Available online at www.sciencedirect.com
ScienceDirect
Historia Mathematica 36 (2009) 395–404
HISTORIA MATHEMATICA
www.elsevier.com/locate/yhmat

# Computing devices, mathematics education and mathematics: Sexton's omnimetre in its time

Peggy Aldrich Kidwell

*Curator of Mathematics, National Museum of American History, Smithsonian Institution, MRC 671, P.O. Box 37012, Washington, DC 20013-7012, USA*

Available online 8 October 2009

**Abstract**

Material objects can tell us much about mathematical practice. In 1899, Albert Sexton, a Philadelphia mechanical engineer, received the John Scott Medal of the Franklin Institute for his invention of the omnimetre. This inexpensive circular slide rule was one of a host of computing devices that became common in the United States around 1900. It is inscribed "NUMERI MUNDUM REGUNT". In part because of instruments such as the omnimetre, numbers increasingly ruled the practical world of the late 19th and early 20th century. This changed not only engineering, but mathematics education and mathematical work.
Published by Elsevier Inc.

**Résumé**

Les objets matériels peuvent nous dire beaucoup sur la pratique mathématique. En 1899, Albert Sexton, un ingénieur de Philadelphie, a reçu la John Scott Medal du Franklin Institute pour son invention de l'omnimetre. Cette régle á calcul circulaire, peu coûteux, a été l'un des objets pour calculer qui est devenue commune dans les États-Unis vers 1900. Il est inscrit: "NUMERI MUNDUM REGUNT". Les instruments comme l'omnimetre ont encouragé l'usage des chiffres dans la vie pratique. Cela a changé non seulement de l'ingénierie, mais l'enseignement de la mathématique.
Published by Elsevier Inc.

*MSC:* 01A55; 97U70

*Keywords:* Sexton omnimetre; Slide rule; Numerical analysis; Albert Sexton; Joseph Lipka

Historians of mathematics generally base their accounts on printed documents, manuscripts (occasionally in the form of clay tablets or papyri), or, for more recent work, oral histories. When little or no other evidence is available, as in the case of the Inca quipu, they may look at physical objects [Ascher and Ascher, 1981]. Objects are also important for

*E-mail address:* kidwellp@si.edu

0315-0860/$ - see front matter Published by Elsevier Inc.
doi:10.1016/j.hm.2009.06.001

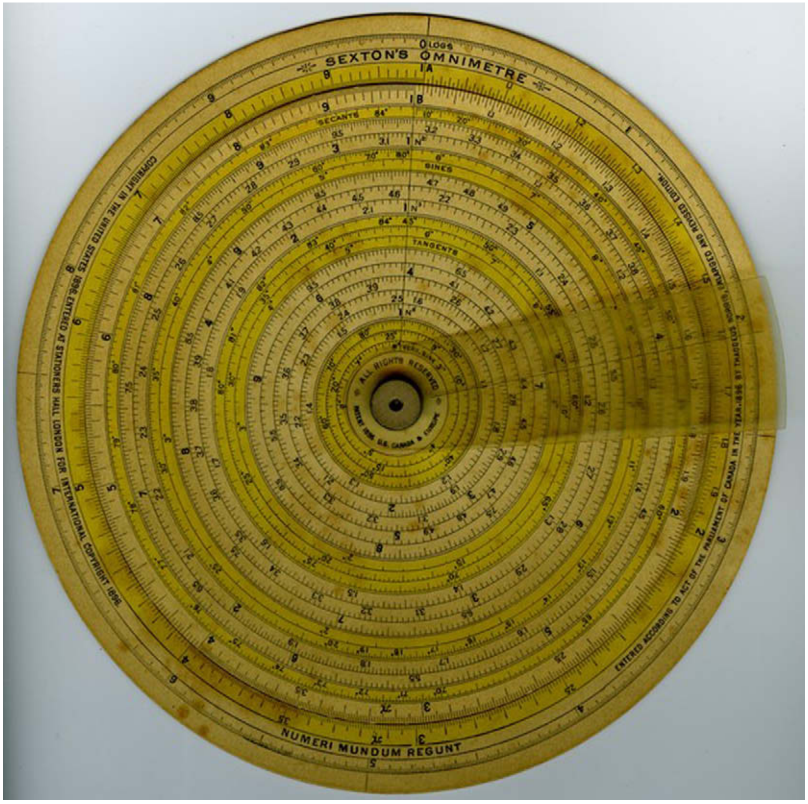



Fig. 1. Sexton's omnimetre, National Museum of American History, Smithsonian Institution.

