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RECENT DEVELOPMENTS IN RESEARCH ON THE INSTITUTIONAL HISTORY OF MATHEMATICS

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RESUMEN

Bien que les premières études sur l'histoire institutionnelle des mathématiques aient été publiées dès la fin du XIXème siècle, des recherches plus intenses n'ont commencé qu'à partir des années 1970, en particulier englobant un nombre plus grand de pays. Même s'il n'a pas été réfléchi explicitement, quelques-unes des études dirigées par Felix Klein ont révélé un raffinement méthodologique, qui n'avait plus été atteint pendant des décennies. Il a fallu de nouvelles directions et approches méthodologiques dans la science historique comme en histoire des sciences, afin que des changements se soient faits remarquer pour l'histoire des mathématiques également, aboutissant à nombre d'études remarquables sur l'histoire institutionnelle.

ABSTRACT

Where as first studies on the institutional history of mathematics have been published since the turn to the 20th century, more intensive researches —in particular including more countries— began in the 1970es. Some of the early studies directed by Felix Klein showed a remarkable methodological sophistication, although not explicitly reflected, which went unrivalled for many decades. New methodological directions and approaches, in history as a discipline and in history of science, eventually shaped changes in history of mathematics, too, and led to numerous seminal studies on institutional histories.

Keywords: Institutional History, History of Science, Systems Theory, History of Mathematics, Functional Analysis, Felix Klein, 20th Century.

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A new generation of studies

Over the last 25 years, there has been a marked change in historiography studying the institutional history of mathematics. One can not only observe a considerable extension of related research, but also telling changes in approaches and methods.

A revealing indicator for these changes are the two editions of the «Bibliography in the History of Mathematics», the first published by J.W. Dauben in 1985 and the second, jointly organized by J.W. Dauben and A.C. Lewis, in 1999, as a CD-Rom publication. The first edition had devoted section proper to «History of Institutions», within the chapter on *Selected Topics* in the history of mathematics. This section documented only nine publications, however, which dealt with rather isolated aspects from a few countries, Great Britain, France, Germany, and the United States. The second edition, on the other hand, presented more than one hundred publications, systematically documenting research on institutional history of mathematics in a great number of countries, and across almost all the continents.

First approaches and a long interplay

In a paper of 1980 on the history of mathematical historiography, Dirk Struik observed that research on social history of mathematics only began in the twentieth century [STRUIK 1980, 18]. First specialised studies on institutional history were published in the 1880s: one by S. Günther on the teaching of mathematics in various institutions in medieval Germany [GÜNTHER 1887], and another by W.W. Rouse Ball on the study of mathematics at Cambridge university [ROUSE BALL 1889]. Rouse Ball's book concentrated on figures important for the mathematical sciences and failed - although exposing the importance of the Mathematical Tripos - to clarify the reasons why mathematics became, just at Cambridge, the almost exclusive subject for the final examination, independent of the future career of the graduates.

Actually, a first peak was even reached for institutional history – which we will soon understand as an element of social and cultural history – at the turn from the nineteenth to the twentieth century: due to energetic initiatives by Felix Klein.

Probably the first serious research in this area was Conrad Müller's history of mathematics at Göttingen university during the eighteenth century. This study, originally Müller's doctoral dissertation, undertaken at Klein's inspiration, presents not only an impressive first approach to institutional history, it combines it with outlining a research programme:

«The last years of the nineteenth century have, in one respect, brought a remarkable esteem for historical research on mathematical scientific activity: insofar namely as the *history of productive science* is concerned. In its very essence, this phenomenon seems to be explained by the fact that one does no longer ascribe an absolute constancy to the edifice of mathematics and that one is meanwhile used to introduce the idea of development and hence of variability even into mathematics. Evidently, this idea can only be established and applied as far as founding mathematics by principles is concerned and not with regard to extension by the process of logical reasoning» [MÜLLER 1904, p. 56].

Based on this insight into the historical process as a restructuring of the foundations and not just as a cumulative extension, Müller claimed the necessity of a new «branch of mathematical historiography»: one which should give account of «the *organisation of scientific work*» in order to grasp the qualitative changes of the «productive mathematics» within «the organism of culture» [ibid., p. 60], 'Culture' was understood here as what mediated between science and society at large. Although sociology of science did not yet exist in those times, the very term 'organisation of scientific work' already implied a sociological approach towards institutional history.

