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THE IDEOLOGY OF APPLIED MATHEMATICS WITHIN MATHEMATICS IN GERMANY AND THE U.S. UNTIL THE END OF WORLD WAR II*

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RESUMEN

Este artículo aborda el problema de la relación entre las ideologías de la matemática pura y aplicada en Alemania y Estados Unidos entre 1900 y 1945 bajo la triple perspectiva de la enseñanza, la construcción y variación histórica del concepto de matemática aplicada por los matemáticos y de las matemáticas en la Segunda Guerra Mundial. La discusión se centra en las condiciones para el desarrollo por los matemáticos de la matemática aplicada como disciplina académica en sí misma.

ABSTRACT

The article deals with the problem of the relation of the ideologies of pure and applied mathematics in Germany and the U.S. between 1900 and 1945 under three perspectives:

I. Education

II. The construction and historical variation of the notion of applied mathematics by mathematicians

III. Mathematics in World War II

The discussion is focussing on the conditions for the development of «applied mathematics» as an academic field of its own performed by mathematicians.

Palabras clave: Matemática Aplicada, Matemática Industrial, Educación matemática, Siglo XX, Alemania, EE.UU. de América.

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Introduction: Legitimation of mathematics and the three levels of investigation

The title of this paper should indicate that this is going to be a piece of comparative history. It is my conviction that comparative history greatly enhances the perspective on the relation of science and ideology. *Ideology* is so multifaceted a notion as to include a multitude of philosophical, political, and pure scientific factors which vary with different institutional, historical and social settings. It remains to be seen what opposed notions such as *German idealism* versus *American utilitarianism and pragmatism*[1], *German authoritarianism and centralism* vs. *American democracy and decentralism* can tell the historian about the problem in question that is the ideological values connected to pure and applied mathematics in both countries. The perspective is mainly on the conditions for the development of «applied mathematics» as an academic field of its own performed by mathematicians. The focus is less on spontaneous use of mathematics in the industry by non-mathematicians which has a rather long tradition, largely separate from the development of the academic field mathematics.

Former chief-mathematician of the Bell Telephone Laboratories, Thornton C. Fry, addressed the *American Mathematical Society* (AMS) in 1953, outlining in his talk the development of applied mathematics in the U.S. through the past 13 years [FRY, 1953]. In 1940 Fry had written an influential and comprehensive report for the *National Research Council* (NRC), entitled *Industrial Mathematics,* which was extremely critical of the state of research and, above all, education in applied mathematics in the United States at that time [FRY, 1941]. Meanwhile, in 1953, Fry saw a decisive change of which *the war was a principal catalyst* [FRY, 1953, p. 89]. Fry pointed out that there were still, in 1953, considerable differences in motives and styles between *typical mathematicians* and *typical engineers* [FRY, 1953, pp. 93-95], as well as between so-called *pure* and *applied* mathematicians. Exactly because modern applied mathematics was using more and more sophisticated mathematical tools, Fry argued, the difference mentioned within mathematics was more one with respect to *attitudes* than with respect to the mathematics used:

> The difference between an applied mathematician and a pure mathematician is not the kind of mathematics he knows, it isn't even whether he can create epoch-making new ideas, or like most of us his ability lies principally in interpreting things that are already known. The distinction resides instead in the nature of his interests; in his attitudes, not in his aptitudes. It is almost a social distinction [FRY, 1953, p. 96].

Fry's notion that *the kind of mathematics* doesn't matter, may seem a little overdrawn, since at any historical moment there are fields within mathematics which are likely to be closer to the applications than others. Still, the notion of *applied mathematics* as a *social distinction* and an *attitude* is historically a valid point and important especially with respect to the relation of mathematics and ideology.

First of all, one has to underscore that, historically, the *autonomy* of mathematics as a discipline, as it emerged in the 19th century, relied on the ideology of *purity*, because otherwise it was in danger of being split into several subdisciplines of rather utilitarian orientation [MEHRTENS, 1986, p. 318]. That means, the following remarks have to take into account, in how far the *legitimation* of (pure) mathematics has been historically affected by the relation of mathematics to its applications. The *ideology of pure mathematics* does not necessarily imply a contempt for applications on the part of the *pure mathematicians.* On the contrary, the fact that pure mathematics, which is being created *for its own sake,* has shown its applicability in history again and again, serves as a welcome proof of the *preestablished harmony*[2] between pure science and the material world and thus as an additional instance of legitimation. The *ideology of pure mathematics* has been dominant within mathematics almost ever since. By way of contrast, the *ideology of applied mathematics*, which stresses the *need* for applications, has been, at least in times of peace and under *normal,* civilian conditions, merely a *marginal and complementary ideology*, serving as a kind of protection belt for pure mathematics.

I am intending to deal with the problem of the relation of the ideologies of pure and applied mathematics in Germany and the U.S. between 1900 and 1945 under *three perspectives*:

I. Education

II. The construction and historical variation of the notion of applied mathematics by mathematicians

III. Mathematics in World War II.

Elsewhere I have dealt with two related problems, the «transfer» of German applied mathematics to the U.S., particular connected to emigration, and with war research in mathematics in international perspective [SIEGMUND-SCHULTZE, 2003 a,b].