understanding the cultural role of mathematics in periods when written materials are available. A slide rule invented by Albert Sexton of Philadelphia in the 19th century well illustrates this principle. This humble object offers an introduction to the world of aids to arithmetic that shaped and reshaped not only American engineering around 1900, but also the activity of mathematicians. Sexton's circular slide rule, which he called an omnimetre, is shown in Fig. 1. It has a paper base and inset rotating disc, with a celluloid rotating indicator. The omnimetre, as its name suggests, was designed to carry out numerous operations of arithmetic and trigonometry. It has scales for multiplication, division, and common logarithms, as well as squares, cubes, and fifth powers of numbers. Trigonometric scales are for sines, tangents, secants, and versed sines (the versed sine of an angle $q$ is $1 - \cos q$).

The history of the slide rule contradicts the easy assumption that once people envision a way to put mathematical principles to work, the new applications are quickly and widely adopted. In 1614, the Scottish nobleman John Napier published his discovery of logarithms [Napier, 1614]. These functions reduce the multiplication and division of numbers to the addition and subtraction of logarithms of numbers. Tables of logarithms were soon published. In the 1620s, British and French authors suggested that adjacent rules marked with scales divided logarithmically could be used to perform calculations.

Both circular and linear slide rules were made from the 17th century. However, the instrument diffused only slowly, in the context of specific applications. Eighteenth century British customs agents had gauger's rules to compute the volume of barrels, and hence excise taxes (Fig. 2). Loggers had carpenter's rules to calculate the volume of the timber in logs of dif-

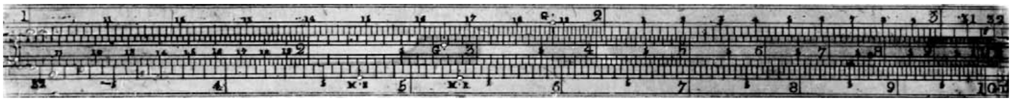


Fig. 2. Gauger's four-sided slide rule by Cook, London, about 1830; Smithsonian Institution negative number 80-17936.

fering size (Fig. 3). Late in the century, James Watt and Matthew Boulton introduced a more general "engineer's rule" for use in calculations relating to steam engineering. French scholars found out about the instrument after the Napoleonic Wars. In 1850, Amadée Mannheim introduced a modified engineer's rule for students at the École Polytechnique. Keuffel and Esser Company of New York (K & E) began importing such slide rules into the United States in 1880. Fig. 4 shows a French engineer's slide rule sold by K & E. In 1881, the American civil engineer Edwin Thacher patented a cylindrical slide rule that was known, logically enough, as the Thacher calculator (Fig. 5). It soon was in use at engineering schools such as Dartmouth College, and in the offices of entrepreneurs such as George Westinghouse. Over the next two decades, slide rules came to be widely owned by engineers, scientists, and other calculating people in both the United States and Europe. Most of these instruments were linear slide rules that were made from plastic and fine wood, with glass and metal runners [Cajori, 1909; Kidwell et al., 2008, 105–122; von Jezierski, 2000].