It was another disciple of Klein, Wilhelm Lorey, who was to realize the programme exposed by C. Müller in an unprecedented and for a long time unrivalled manner [LOREY 1916]. His seminal study on mathematics in the German universities of the nineteenth century investigated this history as a process of professionalisation. Without expliciting this notion and very probably unaware of it, Lorey had unravelled and documented – always prompted by Klein who constantly pressed him to refine his analysis – dimensions which belong today to the canon of professionalisation of scientific disciplines:

- emergence of an own clientele for the new professionals (students specialising in mathematics),
- growing specialisation in research
- establishment of special forms for intensified studies (the 'Seminare')
- founding specialised journals,

- emergence of scientific schools,
- textbook literature,
- systematic biographies,
- means of communication,
- founding professional associations,
- examinations and career patterns,
- disciplinary conflicts,
- relations to the embedding contexts (e.g. school mathematics).

The methodological refinement as demonstrated (although not explicitly reflected) in Lorey's study for just one of the universitarian sciences foreshadowed a development in the sociology and the general history of science which has been revived and strengthened only since the 1970s. In history of mathematics – and in Lorey's own sequel studies, too[1] – no comparable work was done.

An example of a study published in the time between is Ettore Bortolotti's book on mathematics at the prestigious university of Bologna [BORTOLOTTI 1947]. One learns nothing about teaching and studying mathematics, nothing about professional rôles and activities. Some scattered institutional information is restricted to the medieval period and to modern times, since the eighteenth century. The principal content of the book is, however, to present the mathematical work of all people who happened to stay for a certain – even quite short – period in Bologna and having performed either there or anywhere some esteemed work.

New conceptions, coming from outside

Expliciting methodological issues and refining as well as improving research approaches was initiated in the 1970s, but from outside of history of mathematics and history of science: by the sociology of science. It did not proved easy to transfer and to apply such «foreign» elements into proper historiography.

For this sociological direction, the pivotal point of interest were the *beginnings*, the *origins* of processes characteristic for modern science. A key such issue was provided in the 1970s by studies on the emergence of scientific disciplines. Studying these issues was recommended to historians for

bridging the gap between the inner logic of scientific thought and the external conditions:

«The historian of science who is dissatisfied with the traditional disjunctions of his speciality – social vs. intellectual history, external vs. internal history – will find the discipline a natural unit of study for relating the scientific to the non-scientific world» [LEMAINE *et al.* 1976, p. x].

Actually, the emergence of a new discipline entails its institutionalisation, since – in the terms of these sociologists of science – a scientific discipline was understood as a mainly university-based social subsystem, constituted by a stock of theoretical knowledge, a plurality of problematical questions supported by a paradigm, and both a set of research methods on the one hand and a scientific community with specific career patterns and socialisation procedures and a proper clientele on the other hand. It is clear therefore that 'emergence' means acceptance within the university system providing the basic support structures which permit to establish and practice such cognitive and social differentiations. And this is nothing but institutionalisation.

Understood in this broad sense – and not just as listing all the persons who had been active in a certain speciality at a given place –, institutional history has proved to open new ways and permitted to investigate intersections between cognitive and social issues.

The fruitfulness of such an approach to intersections is even enhanced when one considers that institutionalisation – and institutional history in its entirety – constitutes a cultural specificity. This assertion might sound strange and shall hence be explained further. It follows from the above analysis that a discipline cannot exist alone and in an isolated manner. Rather, it forms one of the sub-systems of a larger system (classically a university system) embracing more disciplines. 'Acceptance' of a new discipline thus implies that is has to prove its legitimacy, its agreeing with the overall values of the embracing system. These values use not be universal, but culturally specific. This specificity becomes concrete when one considers an agency which has not been sufficiently taken into account by sociology of science: systems like that of education system, or of higher education, cannot exist out of themselves. To maintain such complex systems requires a continuity which only the state can provide, as it acts on behalf of a given society as a whole. An issue of this continuity is that the society, mediated by the state, has to finance all these institutions and this will only be done when the

institutions fit into generally accepted sets of values, which evidently constitute important dimensions of culture in a given nation-state – and these may differ more or less significantly from the set of cultural values legitimating certain types and directions of institutions in another state.