I. Mathematical education and the conditions for the emergence of the ideology of applied mathematics

Education has traditionally had great importance for the legitimation of mathematics, since that discipline cannot that easily be represented as *applied* or *useful* as the natural sciences, for instance. The value of mathematics as a *general foundation of education (allgemeines Bildungsgut)*, as it was sometimes called in 19th century Germany, or as a means to provide *mental discipline*, as the talk ran frequently in the U.S. at the same time, was independent of immediate applications. The training of teachers at universities has been another source of legitimation for mathematics in both countries. But at this point similarities between Germany and the U.S. are fading already: in the centralized, elitist, state-dominated German system of education of the end of the 19th and the beginning 20th century the education of teachers for high schools (Gymnasia), which would serve there as state officials (Staatsbeamte), had much more legitimatory value for mathematics than in the U.S. with her decentralized (and in its university part mostly private) system of education. Still, the conclusion that applied mathematics would therefore be less promoted in Germany is premature, as we will see.

Connected to the differences *state-dominated/private*, *centralized/ decentralized* and even more pertinent to the point of discussion here were the *conditions for the education of the attitude of an applied mathematician* in both countries.

As a matter of fact, the *attitude towards applications* had and has to be taught at schools[3] and universities. The problem was the connection between two fields, mathematics and engineering, or mathematics and physics, which require very different talents and innate abilities, seldom existent in one and the same individual. While a student would usually be able to get interested in mathematics or physics as such and separately, it takes a deliberate educational strategy to provoke the combined interest in the two subjects. As Fry put it in his address to the AMS in 1953:

> What is needed more than anything else is to alert the individual during these earlier stages of education to the existence of such careers [in applied mathematics; R.S.] [FRY, 1953, p. 96].

One has to admit that neither in Germany (at least until 1900) nor in the U.S. mathematical education succeeded in providing those necessary links between mathematics and applications at an *early stage of education,* that is in the primary or secondary systems of education. This was due to different reasons in both countries, which had, partly, ideological roots: be it enough here to allude to the very academic, theoretical and unintuitive training at German gymnasia on the one hand, and to the less authoritarian, more intuitive and practical but theoretically less sophisticated training at American high schools. There has emerged more recognition of the need of the combination of theoretical and practical, intutitive instruction in German secondary education since the 1890s, with the advance of natural sciences and modern languages in the curricula. At the same time in the U.S. natural sciences were equally promoted but standards in mathematics were even lowered (see below).

That the conditions in the American educational system of the beginning century were less favorable to the training of the *attitude of the applied mathematician* than in Germany is due to *three main factors*, namely the rise of the so-called *elective principle* in American high schools and colleges since the Civil War of the 1860s, the peculiar and generally more liberal *entrance conditions for universities* in America, and the *absence of research and sophisticated mathematical education at most engineering schools* in the U.S.

Servos [1986], in his thought-provoking essay, connected the slow advance of mathematical physics in the U.S. until around 1910 to the shabby mathematical education of most American physicists. Servos points to the ideological influences of *Baconianism* in American education, and its *fear of demon mathematics,* as well as to the *special mystique attached to the laboratory in late nineteenth century America* [SERVOS, 1986, p. 614]. He also mentions the fact that *after the Civil War, mathematics [at high schools and colleges; R.S.] was the subject that suffered the greatest losses* [SERVOS, 1986, p. 616]. These losses were connected to the gradual introduction of the so-called *elective principle* which enabled students to choose among subjects and to reduce education in some subjects, for instance, to skip much of the frequently abhorred mathematics. This educational practice was very different from the stiff, authoritarian policies in the German gymnasium and its mandatory education in mathematics. And of course, the *elective principle* was to a considerable degree, an expression of American *democratic* and *pragmatic* ideological tenets (e.g. expressed in J. Deweys philosophy of education). The impact on the conditions for the education of the *attitude of the applied mathematician* was rather detrimental: both the prospective engineer and physicist were allowed to go forward to studies in his field without comprehensive *mandatory* training in mathematics. It is not as though the mathematical curricula at German gymnasia and American high schools were that different: but one has to differentiate between the *possibility* to study a subject and the *requirement* to take the subject and study it seriously, and in this respect the complaints by educators and mathematicians about the level of mathematical education are most articulate until this date in America and, meanwhile, growing in Germany as well[4]. To be sure, it was *possible* for the student to get a sound training in mathematics at least at the better high schools and colleges in the U.S. Otherwise the rise of pure mathematics in America in the last decade of the 19th century could not be explained[5]. However, there was not enough *institutional coercion* to receive a solid mathematical education at a relatively early stage.

This leads to the *second of the three main factors* mentioned above: there was in Germany, and is partly until today, for students a much more abrupt change from the stiff and authoritarian education at the gymnasium to the liberal, self-determined training at universities. In the U.S., however, the college level at universities or engineering schools was *merely a continuation* of high school training. As to the theoretical level of the topics, especially in mathematics, the American college has frequently been considered as not more advanced than German *secondary* education. That means, it is mainly the *relation between authority and freedom* in education, so fervently discussed, for instance, in Dewey's writings, which was totally different in German and American education. The more liberal American system did not work for *mathematical* education, at least, as has been stressed again and again by American mathematicians and educators[6].