The success of the slide rule and other aids to computation brought with it numerous changes. Computation, once considered a purely intellectual activity, became a mechanical task. Mathematical analysis played a larger role in business, engineering and the social sciences [Porter, 1986; Yates, 2005]. Ownership of computing devices, especially slide rules, became a symbol of technical competence. A handful of professors teaching subjects that included mathematics, surveying, mechanical engineering, and physics began to teach use of the slide rule in the nineteenth century. By the 1920s, providing routine instruction in the slide rule was a task for college mathematics departments. The topic gradually diffused

Fig. 3. Carpenter's rule by S.A. Jones & Co., Hartford, Connecticut, 1842; Smithsonian Institution negative number 2004-40575.

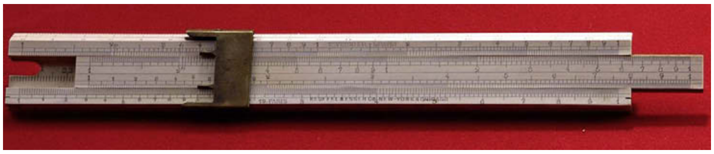


Fig. 4. Slide rule made by Tavernier-Gravet and sold by Keuffel and Esser, 1890s; Smithsonian Institution negative number 2003-26092.

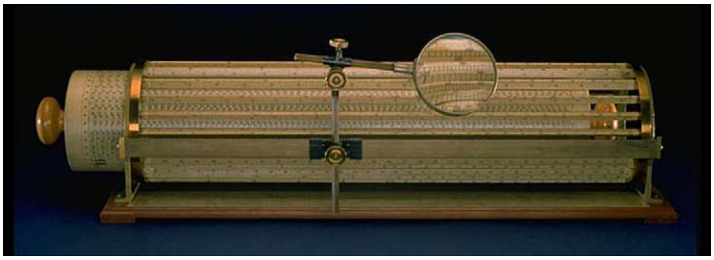


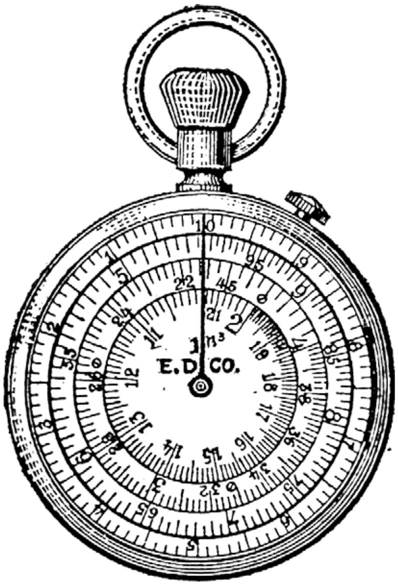
Fig. 5. Thacher cylindrical slide rule, about 1914; Smithsonian Institution negative number 89-13283.

into the curricula of high schools and even junior high schools [Kidwell et al., 2008, 119–122].

The story of Sexton's omnimetre offers a window into the interaction between people, instruments, and ideas that transformed the slide rule into a common technical tool. The tale begins with a few throwaway comments in a speech at the Franklin Institute in Philadelphia in May of 1891. The speaker was the distinguished mechanical engineer and Philadelphia native Coleman Sellers. He spoke about the international effort to generate and transmit power from Niagara Falls. Sellers described in detail meetings relating to this project that he had attended in London and hydraulic works he had visited in Europe. At the close of his address he commented on the widespread use of slide rules by the engineers he had met in both Britain and Europe. One of them had told him that "everybody should learn to calculate by the rules of arithmetic, but as soon as they got hold of a machine to do their work for them, they had better forget the rules learned at school." Sellers especially recommended the slide rule to starting engineers "for it is easier to learn to use them while young than later in life." [Sellers, 1891, 53] He described several forms of slide rule, and showed a pocket-sized circular version of the device designed by Alexandre Emile Marie Boucher, an employee of a French ship repair and building company (Fig. 6). Boucher patented his instrument in 1876. In addition to the pocket-sized device shown, he made a larger circular slide rule for the office. Both instruments included logarithmic scales for multiplication and division on one side, and scales of sines and tangents on the other [Otnes, 2003, 43–48]. Sellers demonstrated how the instrument could be used to solve a simple problem arising in the design of engines.

