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Integrating Technology, Science, and Math at Napoleon's School for Industry, 1806-1815

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In my research on the history of teaching technology in schools, I came across the following account of the Marquis of Worcester's demonstration of the power of steam in 1663. Worcester filled a cannon three-quarters full of water, sealed its end, and then built a fire under it for 24 hours, thus "causing the cannon to explode with a loud noise" (Bossut, 1786-1787, pp. 488-9). This story was recounted by the author of one of the books listed in the curriculum of 1807 at the School of Arts and Crafts of Châlons-sur-Marne in France (hereafter school).[1] The author used Worcester's experiment to illustrate his scientific analysis of fluids and flow (hydrodynamics). Steam engines (and explosions) were undoubtedly of interest to many of the students, who spent most of their time building "real-world" artifacts in the school's shops and two or three hours per day studying drafting, math, and science in classrooms.

In the shops students made a variety of products ranging from basic hardware, files, and furniture to textile machines, scientific instruments, and clocks. From 1808 to 1815 about half of the older students manufactured caissons consisting of interchangeable parts for Napoleon's artillery—the most advanced form of manufacturing at the time. Not surprisingly, the management of some four hundred students, ranging in age from about eight to twenty years old, was a significant challenge. But added to that challenge was the goal of integrating and teaching theory and practice: practice interpreted as shopwork on marketable products according to the drawings and specifications of the director of instruction; and theory viewed as a combination of descriptive geometry, drafting, math, and science. Since that time, the school of Châlons spawned seven more Schools of Arts and Crafts which are now highly regarded schools of engineering that produce about a thousand engineers a year—the largest source of engineers in France (e. g., Ecole Nationale Supérieure d'Arts et Métiers, 1998; Day, 2001).

In this article, I intend to show that the school of Châlons forms an important chapter in the history of technology education. But why is history important for the field of technology education? In 1997 Hill and Hepburn reviewed a new book in this journal called *Changing the subject: Innovations in*

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science, mathematics and technology education. This book, they claimed, depicted technology “as a subject without a history,” suggesting that “in the absence of a more developed history and description, it is difficult to assess the validity of some of the claims that the authors make concerning technology education” (p. 77). The implication here is that the lack of a history of the field contributes to ambivalence among many educators about the place of technology education, its importance, and external evaluations made about the field. In this sense, historical research has a practical side. This article focuses on a particular area of the history of technology education — the integration of technology with math and science.

The integration of technology with science and math has been the subject of research in technology education (for a summary, see LaPorte & Sanders, 1995). Daugherty and Wicklein addressed “perceived integration needs of mathematics, science, and technology education” (1993, p. 38-39). Foster (1994), in one of the most critical analyses of such integration, raised many questions and issues but did not include a historical perspective. In 1996 Childress researched the problem: “Does integrating technology, science, and mathematics improve technological problem solving?” (pp. 16-26). A study by Petrina showed that science and math occupied first and second place out of 24 content areas in terms of their alignment with technology in the content of the *Journal of Technology Education* (1998, pp. 35; 39). In a recent study on how teacher attitudes towards various aspects of teaching technology have evolved, Sanders noted that “the application of science and mathematics was essentially ignored in industrial arts education, ranking last in both 1963 and 1979, but ranked fourth (of 16 purposes) in this study. In practice, however, coordinating technology education with mathematics and science teachers is still relatively rare” (2001, p. 45). Merrill claimed that “the integration of technology, mathematics, and science education has been gaining attention . . .in recent years” (2001, p. 45). In contrast, the low profile of science and math in the new *Standards for Technological Literacy* has resulted in relatively weak guidance for such integration (International Technology Education Association [ITEA], 2000).