The *third point in question* is the mathematical education at American engineering schools, as compared to the *Technische Hochschulen* in Germany [SIEGMUND-SCHULTZE, 1995]. In this instance the argument goes the other way round: it was the *absence* of the *possibility* of graduate work in engineering research and of higher mathematical education at most American engineering colleges (except for very few institutions such as MIT, California Institute of Technology, Michigan) until World War II, which compared unfavorably to Germany. The few prospective engineers with leanings to mathematics did not find an opportunity to get involved in first class work in subjects such as elasticity and hydrodynamics which relied most (along with electrical engineering being the exception: MIT) on mathematics [SEELY, 1993]. In Germany the appointment as professors at Technische Hochschulen of good, even of some first class mathematicians (Dedekind, Steinitz, Blumenthal) coming from the universities had a long tradition since the middle of the 19th century. Engineers with good mathematical education emerged from these Technical Universities (Kármán, Mises, see HENSEL [1989]). In the U.S., however, there were not enough institutional provisions and ideological support to make the profession of a teacher and researcher at engineering colleges an attractive one. This is nicely expressed in a 1910 report on mathematical education by the American Subcommission of the *International Commission for Mathematical Education* (ICME):

> This side-tracking of genuine mathematical talent to engineering work is most seriously felt in applied rather than in pure mathematics. Precisely here, where the American mind might be expected to scintillate with flashes of genius, there is a real poverty of talent [VAN VLECK, 1910-11, p. 95].

This quote reminds, once again, of the need for the creation of stabilizing institutional, especially educational underpinnings for such a precarious subject as *applied mathematics,* being at the borderland between theory and experiment. The quote is also revealing the absurdity of historical *prima facie* judgment on the *ideological influence of American pragmatism* for instance, which is alluded to in the quote, without looking at the totality of institutional and ideological settings.

II. The construction of the notion of applied mathematics by German and American mathematicians and its historical variation

There was another reason for the dislike of mathematics on the part of engineers, both in Germany and the U.S. The quote just given continues as follows:

> The diversion of students to engineering is not solely responsible for this. It is in part a consequence of past influences when mathematics was pursued in our country as a branch of logic and a purely deductive science [VAN VLECK, 1910-11, p. 95].

It was the German mathematician of Göttingen, Felix Klein, who fought the battle around 1900 for a closer collaboration of mathematics with all possible fields of application. He successfully tried to build a network of stabilizing connections with the government, with industry and neighboring disciplines which aimed at the *long-term legitimation* of mathematics within the German society. Klein and several allies in the institutions concerned reached certain changes in the character of mathematical education at German schools and engineering colleges. Interestingly enough, the reference to *the American* *example,* especially *exercises* both in engineering and in applied mathematics at universities, played a certain role in the strategy of Klein's and his allies. In 1898, Klein managed to introduce exams at the universities for teachers in *applied mathematics.* In the years to come this notion was closely related to mechanics and geodesy, which were also institutionally most strongly represented in Klein's techno-scientific complex of institutes at Göttingen, especially the institute of Ludwig Prandtl. The latter, in turn, was closely connected with the military and with the aviation industry.

To be sure, ideologically, Klein was an outsider within the community of German mathematicians. The majority of German mathematicians at the universities continued to prefer, like Hilbert, the pursuit of pure and formal mathematics, partly connected to some abstract parts of physics [SCHWEBER, 1986, p. 70], but were less interested in engineering. But there was something like a double strategy towards pure and applied mathematics among the leading figures at Göttingen, which was continued, e.g., by Richard Courant in the 1920s. Although not every plan of Klein's was to be realized in the following decades, mostly due to financial problems and political pressure, the network once initiated by Klein was still effective during World War II. It greatly helped pure mathematical research in Germany to survive the Nazi years and the war (see below).

By way of contrast, nothing comparable to the Kleinian reform of around 1900 happened in the U.S., although the problems in engineering education were similar [SIEGMUND-SCHULTZE, 1995] and the leading (pure) mathematician E.H. Moore emphatically pleaded for a *laboratory method* in mathematical education [PARSHALL, 1984; MOORE, 1903]. But, obviously, the ties of American mathematicians to the society as a whole were too loose, and, on the other hand, the pressure on them was not strong enough to be shocked out of their *splendid isolation* at that time. So, in a memo submitted to the Prussian ministry of culture, Klein would remark in 1900:

> The [German] engineers are frequently pointing to the example of American institutions of higher learning. By a strange contrast many American mathematicians are currently engaged in establishing in their fatherland the arithmetized science, which they have learned at European universities. The diverging tendencies which are revealed by this contrast, are transgressing the borders of single countries and affect the whole world of culture [quoted from SCHUBRING, 1989, p. 214].

As a matter of fact, most American mathematicians as of 1900 seem to have *preserved* the attitudes instilled into them by pure academic mathematics of German descent in the years before. Ironically, it was Felix Klein himself, who as late as 1893, at the moment of his greatest influence on the fledgling American community of mathematicians, defended the elitist ideal of pure mathematics for its own sake in his talks at Evanston in connection with the *International Congress of Mathematicians* at Chicago [KLEIN, 1894][7]. To be sure, Klein stressed the importance of geometrical intuition as a means of mathematical invention and he referred to applications in his central talk at Evanston *On the Mathematical Character of Space-Intuition, and the Relation of Pure Mathematics to the Applied Sciences* [KLEIN, 1894, pp. 41-50]. But Klein, in his talk, stressed, in the first line, the *heuristic value of the applied sciences*[8] *as an aid to discovering new truths in mathematics* [KLEIN, 1894, p. 46]. So, Klein would say:

> I have shown (in my little book on Riemann's theories) that the Abelian integrals can be best understood and illustrated by considering electric currents on closed surfaces. In an analogous way, theorems concerning differential equations can be derived from the consideration of sound-vibrations; and so on [KLEIN, 1894, p. 46].