Sellers's talk was published in the July 1891 issue of the *Journal of the Franklin Institute*. Another Philadelphia engineer, Albert Sexton (born about 1840, died about 1915),[1] read the article and promptly set out to learn more about slide rules. He soon decided that he

[1] Sexton's birthdate is estimated from records of the 1900 and 1910 U.S. Census for Philadelphia. His date of death is estimated from the fact that he was not included in the 1920 census.




1797.

Fig. 6. Boucher calculator, as shown in *Catalogue & Price List of Eugene Dietzgen Company*, 1904, p. 174. Image courtesy Smithsonian Institution.

could design a much less expensive slide rule than those then available for sale. He even could include a larger range of mathematical functions. Sexton drew the scales for the two discs of his instrument on tracing paper, had blueprints made from these drawings, and using a suspender button for a pivot and a piece of celluloid with a line on it for a runner, succeeded in making what he called a "quite useful and inexpensive slide rule" [Franklin Institute, 1898–1899, A. Sexton to W.H. Wahl, November 28, 1898].

Like many entrepreneurs, Sexton launched his new product by giving away free samples. He provided slide rules to gentlemen in the drawing room of the Southwark Foundry and Machine Company, a local steam engine manufacturer. The instrument particularly pleased Belgium-born civil engineer Arthur Marichal. He wrote on his example "Sexton's omnimetre" and added the Latin motto "NUMERI MUNDUM REGUNT". The view that numbers rule the world was shared by many numerate people in the nineteenth century, most notably the pioneering Belgian statistician Adolphe Quetelet (1796–1874) and his admirers [Quetelet, 1828, title page, 233; Cohen, 1982; Porter, 1986, 45]. No direct connection between Marichal and Quetelet has been found, although both shared in a heritage of French engineering that espoused great faith in numbers [Porter, 1991]. Sexton adopted both the name and the epigram from Marichal.

Sexton also paid careful attention to details relating to the production of the omnimetre. Most previous slide rules had a wooden base, but he found that waterproof Bristol board was both cheaper than wood and less sensitive to changes in temperature. To engrave the plates used in printing the instrument, he constructed a special circular dividing engine, using "a wheel and worm made by one of the best astronomical instrument makers in the country" [Franklin Institute, 1898–1899, Report #2017, 9]. He calibrated the engine to produce the logarithmic divisions needed for the slide rule scales. Such specialized dividing engines were rare. For example, Thacher initially relied on an English maker to divide the scales for his calculator.

Sexton also found a business partner, Franklin Institute member and self-styled "gentleman" Thaddeus Norris. Norris was to pay all outside bills, attend to correspondence not requiring mathematical treatment, and share in half the profits [Franklin Institute, 1898–1899, A. Sexton to W.H. Wahl, November 28, 1898]. Mathematical methods, such as computation using Sexton's arrangement of scales, were not patentable in either the United States or abroad. However, original works, including mathematical instruments, could be copyrighted.[2] Norris took out copyrights on the omnimetre design in the United States, Canada, and Great Britain. Moreover, he patented an improvement in the method for rotating the upper disc of a circular slide rule [Norris, 1895]. By 1898, the partners had arranged for the Philadelphia firm of Theodore Alteneder and Sons to manufacture the instrument. Unfortunately, Norris died that August, leaving Sexton and Alteneder to carry on the work [Franklin Institute, 1898–1899, E.V. Wurts to W.H. Wahl, May 18, 1898; Washington Post, 1898].