Integration: Physical, Conceptual, Social, and Political

This paper focuses on one of the earliest attempts to integrate technology with science and math in a school. After the French Revolution eliminated trade guilds in 1792, subsequent French governments in the 1790s introduced a variety of forms of technological education to compensate for the demise of apprenticeship systems (Artz, 1966; Léon, 1968). In this regard, France led the way in introducing instruction in technology into schools — a difficult challenge because it involved reconceptualizing, articulating, and combining heterogeneous elements in new ways. In this article I use four analytical categories: (a) physical; (b) conceptual; (c) social; and (d) political. These four analytical categories are not mutually exclusive and should thus be considered as overlapping layers, however without the hierarchy implied by layers.

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Napoleon's government addressed the integration of *physical* tools at Châlons by converting a former convent to classrooms and shops, including a waterpowered sawmill. School leaders attempted to integrate *conceptual* tools such as the elements of math, science, and technology as represented in textbooks. There were various science books available, though not written specifically for a school of theory and practice. Even fewer textual resources existed for teaching the elements of technological knowledge. In fact, knowledge of the arts and crafts had only recently been systematized and presented in texts on a large scale (e.g., Diderot & d'Alembert, 1751-1772; Académie des Sciences, 1761-1789).

Social integration was just as difficult to achieve as the physical and conceptual. The school's math and science teachers had been trained in classrooms where they had observed scientific demonstrations. In contrast, the shop foremen had learned their trades as apprentices in shops or in related industrial plants such as foundries. Students differed widely in social origins, ranging from the very poor to upper middle classes. The process of integrating school personnel and students from different social positions also involved managing conflicts, as *political* power was renegotiated among groups within the school and with external power groups that included government officials in Paris, customers, and local authorities. (For an analysis of the politics of production and artifacts at the school, see Pannabecker, 2002.)

At the time the phrase "arts and crafts" or simply "arts" referred to many of the activities now referred to as technology. The school of Châlons was created during the early stages of what proved to be a long transition from craft-based societies (with apprenticeship in shops as the instructional model) to technological societies (with school-based instruction). The word "technology" was not yet used widely despite the increasing systematization of design, knowledge, tools, and production. For example, the French artillery had been the leader of interchangeable or "uniform" manufacturing since the second half of the eighteenth century (Alder, 1997). When the students of the school began making caissons, some of the tools of the artillery's system of uniform manufacturing were transferred to the school. The metric system, invented in the 1790s, was also being introduced into the school. In 1807 F.-E. Molard, director of the school shops, referred in his curriculum to a systematic approach to teaching industrial processes as they related to science and math. In the 1820s and 1830s, Molard was one of five main contributors to a 24-volume work entitled *Dictionnaire Technologique* (Francoeur et al., 1822-1835), which included two volumes of drawings of technological artifacts.

The term "mathematics" had a broader meaning than now, often including math, chemistry, and physics. The phrase "mathematical instruments" referred to a variety of artifacts ranging from drafting compasses and protractors to astronomical instruments such as sextants and reflection circles. At first all teachers of math, descriptive geometry, and scientific knowledge at the school were referred to as math teachers, but the school later began to make more distinctions in analyzing and systematizing knowledge. By the early 1820s the

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school had separate courses in the demonstration of machines, algebra, calculus, chemistry, physics, and descriptive geometry (ADM, 1 T 385, Annual Distribution of Prizes, 1822).

The idea of establishing such a school was linked to the Duke de la Rochefoucauld-Liancourt (hereafter Liancourt), who had established a school for military orphans from his regiment on his property at Liancourt north of Paris in the early 1780s. Liancourt, a progressive nobleman who favored liberal ideas and a constitutional monarchy, was a leader of revolutionary France during its early moderate stage. In 1792, however, he fled to England to escape the growing violence of the Revolution and then traveled for four years in the United States visiting schools, industries, and prisons. In 1799 Liancourt returned to France and in 1800, the remnants of his former school at Liancourt were moved to Compiègne, further north of Paris. In 1803, Bonaparte transformed the school into the first School of Arts and Crafts after asking his minister of the interior, Jean-Antoine Chaptal, the best known industrial chemist in France, to establish a committee and draw up regulations.[2] In 1806, Napoleon appointed Liancourt inspector of the school and soon thereafter had the school moved to Châlons (Day, 1987, 1991; Dreyfus, 1903; and La Rochefoucauld, Wolikow, & Ikni, 1980).