It was only in the second line that Klein proposed the development of an *abridged system of mathematics adapted to the needs of the applied sciences* [KLEIN, 1894, p. 48].

Then, almost apologetically, Klein said:

> What I have here said concerning the use of mathematics in the applied sciences will not be interpreted as in any way prejudicial to the cultivation of abstract mathematics as a pure science [KLEIN, 1894, pp. 48-49].

And Klein added:

> There must be considered here as elsewhere the necessity of the presence of a few individuals in each country developed in a far higher degree than the rest, for the purpose of keeping up and gradually rising the *general* standard [KLEIN, 1894, p. 49].

American mathematicians gathered at Evanston, who were addressed this way as representatives of a *higher human race*, may well have ignored the concluding remarks in Klein's talk where he is warning against the threat of a growing split between pure science and applications in the German university system [KLEIN, 1894, p. 50].

Historians and mathematicians involved have discussed several possible reasons for the dearth of indigenous (that is, not imported by immigration) applied mathematics in the United States until World War II [SIEGMUND-SCHULTZE 2003a]. Several authors referred to this fact as a kind of *paradox* given the *pragmatic* philosophical atmosphere in the U.S. Others came forward with historical explanations such as that most leading American mathematicians were educated in pure German academic mathematics, that they were fewer in numbers going to Germany after 1900, when Kleins reform became effective. Also, the fact that, in a sense, applied mathematics requires the existence of a culture of pure mathematics has been brought forward as an explanation of that *paradox* (R. Courant). Still others considered the abstinence towards applications on the part of pure mathematicians as an *ideological counter-reaction to the exaggeration of utilitarianism* in the American society (H. Mehrtens). As a kind of complementary ideological explanation, the dislike of mathematics on the part of engineers and the public in general has been cited:

> It is our national suspicion of theory, on the part of the general public. [...] One result has been a lack of cooperation between the theoretically-minded scientist and the practically minded scientist [MORSE & HART, 1941, p. 294].

All these explanations have some grains of truth, but for the historian remains to demonstrate the *reasons for the absence of incentives for the rise of applied mathematics under the concrete historical conditions of the United States* in the first decades of our century. Among those reasons were ideological ones, as has been indicated for mathematical education.

Another reason, which I am now going do discuss briefly, is the *notion of applied mathematics as constructed by pure mathematicians.*

Remarks have been made in this paper with respect to the construction of that notion in Germany around 1900. As to the U.S., there has been much talk about *applied science*, especially after World War I[9], when systematic science[10] had shown its superiority to merely making inventions (Edison). American mathematicians tried to capitalize on the favorable ideological climate for science. A historical coincidence was the revolutionary development within physics in the 1920s. The rise of theoretical physics in the U.S. had ramifications for the ideology of mathematicians themselves, with respect to applications. As Loren Butler [1992] has convincingly shown in her dissertation, leading American mathematicians would consider physics, and in particular the General Theory of Relativity, as the foremost field of application of mathematical methods, especially given the poor state of collaboration between the two fields in the U.S. before. In fact, when Einstein's theory stirred up the emotions of the public in the U.S.,

> mathematicians seized upon this curiosity as a public relations opportunity. Relativity theory with its much-publicized abstruse mathematical structure, became an important strategic tool for leading mathematicians, who sought ways to remind laymen as well as their fellow scientists that mathematics —and therefore mathematicians— would play a central and ongoing role in modern physics research [BUTLER, 1992, p. 80].

When the mathematician George D. Birkhoff, as an unofficial envoy of the *International Education Board* (IEB)[11], made an extensive trip to Europe in 1926, the first of Birkhoff's aims which were listed in the Minutes of the IEB was:

> a. To make it possible to cooperate more effectively in the development of mathematical physics in America [IEB Minutes, 19 June 1925, p. 500].

As to Göttingen's request for funds, IEB-official A.Trowbridge put it clearly in his final negotiations in Göttingen, which he held together with Birkhoff in July 1926:

> The Board would be <u>not</u> interested in [...] housing or even helping housing the mathematical department in more agreeable quarters, unless thereby there was a practical certainty that greater and much greater usefulness to a group of sciences would result [IEB 1.2., Box 34, f. 482, 15pp. report, pp. 5-6].

When Birkhoff, O. Veblen and S. Lefschetz, shortly before Birkhoff's trip to Europe, made a list for the IEB on *The essential fields of Higher Mathematics* they listed as the only parts of *Applied Mathematics* the following two: *Mathematical Astronomy* and *Mathematical Physics.* As representatives of *Applied Mathematics* they mentioned, among other persons, P. Debye, M. Born, A. Einstein, A. Sommerfeld, G. Mie, and W. Pauli. That means the notion of *applied mathematics* in the mind of pure mathematicians was very much restricted to mathematical physics. What was worse: American physicists, for the most part, remained uninterested in the work of the mathematicians, e.g. at Princeton. Quantum mechanics was clearly closer to their interest. For instance, Oswald Veblen, who coauthored several papers in the 1920s on the *projective theory of relativity* with physicist Banesh

Hofman, was considered by the latter to be *an outstanding geometer but didn't have much feel for the physics of relativity* [BUTLER, 1992, pp. 93ff.].