The omnimetre came in several forms that differed in size, the scales included, the kind of paper used, and the material of the runner. More expensive versions included holes in the lower disc that made it easier to rotate the disc atop it. This use of perforations was what Norris had patented. At least four forms of omnimetre were actually offered in instrument catalogs of the early twentieth century, although the "improved third edition" seems to have been the only one to sell in later years. On it, the instrument shown in Fig. 1, the upper disc fits into a recess in the lower disc, so that all the scales are in one plane. The outermost scale, on the rim of the instrument, gives logarithms of the numbers immediately inside. The inner rim scale and the outermost scale on the rotating disc are for numbers, with the scale divided logarithmically for use in addition and multiplication. Moving inward, light-colored scales are for squares, cubes, and fifth powers of numbers. Scales in the yellow regions are for trigonometric functions, including, as one goes inward, secants, sines, tangents, and versed sines. A 1905 catalog lists prices ranging from one dollar to three dollars for different forms of omnimetre [Alteneder, 1905, 105]. By 1940, the "improved omnimetre No. 3" sold for $4.00 [Alteneder, 1940, 37].

Sexton had succeeded in designing a slide rule that was less expensive than its competitors. In 1904 the metal form of the pocket-sized Boucher calculator sold for $14 and a paper form for $8.50 [Dietzgen, 1904, 174]. These instruments might look more elegant, but lacked many of the scales of the omnimetre. Ten-inch slide rules of wood and plastic commonly used by students cost about $5 and lacked trigonometric functions. Perhaps inspired by Sexton's example, dealers soon offered student slide rules with scales printed on paper. This paper might be stiff cardboard or thin sheets that were then pasted on wood. These slide rules cost only about a dollar [Dietzgen, 1904, 173–174].

Sexton sought recognition for his instrument from the Committee on Science and the Arts of Philadelphia's Franklin Institute. At the time, this committee reviewed descriptions of inventions, judging whether they appeared to be useful and practical. Inventors whose work contributed significantly to the "comfort, welfare and happiness" of humanity received a special prize, the John Scott Medal [Fox, 1968, 416–430]. In May 1898 Sexton requested a review of his omnimetre. A subcommittee appointed to look at the omnimetre examined it carefully, quizzed Sexton about precisely what he had done and what credit should be assigned to Norris, and deemed the invention worthy of a John Scott Medal.

[2] The Keuffel and Esser *Catalogue* for 1909, for example, lists a variety of metal, hard rubber, and wooden instruments for which the firm held copyrights [Keuffel and Esser, 1909, 167, 168, 205, 228].

Sexton, along with six other inventors, received the prize in 1899. He was the first winner to be honored for an improvement in slide rules. Surviving correspondence relating to this award is the major source relating to the history of the omnimetre [Franklin Institute, 1898–1899].

The omnimetre did not make a major impression on American mathematicians or scientists. Edwin Hoyt Lockwood, an instructor in mechanical engineering and descriptive geometry at Yale University, spent the summer of 1895 working at Southwark Foundry & Machine Company, the Philadelphia firm where Marichal worked and Sexton's omnimetre received its name [Yale University Sheffield Scientific School Class of 1888, 1898, 52–53]. Lockwood mentioned the instrument in an article on the slide rule he later wrote for the *Yale Scientific Review*, but he devoted most of his attention to linear slide rules [Lockwood, 1898, 47]. The omnimetre was discussed in detail by U.S. Navy commander Urban Tigner Holmes in a book entitled *Experimental Engineering* which he prepared for midshipmen at the U.S. Naval Academy in 1911 [Holmes, 1911, 18–26]. At least two surviving examples seem to have been used in the design of ships. The first instrument was the property of Andy MacLachlan of the Sun Shipyard in Chester, PA. [Lovett, 2009]. The second is the Sexton omnimetre shown in Fig. 1, which George A. Dankers recently donated to the Smithsonian Institution. Dankers, a naval architect, acquired his omnimetre when he joined the U.S. Navy's Preliminary Ship Design Branch in 1938. He used it for 30 years, in computations relating to watercraft ranging from small, fast attack vessels (known as PT boats) to aircraft carriers [NMAH, 2008].

At the same time the omnimetre found a niche in naval architecture, educators and mathematicians found roles for the slide rule in mathematics education. The slide rule found a place in university courses on computation, in school mathematics, and in college mathematics clubs. Each of these roles merits brief mention.