Physical Elements of Integration

In order to meet the goal of teaching practice, the regulations stipulated five principal shops: (1) metalwork such as blacksmithing, filing, fitting, and turning; (2) foundry; (3) carpentry and cabinetmaking for furniture and machines; (4) wood turning; and (5) wheelwright (Charmasson et al., 1987, p. 103). Since Parisian bureaucrats admitted students of a very wide range of ages, the staff sought to increase the variety of shops. When Molard drew up his "Plan of Instruction" in 1807 during the first semester at Châlons, he referred to three additional shops: a cotton-spinning shop, which was primarily for the weakest or youngest students, especially those under 12 years of age; a shop for making files; and a forging shop, separate from the fitting shop. He also proposed a ninth shop for teaching decorative patternmaking. A few years later, Molard added shops for making clocks and mathematical instruments, which required more math and science to understand their construction and uses (AN, F17 14327, "Observations préliminaires," [from Liancourt to Bureau], 19 July 1808).

In February of 1807, the municipality of Châlons loaned to the school its collection of scientific instruments, which allowed the teachers to teach at least some of the practical aspects of science in labs (ADM, 1 T 385, Min. Int. to Bourgeois de Jessaint, 6 February 1807). A variety of instruments for the study of physics were included such as a magnet, vacuum pump, Magdeburg globe, Leyden jar, Volta pistols, and a Franklin electrical platform. Instruments for chemistry included a variety of mortars and pestles, stills, tubes, stoves, furnaces, and bellows as well as glassware (ADM, 1 T 385, "Copie de l'Inventaire," 22 July 1818).

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The specified mechanism for integrating technology with math and science was the design and fabrication of products for sale, which in the case of the instrument shop included such components as compass needles, compasses, screws, squares, and parts for cabinets or cases (AN, F12 1085, “Atelier des Instruments de Mathématiques,” December 1808). For example, a letter sent to the General Director of Mines referred to an enclosed "catalogue of astronomical instruments, of Marine, and of Geodesy" made at the school of Châlons (AN, F12 1220, Bureau to Comte Laumond, 7 January 1812). Since the school sold its instruments throughout northern France, they had to meet commercial standards and were at times inspected by some of the top scientific institutions. For example, the school sent drafting sets for inspection to the Ecole Polytechnique (hereafter Polytechnique)—a potential customer and the most elite, theoretical school in France (AN, F12 1220, “Réponse à l’Examen fait à l’Ecole Polytechnique,” 30 May 1812). The school also made instruments for ship navigation and surveying, such as reflection circles as designed by the scientist Charles Borda, with an indexed base and an eyepiece for sighting that pivoted on the base (Borda, 1787). One of the circles made at the school was sent to the Bureau of Longitudes, whose inspection then influenced the quality control of future production (AN, F12 1220, Letter from the Minister to Biot, July 16, 1808; and Report from de Rosily, Rossel, and Beautemps-Beaupré, 20 September 1814).

Conceptual Elements of Integration

The regulations of 1803 for the school stipulated the following theoretical subjects: descriptive geometry, drawing, principles of mechanics, and the nature and properties of materials. The emphasis in teaching these subjects was to be on their practical applications, the details of which were left up to the school staff (Charmasson, et al., 1987, pp. 102-104). But when Molard drew up his “Plan of Instruction” in May 1807 he divided theoretical instruction into four parts: (1) mathematics, (2) drawing, (3) French grammar, and (4) physics and chemistry applied to the arts (AN, F12 1085, "Plan of Instruction," May 14, 1807). Many of the texts that Molard listed for the school were written by teachers associated with Polytechnique but the texts varied considerably in difficulty and in their treatment of practical applications.