In connection with the discussion on the necessity of a separate journal for applied mathematics, which Veblen denied, the latter said in 1929:

> I do not believe that there is, properly speaking, such a thing as applied mathematics. There is a British illusion to that effect. There is such a thing as physics, in which mathematics is frequently used. There is also engineering, chemistry, economics, etc. in which mathematics play a similar role, but the interest of all these sciences are distinct form each other and from mathematics [REINGOLD, 1981, p. 335].

Even less recognition was there among American pure mathematicians for the particular problems of applications in engineering. Mathematical physicist Warren Weaver, who later in World War II would head the *Applied Mathematics Panel*, was surprised, in 1930, *at the emphasis given, in the discussion [on a journal for applied mathematics; R.S.], to the field between Mathematics and Engineering* [BUTLER, 1992, p. 246]. This is not to say, that there was no applied mathematics in the U.S. at that time. In fact, at the Bell Telephone Laboratories a Mathematical Department had been founded in 1928, where seminal research was done, for instance in statistical quality control of industrial production (W.A. Shewhart, Th. Fry). It was simply that much work of this kind did not come to the attention of mathematicians and thus did not influence the character of mathematics as an academic discipline.

The orientation towards physics as the principal field of application led to an underestimation by pure mathematicians of engineering mathematics which would finally prove so important in the war. This ideology was stabilized by a certain estrangement between basic science and the public, especially government, in the *New Deal* of the 1930s, when many a conservative American scientist found that science was insufficiently supported in comparison to the social sciences and when some scientists even put Hitler and Roosevelt in one basket[12].

Ironically, even under the political conditions of Nazi Germany there was not automatically a climate favorable to applied mathematics. Of course, a lot of research in aerodynamics which needed much mathematics was going on in large research facilities in Göttingen, Berlin, and Braunschweig, mostly sponsored by the Nazi government. But at the universities, with rare exceptions (Darmstadt, Rostock), there was no expansion of applied mathematics in peace time either in equipment (calculating machines) and manpower, or with respect to a reorientation of research within mathematics [MEHRTENS, 1986; SIEGMUND-SCHULTZE, 1989, 1991]. This was obviously conditioned by the ruling *ideology of pure mathematical research* among mathematicians who were anxious to protect the *core discipline,* i.e. pure mathematics. The leading German mathematicians realized that they were likely *not* to get *additional* support from the state by going public but rather risked to curtail and endanger their own discipline. The mathematicians's strategy changed only when student rates dropped too dramatically in Germany, and when there was no longer enough demand for the traditional product of university education in mathematics, namely the high school teacher in mathematics. So, in 1937, German mathematicians *invented* the profession of the *industrial mathematician*, although industry had been slow in recognizing the need for employing mathematicians until that moment. The curricula which the university mathematicians proposed for the training of *industrial mathematicians* were not altogether too different from the previous ones for teachers and included the traditional fields of *pure mathematics* [KAMKE, 1937].

III. The ideologies of pure and applied mathematics in World War II[13]

While in times of peace pure mathematicians can resort to some kind of transcendental construction of meaning to create legitimacy for their subject *(preestablished harmony),* things are different in times of national emergency, especially during wars [MEHRTENS, 1996, p. 89].

It was then that a decisive *ideology shift* happened both in Germany and in the U.S. The need of legitimation of mathematics, and be it simply to attain deferments from the draft, greatly influenced the policies of both national mathematical communities.

World War II —at least in the U.S. and in Germany[14]— was *not a mathematician's war* in spite of cryptology, ballistics, operations research, and statistics in war production. Harvard president J.B. Conant called it a *physicists' war,* and it could be easily argued, especially with respect to the German *Ersatzstoff* (chemical substitutes)-production, that it was a chemists' war as well.

So, mathematics was not given priority in the preparation of the war and in war research itself. As a result, both in Germany and in the U.S., mathematics was first subordinated in the leading research organisations[15] to other fields, such as engineering and physics, which was, by the way, an old unpleasant experience for mathematicians, e.g. in the U.S.National Research Council. The subordination of mathematics was also a natural outcome of the slow acceptance, in both countries, of the mathematician as a professional in the industry.

Of course, when it comes to the *relation of mathematics to the military*, not only the problem of legitimation of mathematics, but also general philosophical, political and ethical positions are likely to influence the individuals's attitude to applied mathematics. Even applied mathematician Theodore von Kármán harbored such feelings when still in Germany in the 1920s:

> Physicist Millikan reported that Kármán had stated it was «distasteful to him, after his four years of aeronautical experience in the last war, to feel that he was engaged mainly in preparing for another one. (Kármán would have few qualms about preparing the United States for such a war; his misgivings lay rather in contributing to the military force in Germany) [HANLE, 1982, p. 125].

