Written Knowledge and Complex Technology: A Case Study of the American Institute of Mining Engineers

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Abstract

Written knowledge enables complex technology. This statement marks a major shift in human activity, both in our physical surroundings and in our mental activity. This paper describes the early publication history of the American Institute of Mining Engineers (AIME), founded in 1871, as they sought to create an industrial knowledge-base. AIME was a professional society dedicated to gathering, verifying, mediating and publishing current written, drawn, and quantitative knowledge about the iron and steel industries. As the number of technological discoveries increased and the industry became more complex, AIME split into divisions reflecting the current fields of growth. By the end of the 20th century, most of the divisions of AIME stopped publishing, signaling a decline in the steel industry in the United States. The theme here is that codified knowledge and complex technology grow and fade as two sides of one coin.

Introduction

The American Institute of Mining Engineers (AIME) was an integral part of the development of the American iron and steel industry. Their main *raison d'être* was the development of written knowledge. They peer reviewed and formally published thousands of papers on multiple disciplines about the multiple industrial processes. In the 1971 AIME Centennial Volume's historical summary describes the publication of papers and books as "the very reason for being" [1]. The body of work that AIME has left behind runs into thousands of volumes and provides a history of technological and scientific ideas on many aspects of the evolution of industry, including, eventually, the death of steel in the United States.

There is some knowledge that relies on intuitive physical or tacit (nonverbal) knowledge. This knowledge is necessary and runs in parallel to written knowledge in the development and

operation of complex technology. For instance, David Thomas, the first (mainly honorary) president of AIME created a method of hot blast using common anthracite coal, thereby ushering in the age of Big Steel. He did this while sitting in a parlor, watching an anthracite fire spit and fizzle. He had just been discussing a pamphlet about using hot blast in an iron furnace, a new concept, when suddenly he got an idea that if he used a hot blast on anthracite coal it would make it "burn like pine" [2]. This is the power of tacit knowledge in combination with printed knowledge.

AIME publications created a vast library, detailing the evolution of the iron, steel, mining and petroleum industries from 1871 to the present. AIME's major publication was the *Transactions of the American Institute of Mining Engineers* (TAIME). This paper will describe some of the development and changes in AIMEs publication history [3]. The publications changed as the industry changed and the publications declined when the industry declined in the United States. Now, instead of writing papers on new methods for metals manufacturing steel, AIME is a historical educational foundation.

Background

Three important predecessors to AIME were the Royal Society of London (upon which model most subsequent professional and scientific societies were formed), the increase of visual images published in-line with text and the *Engineering and Mining Journal*, which was the direct predecessor of TAIME. The Royal Society provided a model, the increase in visual communication allowed the communication of complex technical ideas in print, and the *Engineering and Mining Journal* represented fast and inexpensive publication of industrial knowledge from geographically wide-ranging sources. It was also

The Emergence of Knowledge-sharing Organizations: The Royal Society of London

The model for most scientific society publications was the *Philosophical Transactions of the Royal Society of London*. The Royal Society was officially founded in 1660 in order to show experiment demonstrations and read papers. The first collector and editor of the papers did so for profit (and was disappointed), beginning in 1665. Mr. Oldenburg, born in Germany, published No. 1 though No. 136 (1665-1677). His stated purpose was:

> . . . for the advancement of science and the benefit of mankind, to make known to the world, through this channel, the results of the labours, not only of those persons who were members of this Society, but also of other learned men, in this and other countries; that by the communication of such discoveries others might be stimulated and encouraged to similar exertions, in promoting and extending the various branches of natural knowledge [4].

It reprints the major articles, summarizes the minor ones and provides historical annotations. The Royal Society continued conducting experiments and collecting papers, providing a rich source on the emergence of science in the western world. In 1809, an abridged summary of the first published papers (1665 to 1800) was collected and annotated by editors who added historical data, so it is still possible to study these journals today. Although it was based on the scientific method of Francis Bacon and the transactions contain significant papers of major scientists such as Robert Hooke and Isaac Newton, they also contain hundreds of minor collected observations on all aspects of the natural world from many different people, such as "On Glow-worms," "Damps of the Hungarian Mines," "Curiosities about Connecticut," and "On the Large-breasted Woman." At times, during its publication, the *Philosophical Transactions* were in disfavor among serious scientists [5].