In mathematics, Molard included the study of arithmetic, including ordinary fractions and decimal fractions; algebra until equations of the second degree; geometry including conical sections; the application of algebra to geometry; rectilinear trigonometry; descriptive geometry and its applications to the cutting of stones, carpentry, shading, perspective, sundials; and applications of differential and integral calculus to curves. He also listed differential and integral calculus, the application of differential and integral calculus to mechanics and fluids, differential and partial equations, statics, mechanics, hydrostatics, and hydrodynamics. Some of the authors listed included content that was probably quite accessible. For example, Bossut treated all kinds of

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machines, including the account of the Marquis of Worcester's demonstration of the power of steam already referred to above.

Under the category of physics and chemistry applied to the arts, Molard listed the general principles of physics such as the properties of air, water, heat, light, magnetism, electricity; principles and types of measurement, including conversion to the recently invented metric system; and the practical use of thermometers, barometers, pumps, siphons, and steam engines (Haüy, 1803). For chemistry Molard referred to works that included the properties and behavior of the elements as well as compounds such as oils, acids, and oxides; natural causes that modify chemical action; and tools and equipment used by chemists to prepare materials, such as furnaces and distillation equipment (Chaptal, 1807; Fourcroy, 1801). Molard also listed a book on carpentry by J.-H. Hassenfratz, former colleague of the famous chemist Lavoisier and teacher at Polytechnique. Hassenfratz' book was practical, covering the nature and properties of woods such as specific gravity, decay, resistance, and combustibility; strength testing methods; a wide variety of saws driven by water, wind, horses, and steam power; and cost comparisons of the different methods of sawing (Hassenfratz, 1804). Finally, Molard recommended that each teacher use the *Encyclopédie* at the end of each lesson for illustrating the arts. This large compendium with its 17 volumes of text and 11 volumes of plates illustrated and described hundreds of arts and crafts as they existed in the middle of the eighteenth century (see Pannabecker, 1992, 1994, 1998).

One of the key conceptual bridges between theory and practice was descriptive geometry, as invented by Gaston Monge in the late eighteenth century. It was, and still is even today, considered the theory underlying three-dimensional representation. But it was then considered a branch of mathematics. It was not, however, very useful for generating shop drawings quickly nor was it accessible to all of the students. As for drawing, Molard included figure drawing and architectural or plan views of buildings, land plots, and machines. Since the scientists gave considerable attention to the use of drawing as a social means of controlling design and production, I consider drawing here as a bridge to social elements of integration.

Social Elements of Integration

Napoleon hoped that the school would produce a new type of leader for industry; however, there were no clear educational distinctions for training entrepreneurs, industrial engineers, shop foremen, shop managers, or skilled workers. In this regard, the school of Châlons provided a general education in technology, along with reading and writing skills. The emphasis on drawing was unusual in that it served as a means of designing and controlling production and social relationships. The regulations specifically directed the shop director to design and draw the plans for the objects to be fabricated, to show them to the students, and to guide the shop foremen, who were not allowed to make any changes in the drawings without the shop director's permission. Students were

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to participate in this control system of drawing, planning, and estimating by working in the drawing office as draftsmen, calculators, or writers.

Although the director of shopwork was supposed to have a pivotal role in designing and controlling all production, there were practical problems. For instance, Molard noted that the position for a “teacher of physics and chemistry applied to the arts" had not yet been filled (AN, F12 1085, “Plan of Instruction, 14 May 1807). Already at Compiègne, Liancourt had pushed the minister to establish classes in physics and chemistry that would emphasize their relationship to the arts and would be taught by the same teacher. But Molard was too busy to teach those subjects and to manage all shopwork and there was no one else at the school qualified to take his place—a social problem recognized as such by Liancourt:

> It is very natural, perhaps, that the teachers, and I speak particularly of recent graduates in mathematics, for the most part, having distinguished themselves in the best schools, have a passion for their science and the desire to push their instruction as far as they can. But this inclination—very natural in them—ends up actually being an inconvenience for the welfare of the School, which is to teach mathematics to students in their relationships with the arts, and to not create in them a dislike of the work of the arts that are the object of their institution, by a career of sciences of too high a level and too extensive in orientation. (AN F 12 1085, Liancourt’s "Supplementary observations," 12 July 1806)

Both Molard and the head mathematics teacher, Philippe Rouby, were graduates of Polytechnique, but Molard was far more knowledgeable about shopwork than Rouby. Molard had gained practical experience in the artillery in Bonaparte’s campaigns until 1802 and he had taught at the military school for hot air balloons. Moreover, his older brother, C.-P. Molard, was director of the Conservatory of Arts and Crafts in Paris—the foremost institution in France for the advancement of technology (Michaud, Michaud, & Desplaces, 1854-1865, pp. 517-519).