It has to be emphasized that the state itself must have reached a level of development where it is capable to assume such general tasks, and must have had overriden interests too narrowly bound to particular strata of the society. It is not surprising therefore that institutionalisation of disciplines did not begin until the feudal state had been more or less superseded. On the other hand, such a functionality of the state for general interests need not be everlasting, rather, it might be changing, as the present post-modern situation shows where there are tendencies in many states to privatise considerable parts of the classical public sector.

Despite its importance for elaborating methods and categories which can be used and concretised by historians of science, sociology of science shows, at the same time, a curious blindness – and even a refusal to take an essential and fundamental dimension in sociology into account: on the theoretical level and on the practical level, as well. This blindness is due to the claim that modern scientific disciplines have attained a status of «autonomy». This reductionist view has in particular been elaborated and propagated by the sociological systems theory, by Niklas Luhmann and Rudolf Stichweh.

Stichweh, for example, explains his view by juxtaposing professions - represented by the classical three «higher» faculties - and disciplines - represented by the subjects in the Philosophical Faculty. While he ascribes external relations and an orientation towards the clients to the professions, he depicts disciplines as a relatively self-sufficient social system «which achieves its institutional form by casting off rôle connections with its social environment.» [STICHWEH 1987, p. 241]. Disciplines are, according to him, «primarily concerned with internal operations and with observing its intra-scientific environment.» [Ibid.]. He understands scientists as members of a discipline as being merely dependent on their colleagues, on their critics and evaluation, whereas professionals work with their clients [ibid., p. 245]. The pretended autonomy becomes even exaggerated to an «absence of external contact» [Ibid., p. 249].

Although history of universities has established that one of the main features of universities modernised in the spirit of the Prussian reforms was

the *dual* rôle of professors as teachers and as researchers, the teaching function and the evidently consequent client orientation becomes «forgotten» and only the rôle as researcher is reflected. The apparent «autonomy» arises by taking absolutely one single, «happy» moment in the development of the science system: when scientists and politicians all shared the same values on science and education and when the industrialised states enjoyed an economic stability or even an expansion which allowed to fulfill major exigencies in the scientific institutions.

A more fundamental reason, however, for the sociological blindness, for abstracting from the impact by which the teaching role will mold – under the specific conditions of the functioning of the embedding university system in the given state – orientations, methods and practice of the complementary research rôle, consists in the ideologised understanding of modern universities as adhering to and applying the Humboldtian ideal of «Einsamkeit» and Freiheit». This ideal is not only understood as a plea for the autonomy of the university, but the ideal is even taken as reality. It demonstrates the strength of such ideologised views that the very sociology of science – instead of revealing the illusionary character of that ideology – undertakes it to legitimate and to propagate it.

Implementation in History of Science

Historians of the sciences and of mathematics who implemented sociological approaches to studies on institutionalisation and on institutions, either started from the same ideological viewpoint, or felt comforted by its confirmation; in any case, it is characteristic that in their studies, the respective discipline is treated separately: without considering the other disciplines coexisting in the same system, so that negotiating or fighting had to occur in order to establish a coexistence which might modify rôles and functions of all the partners.

On the other hand, among the best and innovative studies undertaken by historians of science are those which study the teaching in the respective institutions, the successes and failures of the formation for a professional life, and which even investigate the later professional careers of their graduates.

A landmark in such institutional studies was Fruton's search for the graduates of Justus Liebig's famous chemical laboratory in Giessen, the para-

digm for an institution whose fame was to have achieved the unity between teaching and research in the formation of young chemists - and thus also alluded to as «the chemist breeders» [MORRELL 1972]. Thanks to large-scale and minute investigations, Fruton was not only able to identify all those who had studied in this laboratory during the twenty-eight years in which it was directed by Liebig but also to establish for a high percentage of them - that is for the enormous quantity of more than seven hundred persons - their later professional career. Contrary to the conventional fama, only a small minority of them became research chemists. All the others, however, showed quite different or disparate careers, ranging from physicians and pharmacists to industrialists and farmers [FRUTON 1988].

This important study enabled Frederic Holmes to undertake on his own part a closer scrutiny of the functioning of Liebig's laboratory founded in 1824. Holmes showed that it was for a long time very distant from that model for the unity of teaching and research, and that it first functioned over an extended period, like the traditional laboratories, as a training school for pharmacists. Only during the 1830s, Liebig began to expand his research agenda - in particular by promoting organic analysis - and to integrate students into his research projects [HOLMES 1989].