Courses in computational techniques seemed particularly important in an age when the interpretation of vast amounts of quantitative data challenged not only scientists and engineers, but social scientists, businessmen, and government bureaucrats. It was an era when, as the omnimetre said, numbers ruled the world. The need to reduce data had not only encouraged the improvement and diffusion of the slide rule but created a market for other relatively new instruments such as the commercial calculating machine, the integrator, and the harmonic analyzer. In a 1911 Ph.D. dissertation written in the Department of Mathematics of the University of Chicago, Theodore Lindquist examined mathematics teaching for freshmen at over 100 engineering schools. He commended four schools that had introduced courses in computation that included instruction on the use of calculating instruments. Lindquist also polled several hundred mathematics teachers and engineers, eliciting opinions about what should be taught to freshman engineers. Somewhat over one-third of those who replied favored a course in computational techniques, while about a fifth of them were opposed. Both those in favor of the course and those opposed were concerned about fitting more material into the crowded academic schedule of engineering students [Lindquist, 1911, 61–63, 67–70, 85–86].

One of the most ambitious courses in computation offered for engineers was introduced not long after Lindquist completed his dissertation. In the summer of 1913, the Polish-born mathematician Joseph Lipka (1883–1924) of MIT visited the Mathematical Laboratory recently established by Edmund T. Whittaker, professor of mathematics at Edinburgh University [Martin, 1958, 1–10; Warwick, 1995, 338–340]. Impressed by what he saw, Lipka persuaded MIT officials to set up a similar institution. In the fall of 1914, the MIT mathematics department began offering a "Mathematical Laboratory" that met two hours a week. This was to be

> A course for practical instruction in numerical, graphical and mechanical calculation and analysis as required in the engineering or applied mathematical sciences. The course will include: methods for checking the accuracy of arithmetic and logarithmic computations; numerical solution of algebraic, transcendental and differential equations; graphical methods in the processes of arithmetic, algebra and the calculus; curve fitting to empirical data; the use and principles of construction of instruments employed in calculation, such as slide rules, arithmometers, planimeters and integraphs; and many kindred topics [Massachusetts Institute of Technology, 1914–1915, 397].

Descriptions of the course from later years mention such related areas as nomography and the construction of graphical charts, as well as approximate methods of differentiation and interpolation. This course in numerical methods was not required by most departments at MIT, although it still drew a large number of students [Wiener, 1924, 63]. Lipka also wrote a book, *Graphical and Mechanical Computation*, which described a wide range of slide rules and computing devices, including the omnimetre [Lipka, 1918, 16–19].

A second, much more elementary course taught by Lipka was more typical of university instruction. In the academic year 1917–1918, he began offering an elective course of four exercises for first semester freshmen that provided them with a basic introduction to the slide rule. These lectures became, to use the words of Lipka's colleague Norbert Wiener, "a landmark of the Institute" [Wiener, 1924, 64]. It seems likely that the instrument introduced was a simple linear slide rule, not a circular one [Massachusetts Institute of Technology, 1917–1918, 348]. The mathematics laboratory course continued to be offered by the MIT mathematics department even after Lipka's untimely death in 1924. However, the focus of the department shifted to preparing students for doctorates in mathematics. Mathematics faculty such as Wiener might advise MIT electrical engineers about the development of sophisticated analog computing equipment such as MIT's network analyzer and differential analyzer, but introducing students to slide rules, graph paper, and new forms of nomogram would not be a major concern of the department [Graustein, 1924, 352–353; Conway and Siegelman, 2005, 52–55].

Indeed, most American colleges and engineering schools found little room for computational techniques in their curricula. There was a considerable move to encourage high schools and even junior high schools to offer the instruction in computing devices, particularly an introduction to the slide rule. In a 1902 address as outgoing president of the American Mathematical Society, Chicago mathematician E.H. Moore, urged that high schools be equipped with mathematical laboratories. Apparatus in the laboratory would include not only geometric models and drawing instruments, but a slide rule [Moore, 1903, 418]. By 1923, a report of the National Committee on Mathematical Requirements (NCMR) of the Mathematical Association of America could describe several schools that included instruction in the slide rule in their curricula. Writing on "optional topics" that might be included in grades 7, 8, and 9 of secondary school, the committee reported that it looked with favor on efforts "to introduce earlier than is now customary certain topics and processes which are closely related to modern needs, such as the meaning and use of fractional and negative exponents, the use of the slide rule, the use of logarithms and of other simple tables..." [MAA NCMR, 1923, 27; Roberts, 1997, 367–391].