In 1807 Rouby wrote to the minister requesting permission to work in the school shops, which suggested that he was finally responding to Liancourt’s pressure to take a more practical approach in his teaching (AN, F12 1085, Liancourt's "Supplementary Observations," 12 July 1806). Rouby wrote that in view of the goal of teaching to students the mathematics “necessary to the calculation and construction of machines, and to have them perform frequent applications in order to make the theory of the [mechanical] arts as familiar to them as practice, he [Philippe Rouby] has for several years now believed that he should work at the manual tasks necessary to guide himself in the applications of the Theory that he has to teach to the students” (AN, F12 1084, Philippe Rouby to Min. Int., no date, but received by the Ministry on 13 January 1807).

But why did Rouby not simply ask the school’s director Joseph Labâte, Liancourt, or Molard for permission to work in the shops? Not long before moving to Châlons, most of the teachers signed a petition to the minister

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protesting the lack of vacation time as in other schools and requesting a month of vacation (AN, F12 1085, Letter from teachers to Min. Int., 8 August 1806). Although they admitted that they had been told that the school of Châlons was designed to be a different type of school, with little or no vacation periods, they did not agree with the lack of vacations. Rouby's signature is among the dozen and a half names at the bottom of the letter. The next year most of the same teachers protested the elimination of Thursday afternoon holidays typical in other secondary schools (AN, F12 1085, Letter from teachers to Min. Int., 19 June 1807). This controversy continued for a few more years, thus underlining differences in social attitudes between traditional teachers and shop foremen. Later two math teachers claimed that more teachers would have signed the protest letter but instead agreed to write to Liancourt, in his capacity as inspector, "out of fear of being considered informers" (AN, F12 1085, Aboilard and Odet to Min. Int., 14 January 1809). Liancourt responded in a scathing letter in which he severely criticized the teachers for their insubordination and its effects on the students:

> . . . I will repeat what I have already told you many times, that at the School of Arts theoretical instruction is only subsidiary to industrial instruction; that there is absolutely no reason for you to continue to liken this School to the *lycées* or other purely theoretical institutions; that the very small number of hours that your classroom teaching takes of your time leaves you with plenty of time for preparing your lessons and reviewing your students' compositions…(AN F12 1085, Letter from Liancourt, January 17, 1809)

Indeed, the high social status of theory would have made it especially difficult for math teachers to accept that practical instruction in the shops took precedence over theoretical instruction.

But these were not the only social conflicts. Teachers taught in classrooms separate from the shops. Sometimes the teachers excused the best students from shopwork so that they could progress faster in mathematics and the shop foremen excused students from classwork so that they could contribute more to production. Rouby also had a longstanding feud with Arnauld, the assistant director of shopwork, who at Compiègne had accused Rouby of attempting to assassinate him by shooting at him from his window (AN, F12 1130, Rouby to Min. Int., 29 July 1806). In light of this feud and knowing full well the extent of the autocratic rule under Napoleon, perhaps Rouby wanted to document his support of the goals of the school. Indeed, perhaps he was beginning to accept that the goal of teaching theory as it related to practice would not go away by simply placing more emphasis on mathematics.