In an analogous approach, K. M. Olesko, who analysed the functioning of Franz Neumann's *Seminar* for mathematics and physics, the institution which gave rise to the discipline of theoretical physics, was likewise successful in identifying a remarkable percentage of the *Seminar's* one hundred and fifty graduates, and their careers. Her result that more than seventy-five per cent of the total pursued either academic careers or careers as teachers at secondary schools impressively demonstrates Neumann's achievements. [OLESKO 1991, pp. 318 - 323 and 469 - 472].

In a study on the rare case of an institution which deliberately refused disciplinary differentiation and aimed at a holistic study of the natural and exact sciences, the *Seminar* for the entire *Naturwissenschaften* at Bonn university, I have identified all the graduates, too, and minutely researched their careers. Due to the broader spectrum of careers in this case, this search proved to be highly complicated. For the first successful stage of the *Seminar*, from 1825 to 1864, 261 out of the 297 participants were identifiable. In the second stage from 1865 to 1886, where it already faced centrifugal tendencies, for noticeable 261 students out of the total of 373 the later professional career

could be determined. The overwhelming majority, for both periods, entered the teaching profession or obtained an academic position [SCHUBRING 1989a, pp. 79 and 89].

It becomes evident from these examples that institutional histories have to investigate both respective contributions to research and the outcomes of teaching which will establish characteristic relations to the cultural and social context. What should moreover be emphasized is the critical spirit orienting these studies which makes them transcend conventional views and limitations of earlier accounts which often originated from hagiographic approaches towards venerated famous scientists.

There is another direction of research, mainly pursued by historiographers of science in North America: scientific schools or research schools. Typically, the work of the founder of a scientific school is explored there, in his institution, and the work of his disciples, formed by him within that institution, and disseminating his «paradigm» to other institutions [see for instance COLEMAN/HOLMES 1988, GEISON/HOLMES 1993].

As these research directions in institutional studies exemplify, the historiography of science has adopted methodological approaches and standards from sociology of science and from history itself as well, and is thus achieving considerable progress in understanding history of science.

Implementation in History of Mathematics

Remarkably enough, an analogous implementation in mathematical historiography occurs on a comparatively lower level.

A great number of institutional studies in mathematics is still published at the occasion of some anniversary. One might attribute it to the often solemn character of the occasion that an analogous critical spirit as for history of science does not likewise prevail. But it seems also to be due to the relatively smaller number of historians for mathematics and to their being less frequently introduced to, and less familiar with modern methods of historiography that they largely continue to give descriptive collections of data without structural analysis. Since anniversaries tend to express a success of the respective institution, they sense no need for reflecting the institution's position in embedding

contexts or changes which mathematics might have undergone within that institution. Mathematics is rather seen as a constant.

To give an example: When, as in a book published in 1996, the history of mathematics at a German (Catholic) university over the 500 years from 1492 on is presented, one expects a methodological discussion about such a long-term endeavour and in particular about structural changes of the entire institution and of its constituent parts. Instead, even such a basic entity as the professor for mathematics is presupposed to remain identical. This results, among others, in using the term «Ordinarius» (full professor, chair) indiscriminately over all the different periods - even for the Jesuit dominated period where the arts faculty was reduced to a college[2].

Where one has centers for historical studies which permit continuity in maintaining and in developing scholarly standards, one can observe a concentration of efforts favoring methodologically innovative research. A telling example is provided by the history of science center in Zaragoza, where an impressive number of studies exploring the instutional history of mathematics in Spain has been published over the last decade [see for instance: AUSEJO 1993, AUSEJO/MILLÁN 1993, VEA MUNIESA 1995, VELAMAZÁN 1994].

To achieve even more sensible increase in methodological consciousness, it is imperative to implement *functional analysis* as basic historiographical dimension. No institution exists *per se*; they all serve definite *functions*. Since there were almost never institutions exclusively devoted to mathematics, this discipline always had to coexist with others. One has therefore not only to consider the functions of the frame institutions, but also the function of mathematics with regard to other, probably competing and rivalling disciplines. In fact, for the longest periods of its existence, mathematics had no independent function in formative processes, but rather an auxiliary or propaedeutic function.