In 1940, the English pure mathematician G.H. Hardy published his well-known *A mathematician's apology*, in which he takes pride in the uselessnes of mathematics. The book was discussed among British and American scientists and mathematicians under war conditions, and, for the most part, rejected. As to the long-term effects of the war on mathematics, however, both in the U.S. and in Germany pure mathematicians harbored concerns lest mathematics would suffer damage from a too utilitarian point of view. Owens is quoting pure mathematician M.H. Stone's distrust of the *Applied Mathematics Panel* (see below) as a harbinger of *federal-political control* [OWENS, 1989, p. 299]. In Germany, even the applied mathematician and head of the *Institute for Practical Mathematics* in Darmstadt, Alwin Walther, said after the war:

> I have tried [...] to do as much work as possible of general, peaceful value, and further to save as many young scientists as possible [quoted from MEHRTENS, 1996, p. 121].

If there may have been some after-war apologia in Walther's quote, the motive of saving mathematics was certainly a strong incentive for getting involved in science policy in times of war. Only few could afford to stay aloof and not to get involved at all in war research. In the U.S. it was Harvard mathematician George David Birkhoff who, notwithstanding his patriotic feelings, tried to secure a survival for pure mathematics, and said, for instance, in a letter to S. Ulam, dated 8 October 1942:

In the period ahead it seems to me extremely important that the cultural side of our American life should be kept in a good condition [...] I am convinced that good mathematical work is more important than a large part of the effort which is expended now under the guise of war effort [BP 4213.2.2, box 2, file 1942].

But the dominant feeling among leading German and American mathematicians was that they could not escape the war situation and were in need to show the importance of their subject. However, mathematicians in Germany and in the U.S. were differently prepared for the war situation due to different traditions both within mathematics and in the relations between mathematics and the government. While the policies of mathematicians in Germany can be most adequately described by the word *self-mobilization* ([MEHRTENS, 1986], following Ludwig), mathematics in the U.S. was much more *mobilized* than active.

Butler and Owens have discussed the policies of the *American Mathematical Society* (AMS) during World War II. They are arguing that M. Morse and M.H. Stone, as spokesmen for the AMS, were working with all of the assumptions of the *status quo.* They believed that, as leading researchers in pure mathematics, they alone were best suited to organize the utilization of mathematical skill on behalf of the war. They had only little understanding of or respect for the Washington bureaucracies that were in charge of general mobilization of scientific workers. Instead of working within the rigid wartime protocols, Morse and Stone appear to have conducted their business in a manner typical of their professional community: power placed with a small elite, whose knowledge of the field and of the colleagues acted as necessary and sufficient criteria for any and all decision making.

Underlying these assumptions about the appropriate leadership of the mathematics community were familiar and long-standing beliefs about the relationship of pure and applied mathematics. Some mathematicians even bristled at the very use of the word «applied» in the name of Weaver's panel [BUTLER, 1992, pp. 260-261].

So, American mathematicians who were in charge of a joint committee of the *National Academy of Sciences* (NAS) and the *National Research Council* (NRC) since Spring 1942 simply did not know what to do next and Warren Weaver had to step in with his *Applied Mathematics Panel* (APM), founded in November 1942 within the *Office of Research and Development* (OSRD).

Conflicts with the pure mathematicians of the AMS led Weaver to the notion that

> There was a difference between the two disciplines and it was generally the applied mathematician who had the qualities of character and training to be useful in the current crisis. [...] There was something in the training and discipline of applied mathematicians, Weaver mused, that instilled an attitude of service [BUTLER, 1992, p. 296].

Obviously the estrangement between mathematics and engineering, and even, to some degree, between mathematicians and physicists[16], in the 1920s and 1930s led to the relatively small impact of the AMS, as an organization, on war research. Much more important were initiatives by single individuals or groups, such as Courant's plans for an institute at New York University and Richardson's parallel and partly competing project at Brown University. But these projects were not typical of the strategies of the AMS as an organisation. When Richardson promoted his center for applied mathematics at Brown, he did no longer do it as a secretary of the AMS, since he had quitted that service in 1940.

In comparison, German pure mathematicians became much more intimately involved in the organization of war research, especially through the head of the *German Mathematicians' Association* (DMV), Wilhelm Süss. Süss had first hand knowledge of the policies of the state bureaucracy (especially the *Forschungsgemeinschaft)* from earlier activities. What weighed more, however, was the tradition, in Germany, of an existing network of relations of mathematics to its border subjects, engineering, physics, school policies, etc., which was going back to Felix Klein's reforms.

To be sure, the actual involvement of individual (pure) mathematicians in war research and training was very similar in Germany and the U.S. Many a pure mathematician on both sides (Hasse, Wielandt, Haack, Morse, Veblen, Garrett Birkhoff) had to turn to the immediate concerns of warfare be it technology or training of soldiers or the like. But the outcome for pure mathematics after the war was different in so far as the German mathematical system did not undergo such a tremendous change as the American one: German (pure) mathematicians had always remained in control of the war policy with respect to mathematics; they convinced the government to introduce exams for *Industrial Mathematicians (Diplommathematiker)* at the universities in 1942 and secured the survival of pure mathematics in a *Reichs Research Institute*, founded in the last months of the war.

By way of contrast, the call for the *industrial mathematician* in the US came from an applied mathematician in industry (Th. Fry) in 1940 [FRY, 1941]. Pure mathematicians had to acknowledge a neglect of training and of concern for engineering mathematics in the past decades. Richardson's Memo of 1943 stressed the relations of mathematics to mechanics which had been developed for long in Germany[17]. Richardson hastened to dispel the impression that applied mathematics was equivalent to *mathematical physics* [RICHARDSON, 1943]. So, it was rather a historical coincidence that pure mathematics in America could flourish after the war as before: it was due to the general expansion of resources, for example, due to the fact that the *Office of Naval Research* would fund work in pure mathematics in the first years after the war [REES, 1980].