In any case, Rouby's letter confirms the difficulty that teachers without much practical experience had in integrating math and science with practice. But Molard and the shop foremen also had their reasons for not focusing on the integration of technology, math, and science. The Bureau in Paris was exerting tremendous pressure on them to increase production and income, thus pitting

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production against instruction (AN, F17 14327, “Règlements (projets),” 1807-1812). Liancourt, who had long been supportive of the emphasis on shopwork and the generation of income, favored pay incentives to students to motivate them and thereby render them more compliant in order to increase production. The Bureau’s pressure to produce income, Liancourt’s emphasis on production, and the Bureau’s failure to provide appropriate markets distracted Molard from focusing more energy on innovative ways to integrate math, science, and technology. The importance of these social problems cannot be overstated. In fact, a later example in the history of nineteenth century United States confirms this very problem. In citing the “Prospectus” of 1879 of the Manual Training School of Washington University, Calvin M. Woodward, a leading figure in the promotion of manual training in the United States, drew the following conclusion: “A shop which manufactures for the market, and expects a revenue from the sale of its products, is necessarily confined to salable work, and a systematic and progressive series of lessons is impossible” (Woodward, 1887, p. 6).

The Politics of Integration

The disputes between teachers and administrators over holidays and between teachers and shop foremen over instructional priorities were also political in that they concerned the distribution of power within a hierarchy. These problems were compounded by social structures external to the school. For example, Liancourt complained of the lack of teachers trained to teach integration of theory and practice: “I don’t know if there are in France a satisfactory number of authors who have treated the sciences purely in relationship to the arts” (AN, F12 1085, Liancourt’s “Observations Supplémentaires,” 12 July 1806). As a result, Molard had considerable authority, and administrators in Paris worried about the extent of his power. The regulations of 1803 provided for a shop director, but no director of instruction to formally promote integration, an arrangement that facilitated the tendency of the bureaucrats in Paris to exploit the system of production over instruction (AN, F17 14327, Lausel and Costaz to Min. Int., 3 July 1807). And by keeping up pressure on Molard to increase sales and income, the Bureau kept Molard busy identifying markets and coordinating sales of products (ADM, 1 T 2233*, “Conseil des ateliers,” 1 July 1808–16 February 1815). Disputes revealed that the bureaucrats opposed an integration of the two functions of coordinating both theoretical and practical instruction in one person (Molard), an arrangement that they finally approved reluctantly due to the persistence of Liancourt (AN F 12 1085, Liancourt’s "Supplementary observations," 12 July 1806).

Politics affected students as well. For example, the regulations of the school promoted a particular political view of power in that students were to be organized into military-style companies supervised by a student sergeant and two corporals, selected according to their experience, instruction, and ability (Charmasson et al., 1987, pp. 103-104). Students were also supposed to receive pay for their work according to a sliding scale linked to their rank. In this way the Napoleonic regime promoted a meritocracy that contrasted with the

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emphasis of Old Regime France on power defined by aristocratic birth and privilege. Not surprisingly, there existed a wide range of attitudes among students. This situation was exacerbated by the fact that the bureaucrats in Paris flooded the school with an excess of students, with little regard to age and abilities. Parents who were well off financially sought special privileges for their sons. Labâte also reinforced a dualism of theory and practice. At one extreme, Labâte exempted two students from shopwork for a month in order that they could prepare for the entrance exams for the Ecole Polytechnique (AN, F12 1084, Labâte to Min. Int., 13 November 1807). On the other hand, he excused some students from class with only a minimal introduction to math and science. Before the move to Châlons, Labâte reported that about 40 students (about 10% of the total) had completely wasted their time in the classwork and had learned nothing, either by lack of ability or willingness. All sorts of punishment had failed to improve the situation and Labâte finally proposed that they spend the entire day in the shops except for an hour and a half per day of writing, reading, and the simplest calculations (AN, F12 1084, Labâte to Min. Int., 4 Fructidor year 12 [1804]).

Teachers and shop foremen also contributed to polarization. Some of the students who lacked ability or interest in math would hassle the teachers, who then excused them from classes. Some of those teachers then failed to notify the principal of absences and some of the shop foremen were willing to accept the additional students to increase production. Liancourt noted that the shop foremen, “believing within themselves, like all ignorant persons, that instruction in the sciences is useless, and far from encouraging their students, are disposed to discourage them and even create in them a dislike [of the sciences]” (AN F 12 1085, "Supplementary Observations," July 12, 1806). Nevertheless, bureaucrats in Paris complained frequently of instability at the school, but did little to optimize the educational climate of the school; worse, they pushed for maximum production through specialization and repetition.