As the slide rule became ubiquitous, mathematicians published and spoke on the topic. Some, like John P. Ballantine of the University of Washington and Maurice L. Hartung of the University of Chicago, wrote manuals for slide rule manufacturers [Ballantine, 1931; Hartung, 1947]. Others, most notably Florian Cajori of the University of Chicago, explored the history of the instrument. Cajori's *History of the Logarithmic Slide Rule* has been republished many times, and is still used by historians today [Cajori, 1909]. In the 1920s, when Cajori's work was well known and mathematics majors knew their slide rules, talks on the history of the instrument became a standard of college mathematics clubs in the United States. The slide rule—if not the omnimetre—would remain a part of school and college mathematics teaching until the introduction of inexpensive hand-held electronic calculators in the mid-1970s.

In summary, late 19th century American enthusiasm for improvement, combined with vast quantities of accumulated data and wider technical education, prompted the development and introduction of several new forms of slide rule in the United States. Logarithmic scales were arranged not only on linear rules, as was most common, but on cylinders and in flat spirals on circular discs. Promoters vied to produce instruments at low cost with scales for both arithmetic and trigonometric functions. Sexton's omnimetre well illustrates this ambition. Though never a widely used product, it sold successfully for sixty years [Alteneder, 1958, 36] and was part of a modest expansion in the use of computing devices in mathematics education. University courses in computational techniques, courses for freshmen entering college in technical areas, and even high school and junior high school mathematics classes came to include the slide rule. Students planning advanced scientific and technical work, including mathematicians, learned to use slide rules in school. They often reviewed the subject in the first year of college mathematics and might hear of the history of slide rules at an extracurricular meeting. Some, such as George Dankers, continued to use some form of slide rule for the rest of their careers.

Numbers seemed to rule the world in the late 19th and early 20th century. However, the very introduction of slide rules and more powerful computing tools increasingly made arithmetic seem a mechanical process best left to machines. In the 17th century, eminent mathematicians like Johannes Kepler concerned themselves with the mundane calculations needed for their work and welcomed the advent of new computational techniques such as logarithms. By the 20th century, those who took an interest in mechanical computation focused on devices far more complex than the slide rule.

**References**

Alteneder, T., 1905. Drawing Instruments. Theo. Alteneder & Sons, Philadelphia.

Alteneder, T., 1940. Alteneder Drawing Instruments. Theo. Alteneder & Sons, Philadelphia.

Alteneder, T., 1958. Alteneder Drawing Instruments. Drafting Scales, Stainless Steel T-Squares, Stainless Steel Triangles Stainless, Steel Straightedges. Theo. Alteneder & Sons, Philadelphia.

Ascher, M., Ascher, R., 1981. Code of the Quipu: A Study in Media. Mathematics and Culture. University of Michigan Press, Ann Arbor.

Ballantine, J.P., 1931. The MacMillan Table Slide Rule. MacMillan, New York.

Cajori, F., 1909. History of the Logarithmic Slide Rule. The Engineering News Publishing Company, New York.

Cohen, P.K., 1982. A Calculating People: The Spread of Numeracy in Early America. University of Chicago Press, Chicago and London.

Conway, F., Siegelman, J., 2005. Dark Hero of the Information Age: In Search of Norbert Wiener the Father of Cybernetics. Basic Books, New York.

Dietzgen, E., 1904. Catalogue and Price List of Eugene. Dietzgen Co., Dietzgen, Chicago and New York.