Thus one has to analyse which consequences the propaedeutic function implied for the rôle of the mathematicians within the respective institution, say a university. In general, it implied a universalist stance, and no scholarly specialisation. It is therefore necessary to overcome the illusion of institutional and disciplinary autonomy. To put it otherwise: it is not of merely peripheral interest for institutional histories which type of teaching had to be delivered - thus, whether there existed a separate and complete course of studies leading to a graduation enabling a professional career, or whether the teaching consisted

in courses aiming at a general formation of students who either majored in an entirely different subject - say law or medicine - or an applied one, like physics, or engineering.

Institutions can hence embody a broad range of different functions - from a specialised formation leading to a related professional career, diverse propaedeutic functions, to so-called polytechnical functions. Clearly, the respective dominating teaching function will have a formative impact on the mathematicians' view of their discipline, on their methodological predilections, and in general on the orientation of their research. This the more, as the type of research pursued uses to be induced or favoured by the institutional context.

A revealing example for this kind of indirect interaction is given by the emergence of pure mathematics in the neohumanism-dominated Prussian universities of the first half of the nineteenth century [cf. SCHUBRING 1981]. Moreover, in all institutions which are not mono-disciplinary but embrace several disciplines - which is the general case - , there is no mere addition of disciplines, rather there functions a «concert» of disciplines, even with some leading or «directing» discipline, which influences teaching and research orientations of the other disciplines. Think of classical philology, the leading discipline in nineteenth century Germany, but now entirely marginalised, and today of, say, biotechnology at the top of the hierarchy.

A few studies should be mentioned which exemplify the outlined approach of functional analysis. In an essay published in 1989, I exposed and applied this approach for the first time to studying the institutional development of nineteenth century Germany [SCHUBRING 1989b]. This development was analysed by exploring two different pairs of opposite pôles: first, universities versus technical colleges on the institutional level - the mathematical courses in the philosophical faculties prepared the students for a professional career as teachers of mathematics, whereas those offered at techncal colleges did not, they were solely designed as preparatory courses for engineers and technicians. The second pair meant a geographical-cultural level: the northern German, and in fact Protestant, conceptions of higher learning which enhanced the emergence of pure mathematics versus the southern German and Catholic conceptions wherein mathematics was a subordinate discipline so that it became more favored in technical contexts. The study showed how these opposing conceptions affected the institutionalisation of mathematics within the different educational subsystems constituted by the

then multiple independent German states. The new element disturbing the monopoly of the university system was the rise of polytechnical schools: they started out as secondary schools in the 1820s/1830s and achieved the status of technical colleges already in the last third of the nineteenth century. As a consequence of this rise, the fundamental rôle of mathematics within their curriculum was challenged. It was Felix Klein who attempted to master this growing crisis for mathematics. The evolution and the changes of his programme for reorienting mathematics and mathematics education were examined, and an important hitherto unknown document of 1900 discussed and documented which showed a new policy addressing consciously the functional relations between the subsystems of secondary schools and the universities and technical colleges. Since Klein's programme implied a revival of applied mathematics, the notion and the reality of applied mathematics was analysed.

In a paper of 1990, this analysis was continued up to 1950, showing in particular the importance of the growing number of teacher students and the subsequent need for intensifying teacher education in mathematics for the evolution of the institutional forms and the differentiation of the staff for emerging different functions in the formation process. The late establishment of a second and parallel course of studies, the Mathematik-Diplom in 1942, envisaged for the first time careers outside the education system, in industry, and thus initiated a radical redefinition of the institution's rationales [SCHUBRING 1990].

In a recent paper, the approach was extended to investigate the differences in institutionalisation of mathematics in the European countries of the eighteenth century as they had been effected by the Protestant Reform and the Catholic Counter-Reform during the sixteenth century [SCHUBRING 2002]. The religious opposition produced two contrary forms of institutionalisation for mathematics: a rather comfortable propaedeutic function in the philosophical faculties of universities in Protestant territories versus a very brief instruction in a secondary school type institution in most Catholic countries.

Perspectives

Looking back at about one hundred and fifteen years of research on the history of institutions, we can observe, over the past twenty-five years, a considerable acceleration in elaborating respective studies and in refinement of

methodology and analysis. It is legitimate hence to look optimistically forward to future developments in this field of research.

NOTES

1. These studies on mathematics at the universities of Gießen (1934, 1937), Marburg (1953), and Münster (1934-1937) presented accumulations of biographical information rather than a structured analysis.
2. See my review of this book [SCHUBRING 1998].

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