[55] K. Krüger, *Aufbruch in die mathematische Bildung für Mädchen zu Beginn des 20. Jahrhunderts*.

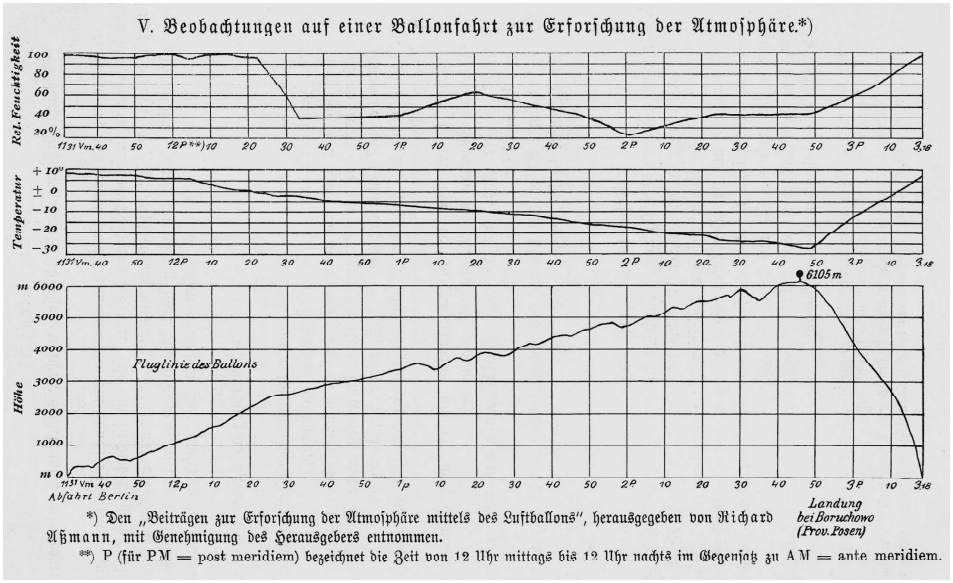

Fig. 3. Graphical representation of data as functions.

Source: F. Kundt, *Arithmetische Aufgaben für höhere Mädchenschulen*, vol. 1, Teubner, Leipzig 1910, p. 23.

> Could not the interdependence of variables be made plausible at an early stage, with appropriate elementary instruction, by constructing annual temperature and barometric curves for different cities, by graphing fluctuations in the population of cities and other statistical results? Learning to "read" such graphical representations correctly is not only beneficial for geographical education itself, but also trains the mind to a high degree, prepares the understanding of the laws of nature, and stimulates interest in mathematical considerations.[56]

In her 1910 textbook, Kundt also dedicated a chapter to graphical representations, beginning with linear functions and subsequently visualizing functional dependencies across various applications. Her examples show the usefulness of such graphical representations of empirically obtained functions from data, such as time series of temperature curves in different climate zones or the average food prices in different cities, in direct comparison or graphical timetables[57]. She also visualized real data from a contemporary scientific study of the atmosphere (see Fig. 3).

Three time series – measurements from a balloon research flight – are presented in such a way that comparisons can be made: the altitude of the balloon, temperature, and relative humidity are plotted as a function of time. Kundt as-

[56] G. Noodt, *Wie ist auf den höheren Mädchenschulen das Interesse für den mathematischen Unterricht zu wecken?*, p. 258.

[57] F. Kundt, *Arithmetische Aufgaben für höhere Mädchenschulen*, vol. 1, Teubner, Leipzig 1910, p. 22–33.

signed a series of tasks that begin with practicing how to extract values from graphical representations of data. These tasks then progress to calculating gradients and velocities, and finally require relating the diagrams to one another – for example, interpreting how decreasing temperature corresponds with increasing altitude. From today's point of view, the following task seems modern, because the students are asked to change the representation of the described factual situation of the balloon flight (sea of clouds and blinding sunlight) into diagrams.

> The report on the flight states that the balloon ascended in heavy rain, but that it emerged from the sea of clouds at an altitude of 2500 meters and found itself in blinding sunlight. To what extent does the humidity curve show these facts? Which other part of the humidity curve indicates that the balloon was in sunshine and at what altitude was it now?[58]

Kundt's suggestions for the use of empirical functions appear as a preliminary stage of the connection between data and functional dependencies that is required today[59]. In Kundt's textbook, female students first learn about the concept of a function as a phenomenon, the first stage of intuitive understanding of this concept[60].

Conclusion

Considering the challenge of introducing mathematics education for girls, appropriate teaching methods were emphasized in the new Prussian curriculum. The influences of the Meran Reform on the design of mathematics lessons can be identified: Education in functional thinking and the cultivation of intuition (*Anschauung*). Within just three years, some of the progressive proposals of the Meran Reform found their way into the new mathematics curriculum of the *Höhere Mädchenschule*. In fact, this sudden leading role of girls' schools was already noted at the time: 'The girls' school system with its curricula for mathematics is therefore in this respect in advance of the boys' schools'[61].

On this basis, girls' interest in the new subject of mathematics should be awakened, and their understanding of mathematical considerations developed. The new Prussian mathematics curriculum for the *Höhere Mädchenschule* was a remarkable step in the development of mathematics education. Didactic approaches to mathematics education were developed further in this challenging situation by ex-

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[58] Ibidem, p. 23

[59] See J. Engel, *Anwendungsorientierte Mathematik: Von Daten zur Funktion. Eine Einführung in die mathematische Modellbildung für Lehramtsstudierende*, vol. 1, Springer, Berlin, Heidelberg 2009.

[60] H.-J. Vollrath, *Algebra in der Sekundarstufe*, vol. 1, BI-Wiss. Verlag, Mannheim 1994.

[61] J. Schröder, *Die neuzeitliche Entwicklung des mathematischen Unterrichts an den höheren Mädchenschulen Deutschlands insbesondere Norddeutschlands*, p. 66.

perienced teachers at girls' schools. They reported their innovative and proven lesson plans in newly published textbooks and educational journals for women. Thus, in addition to the Meran Reform, the dawn of girls' mathematics education can be seen as an important step in the development of mathematics didactics[62]. On the other hand, the comparison of the corresponding mathematics curricula for girls at the *Höhere Mädchenschule* and boys at the *Realschule* revealed that the introduction of mathematics education for girls was associated with obstacles. Girls were allocated less teaching time for nearly equivalent mathematical subject matter. Because of the existing prejudices (such as girls supposedly lacking mathematical talent, see the first section), it would be of interest to investigate differences between girls' and boys' textbooks. This analysis should be carried out with a focus on geometry, because in these lessons logical thinking and proofs are essential.

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