The Emergence of Visual Communication

In the mid-19th century, it became possible to have inexpensive images printed in-line with text. Prior to that, images were expensive and rare, and often printed as plates at the end of a book or in a separate book [6]. William Ivins, who was Curator of Prints at the Metropolitan Museum of Art in New York City for thirty years, wrote that the emergence of the "exactly repeatable image" was a revolutionary advance for science and technology. He viewed prints as the most important tool of modern life, with "incalculable effects upon knowledge and thought, upon science and technology, of every kind." He goes so far as to say that "since the invention of writing there has been no more important invention than that of the exactly repeatable pictorial statement" [7].

The Royal Society used written, visual and quantitative information pathways and many other societies imitated this method. The quality of the illustrations increased in complexity and resolution through time. The advantages of complex images printed in-line with the text can be

seen in Fig. 1, an illustration from the *Engineering and Mining Journal*, which relays more information than is possible with words alone. When illustrations such as this became common, the stage was set for rapid communication and innovation in creating new technologies.

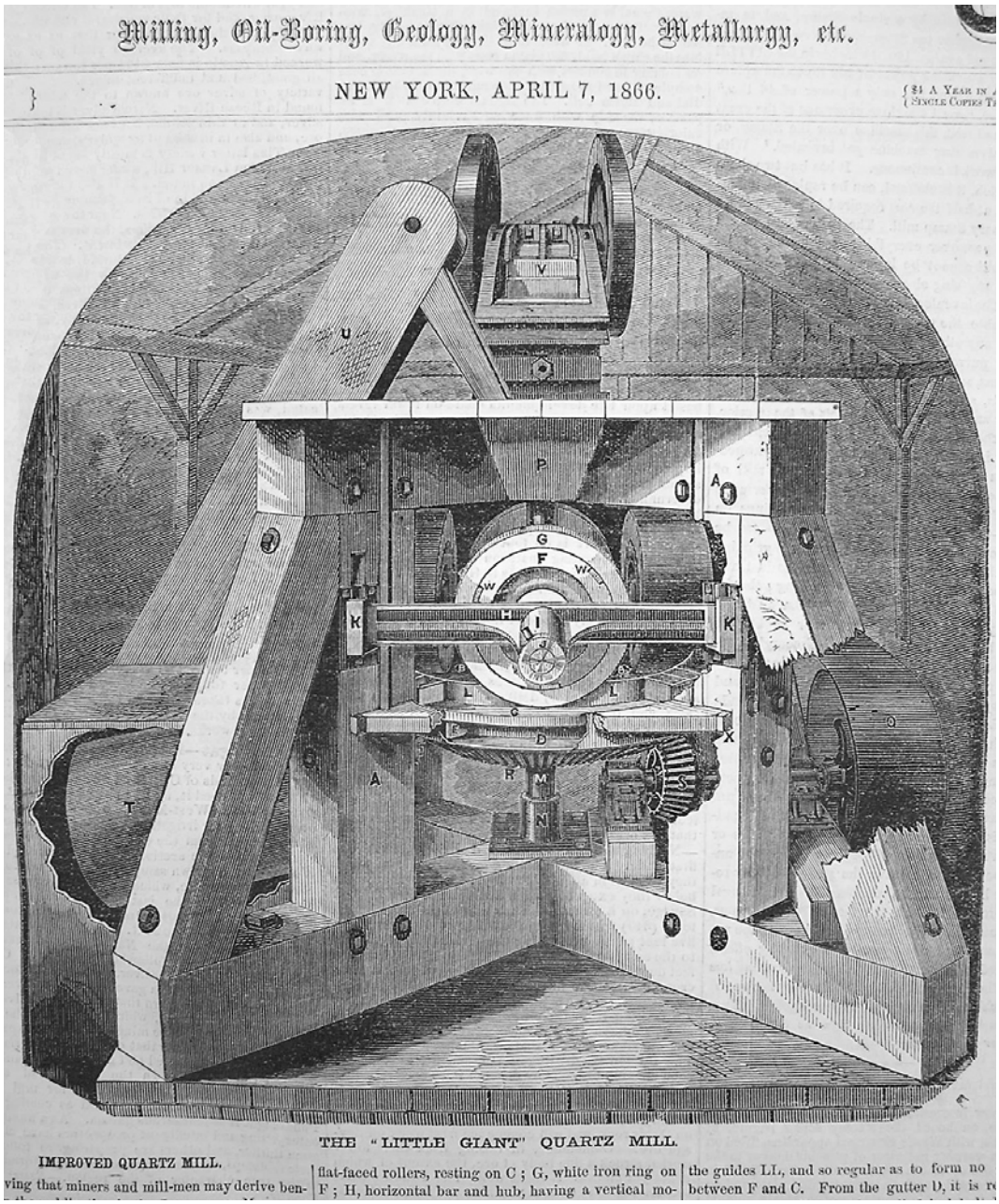

Figure 1 – Illustration of a Quartz Mill on the front page of the *Journal of Mining* in 1866. Better technology, smooth paper and improved woodcut technique made inexpensive newspapers possible on a wide scale in the mid-19th century.

The Emergence of Inexpensive and Rapid Printmaking Technology: The Engineering and Mining Journal

The *Engineering and Mining Journal* (EMJ) preceded TAIME by several years and then became the official "Organ of AIME." EMJ was started in 1866 as the *American journal of mining, milling, oil-boring, geology, mineralogy, metallurgy, chemistry, etc.* At first it carried information about the deposits of gold and silver in the American west. EMJ published packets of information about a variety of topics, including reports on mining activities from every region of the country (that arrived by steamship), notes on inventions, poems, patents pending, brief discussions of geology, machinery, chemistry, prices for coal, securities, gold and other minerals, and advertisements and filler. AIME and TAIME grew out of EMJ – through advertisement, a group proposed to create a society in which "members exchange their views, and consult for mutual advantages upon the difficulties encountered by each; these 'Transactions' or 'Proceedings' when published would form a most valuable, and greatly needed, addition to our professional literature" [8]. This model of knowledge exchange and transfer that developed in the 17th century with the Royal Society is still effective today in societies such as the ASEE.