If the relation between the ideologies of pure and applied mathematics changed much more dramatically in the U.S. than in Germany, the return to *normal* research has led, in both countries, to a reinstatement of the preeminence of the values of pure mathematics[18], which has only in recent decades been questioned by the advent of informatics and the computer [DAVIS, 1994].

IV. Archival Sources

BP - George David Birkhoff Papers, Harvard University Archives, Cambridge, Massachusetts.

IEB Files - International Education Board, Rockefeller Archive Center, Tarrytown, New York.

NOTES

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1. Schweber [1986, p. 92] quotes K. Compton after Germany's defeat in the war 1946: «Pragmatism has beaten the A priori».
2. Hilbert called it *prästabilierte Harmonie*. [HILBERT, 1992, p. 69], in allusion to philosopher Leibniz.
3. As late as 1965 Maclane [1965, p. 196] stressed the need for school teachers in applied mathematics.

4. Cf. DUREN [1989], MAY [1972]. A recent 1997-report, called *Third International Mathematics and Science Study (TIMMS)* has shown that Germany is falling back in mathematics education in comparison to Asian countries in particular.
5. Until today there has always been a host of brilliant pure (and, more recently, also applied) mathematicians in the U.S. of American origin in spite of the critical state of American school mathematics. Availability of mathematics in *some* secondary schools and of sufficient money in the university system is enough to account for that fact. But in addition, the influx of immigrants has always been important for American applied science and mathematics.
6. Servos [1986] is claiming that mathematical education for physicists and engineers improved considerably in the high schools and colleges of the 1910s and 1920s, but evidence is lacking in his article, and other sources [DUREN, W.L., 1989; MAY, 1972] disagree. Above all, this does not explain what Servos seems to intend, the rise of theoretical physics in the U.S. in the 1920s, which was rather a phenomenon of internationalization within physics. Finally, Servos thesis clearly fails to explain the very late rise of applied mathematics in the U.S., which did not arrive before World War II.
7. This fact has been noticed first by Schubring [1989].
8. Among them Klein counted geometry.
9. See e.g. KLINE [1995], on the rhetoric strategies of engineers as *applied scientists.*
10. For instance submarine detection: Max Mason's hydrophone. Mason was, by the way, Hilbert's student.
11. A systematic study of support for mathematics given by the Rockefeller philanthropies, among them the IEB, is [SIEGMUND-SCHULTZE, 2001].
12. E.g. the applied mathematician Ch.A. Slichter [INGRAHAM, 1972, p. 281]. See also KUZNICK [1987].
13. See also the recent study [SIEGMUND-SCHULTZE, 2003b].
14. It may be argued that things were different in the U.K., where several pure mathematicians, such as A. Turing, made decisive contributions to the war effort. Today, *Star Wars* might be a mathematicians' war as well.
15. In Germany: *Reichsforschungsrat* since 1937, and *Forschungsführung der Luftwaffe.* In the U.S.: Office of Scientific Research and Development, since 1941. [MEHRTENS, 1986, p. 330; OWENS, 1989].
16. Who were more powerful traditionally in the science bureaucracy in Washington, e.g. Millikan, Hale [KEVLES, 1971].
17. Especially in Klein's Göttingen. There have existed in Germany both a journal and a society for applied mathematics and mechanics since the beginning of the 1920s: ZAMM and GAMM.
18. Most dramatically articulated in the Bourbaki movement.

BIBLIOGRAPHY

BUTLER, L. (1992) *Mathematical Physics and the American Mathematics Community.* Chicago. Unpublished Ph.D. Dissertation.

DAVIS, Ch. (1994) «Where Did Twentieth-Century Mathematics Go Wrong?». In: S. Chikara, S. Mitsuo, & J.W. Dauben (eds.) *The Intersection of History and Mathematics.* Basel, Birkhäuser, 129-142.

DUREN, P. (ed.) (1988-89) *A Century of Mathematics.* 3 parts. Providence, American Mathematical Society, 3 vols.

DUREN, W.L. (1989) «Mathematics in American Society 1888-1988. A Historical Commentary». In: P. Duren (ed.) *A Century of Mathematics.* Providence, American Mathematical Society, vol. 2, 399-447.

FRY, Th. (1941) «Industrial Mathematics». *The Bell System Technical Journal, 20,* 255-292.

FRY, Th. (1953) «Applied Mathematics as a Responsibility of the Mathematical Profession (Summarizing Address of Conference)». In: F. Joachim Weyl (ed.) *Proceedings of a Conference on Training in Applied Mathematics.* AMS & NRC, Columbia University, New York City, 22-24 October 1953, unprinted manuscript, pp. 89-97.

HANLE, P. (1982) *Bringing Aerodynamics to America.* Cambridge, MA, MIT Press.

HENSEL, S. (1989) «Zu einigen Aspekten der Berufung von Mathematikern an die Technischen Hochschulen Deutschlands in letzten Drittel des 19.Jahrhunderts». *Annals of Science, 46,* 387-416.