Indeed, social and political conflicts also existed at the highest levels of French government. In January 1808 the minister of the interior proposed to Napoleon to eliminate the school due to its instability and failure to produce income commensurate with the ministry’s expectations. Napoleon refused to hear of it and immediately made a counterproposal that the school manufacture artillery equipment, which triggered student involvement in interchangeable manufacturing (Napoléon, 1864, p. 337). Caisson production had both negative and positive aspects. Students were exposed to the most up-to-date style of manufacturing in existence, involving the use of physical and conceptual tools: standardized drawings, specifications, models, and limited use of jigs and fixtures. The demands on Molard for managing drawings were reduced because the school simply adopted the drawings of the artillery. Income from production increased and pressure from the bureaucrats was somewhat relieved. But students who specialized lost in terms of the breadth of their learning. They eventually achieved acceptable standards of uniformity, but only after a long series of disputes with Paris and the artillery over uniformity. These disputes,

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often expressed as technical disagreements over uniformity, were in fact linked to political issues such as the artillery's preference for controlling production in its own shops.

Conclusion

Historical studies expand the research discourse of a field by introducing a broader set of questions. For example, Merrill emphasized the growth of interest in the integration of technology, mathematics, and science education in recent years (2001, pp. 45; 47; 58). But is Merrill implying that we are facing a new idea or challenge, or rather a renewed interest that is part of a cyclical pattern of waxing and waning interest over the last two centuries? If there has been such a cycle, does its behavior correspond to other technological, educational, social, or political trends? Do governments promote the integration of technology with math and science in hopes of spurring national economic development? What are the politics of integrating technology with math and science? How are politics embedded in educational programs, their physical artifacts, conceptual tools, and social forms of instruction?

In addition to stimulating these broader questions, historical narratives and analyses recall and reinterpret specific stories of the past and in so doing redefine the heritage of an evolving field. In the case of the school of Châlons, for example, historical documents suggest that manufacturing caissons was an anomaly in the school's history. The school eventually did supply the artillery with caissons of acceptable uniformity, but the demise of Napoleon in 1815 brought that experience to an abrupt halt. The school did not continue interchangeable manufacturing or military production, but it did continue to pursue industrial precision and the integration of math, science, and technology. Eventually the curriculum of the school influenced programs in the United States, thus raising broader questions about how and why educational programs are transferred across international boundaries. More extensive study of the history of the integration of math, science, and technology would provide insights into how technological knowledge and practice have evolved along with, and distinct from, math and science. Historical study is therefore practical in that it expands the context in which today's educational efforts are assessed by revealing how physical, conceptual, social, and political values have influenced the integration of technology with math and science in the past.

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Endnotes

[1] The author gratefully acknowledges the assistance of the staff of the Archives Nationales (Paris, France) = AN; and the Archives Départementales de la Marne (Châlons-en-Champagne, formerly Châlons-sur-Marne) = ADM. References to archival documents include four components: (a) archive (e.g., AN); (b) series and carton number (e.g., F12 1084); (c) brief title or description of the document; and (d) date of document. In these references, the Ministry of the Interior is abbreviated "Min. Int."; the Bureau of Arts and Manufactures is abbreviated "Bureau". The Ministry of the Interior managed the school through the Bureau of Arts and Manufactures. For an excellent reference work and guide to the National Archives of France for the history of technical education in France, see Charmasson, Lelorrain, & Ripa (1987). Translations are my own unless otherwise noted.

[2] The original regulations in 61 articles for the school were promulgated on 6 ventôse year 11 and reproduced in Charmasson, Lelorrain, & Ripa (1987, pp. 102-108). At the time of their promulgation, the Revolutionary calendar was still in effect, hence the date 6 ventôse year 11, which corresponds to 25 February 1803.