Franklin Institute, 1898–1899. Case 2017, Records of the Committee on Science and the Arts of the Franklin Institute, Philadelphia.
Fox, R., 1968. The John Scott Medal. Proceedings of the American Philosophical Society 112, 416–430.
Graustein, W.C., 1924. The scientific work of Joseph Lipka. Bulletin of the American Mathematical Society 30, 352–356.
Hartung, M.L., 1947. How to Use the Deci-Log Log Slide Rule. Pickett & Eckel, Chicago.
Holmes, U.T., 1911. Experimental Engineering. U.S. Naval Institute, Annapolis, MD.
Keuffel and Esser, 1909. Catalogue of Keuffel and Esser Co., Keuffel and Esser Company, New York.
Kidwell, P.A., Ackerberg-Hastings, A., Roberts, D.L., 2008. Tools of American Mathematics Teaching, 1800–2000. Johns Hopkins University Press, Baltimore.
Lindquist, T., 1911. Mathematics for Freshmen Students of Engineering. Ph.D. Dissertation. University of Chicago, Chicago.
Lipka, J., 1918. Graphical and Mechanical Computation. Wiley and Sons, New York.
Lockwood, E.H., 1898. The Slide Rule. Yale Scientific Monthly 5, 39–47.
Lovett, R., 2009. Rod Lovett's Slide Rules. Available from: <http://sliderules.lovett.com/omnimetre/omnimetrepics.htm> (accessed 15.01.09).
Martin, A., 1958. Sir Edmund Whittaker, F.R.S. Proceedings Edinburgh Mathematical Society Series 2, 11, 1–10.
Mathematical Association of America, National Committee on Mathematical Requirements, 1923. The Reorganization of Mathematics in Secondary Education. Mathematical Association of America (no place).
Massachusetts Institute of Technology, 1914–1915. Annual Catalogue, Cambridge, MA.
Massachusetts Institute of Technology, 1917–1918. Annual Catalogue, Cambridge, MA.
Moore, E.H., 1903. On the Foundations of Mathematics. Bulletin of the American Mathematical Society 9, 402–424.
Napier, John, 1614. Mirifici Logarithmorum Canonis Descriptio. A. Hart, Edinburgh.
NMAH, 2008. Non-accession File 2008.3041. National Museum of American History, Smithsonian Institution, Washington, DC.
Norris, T., 1895. Marker for Slide Rules. US Patent 540184.
Otnes, B., 2003. The Boucher Style Pocket Calculator. Journal of the Oughtred Society 12, 43–48.
Porter, T.M., 1986. The Rise of Statistical Thinking 1820–1900. Princeton University Press, Princeton.
Porter, T.M., 1991. Objectivity and authority: how French engineers reduced public utility to numbers. Poetics Today 12, 245–265.
Quetelet, A., 1828. Instructions populaires sur le calcul des probabilities. H. Tarlier and M. Hayez, Brussels.
Roberts, D.L., 1997. Mathematics and Pedagogy: Professional Mathematicians and American Educational Reform, 1893–1923. Ph.D. Dissertation. Johns Hopkins University, Baltimore.
Sellers, C., 1891. The utilization of the power of Niagara Falls and notes on engineering progress. Journal of the Franklin Institute 132, 30–53.
von Jezierski, D., 2000. Slide Rules: A Journey through Three Centuries (R. Shepherd, Trans.). Astragal Press, Mendham, NJ.
Warwick, A., 1995. The laboratory of theory or what's exact about the exact sciences. In: Wise, M.N. (Ed.), The Values of Precision. Princeton University Press, Princeton.
Washington Post, 1898. Death of Thaddeus Norris, August 20, p. 7.
Wiener, N., 1924. In memory of Joseph Lipka. Journal of Mathematics and Physics 3, 63–65.
Yale University Sheffield Scientific School. Class of 1888, 1898. [Decennial Record], [np], New Haven.
Yates, J., 2005. Structuring the Information Age: Life Insurance and Information Technology in the Twentieth Century. Johns Hopkins University Press, Baltimore.