HILBERT, D. (1992) *Natur und mathematisches Erkennen; Göttinger Vorlesungen von 1919/20.* Basel, Birkhäuser, ed. D. Rowe.

INGRAHAM, M.H. (1972) *Charles Sumner Slichter. The Golden Vector.* Madison, Milwaukee & London, The University of Wisconsin Press.

KAMKE, E. (1937) «In welche Berufe gehen Mathematiker außer dem Schuldienst noch über, und was muß auf den Hochschulen für sie geschehen?». *Jahresbericht Deutsche Mathematikervereinigung, 47,* 250-256.

KEVLES, D.J. (1971) *The Physicists. The History of a Scientific Community in Modern America.* Cambridge, Mass., Harvard University Press.

KLEIN, F. (1894) *Lectures on Mathematics (Evanston 1893). Reported by Alexander Ziwet.* New York & London, MacMillan.

MACLANE, S. (1965) «Leadership and Quality in Science». In: *Basic Research and National Goals.* Washington, D.C., Academy of Sciences, 189-202.

MEHRTENS, H. (1986) «Angewandte Mathematik und Anwendungen der Mathematik im nationalsozialistischen Deutschland». *Geschichte und Gesellschaft, 12,* 317-347.

MEHRTENS, H. (1996) «Mathematics and War: Germany, 1900-1945». In: P. Forman & J.M. Sánchez-Ron (eds.) *National Military Establishments and the*

Advancement of Science and Technology. Studies in the 20th Century History. Dordrecht, Boston & London, Kluwer, 87-134.

MOORE, E.H. (1903) «On the Foundations of Mathematics». *Science, 17,* 401-416.

MORSE, M. & HART, W.L. (1941) «Mathematics in the Defense Program». *American Mathematical Monthly, 48,* 293-302.

OWENS, L. (1989) «Mathematics and War. Warren Weaver and the Applied Mathematics Panel 1942-1945». In: D. Rowe & J. McCleary (eds.) *The History of Modern Mathematics.* Boston, Academic Press, vol. 2, 287-305.

PARSHALL, K.H. (1984) «Eliakim Hastings Moore and the Founding of a Mathematical Community in America, 1892-1902». In: P. Duren (ed.) *A Century of Mathematics.* Providence, American Mathematical Society, vol. 2, 155-175.

REES, M. (1980) «The mathematical sciences and World War II». *American Mathematical Monthly, 87,* 607-621.

REINGOLD, N. (1981) «Refugee Mathematicians in the United States of America 1933-1941». *Annals of Science, 38,* 313-338.

RICHARDSON, R.G.D. (1943) «Applied Mathematics and the Present Crisis». *American Mathematical Monthly, 50,* 415-423.

ROWE, D. & MCCLEARY, J. (eds.) (1989) *The History of Modern Mathematics.* Boston, Academic Press, 2 vols.

SCHUBRING, G. (1989) «Pure and Applied Mathematics in Divergent Institutional Settings in Germany: The Role and Impact of Felix Klein». In: D. Rowe & J. McCleary (eds.) *The History of Modern Mathematics.* Boston, Academic Press, 171-220.

SCHWEBER, S.S. (1986) «The Empiricist Temper Regnant: Theoretical physics in the United States 1920-1950». *Historical Studies in the Physical Sciences, 17(1),* 55-98.

SEELY, B. (1993) «Research, Engineering, and Science in American Engineering Colleges: 1900-1960». *Technology and Culture, 34,* 344-386.

SERVOS, J. (1986) «Mathematics and the Physical Sciences in America, 1880-1930». *Isis, 77,* 611-629.

SIEGMUND-SCHULTZE, R. (1989) «Zur Sozialgeschichte der Mathematik an der Berliner Universität». *NTM-Schriftenreihe, 26(1),* 49-68.

SIEGMUND-SCHULTZE, R. (1991) «Mathematics and Ideology in Fascist Germany». In: W.R. Woodward & R.S. Cohen (eds.) *World View and Scientific Discipline Formation.* Dordrecht & Boston, Kluwer, 89-95.

SIEGMUND-SCHULTZE, R. (1995) «Las frustradas tentativas de reforma de la formación matemática de los ingenieros en los Estados Unidos de América en torno a 1900 sobre el trasfondo de similares reformas en Alemania». *Llull, Revista de la Sociedad Española de Historia de las Ciencias y de las Técnicas, 18,* 619-652.

SIEGMUND-SCHULTZE, R. (2001) *Rockefeller and the Internationalization of Mathematics Between the Two World Wars. Documents and Studies for the Social History of Mathematics in the 20th century.* Basel, Birkhäuser.

SIEGMUND-SCHULTZE, R. (2003a) «The late arrival of academic applied mathematics in the United States: a paradox, theses, and literature». *N.T.M. International Journal of History and Ethics of Natural Sciences, Technology and Medicine* (N.S.) *11*, 116-127.

SIEGMUND-SCHULTZE, R. (2003b) «Military Work in Mathematics 1914-1945: an Attempt at an International Perspective». In: B. Booss-Bavnbek & J. Høyrup (eds.) *Mathematics and War*. Basel, Birkhäuser, 23-82.

VAN VLECK, E.B. (1910-11) «The preparation of College and University Instructors in Mathematics». *Bulletin of the American Mathematical Society, 17*, 77-100.