19th Century: "Renaissance Personality" in Industry

The 19th century was a time of rapid experimentation and industrial development. It was also a time when disciplinary boundaries were continually shifting to make room for new discoveries and/or the discovery of new connections. Thus, during this time period, TAIME and AIME were run a man and a woman, each with a Renaissance personality [9]. Rossiter W. Raymond was the editor of EMJ and then the secretary of AIME, responsible for almost all aspects of the group including publications, a position which he held for 27 years (1884-1911). Mrs. Henry Stevens Conant , Raymond's assistant, was a multilingual author as well. A written history of AIME, published in the seventy-fifth anniversary TAIME volume of 1947, divides its AIME's history into two periods – pre- and post-Raymond. The post-Raymond period was a period of decentralization and redistribution of the power and responsibility over a wider range of people.

Rossiter Raymond was a knowledge-broker. He was moderator of the networked enterprise of advancing iron and steel technology. His moderating role had analogues in other technological arenas. For instance, Alexander Holley worked on the problems of the quality of steel rails, Octave Chanute moderated the information flow necessary to the invention of the airplane, and today individual moderators volunteer their time to open-source programming

projects [10]. Knowledge brokers or gatekeepers of published knowledge play a major role in keeping the knowledge disseminated relevant to the industry or the science for which it was intended.

The 19th century was also a time of rapid development in office technologies such as typing and shorthand dictation. In the 1880s, women began learning shorthand and, after the turn of the 20th century, they monopolized the fields of typing and stenography. Thus, although AIME did not include women and had only one female member (Ellen Richards, joined 1879), women were at the foundation of this massive publication effort from the beginning. Sometimes you can find historical presence in absence – Conant was never mentioned, and we would not know of her today, except that she died in 1899 and Raymond wrote in a preface to TAIME: "No one but myself will ever know how much of the credit universally given to our *Transactions* for exceptional freedom from errors of the pen or the press was due to this patient and skillful worker at my side." The authors of the papers were men, but the many of the hands editing them and putting them into print were, throughout TAIME history, women.

In the same preface in which Raymond mourns the death of Conant, Raymond took the occasion to include a description of the work process of publishing TAIME:

> . . . this department has on hand, at any given period, an average of more than sixty papers, in various stages of publication, from the original manuscript to the final sheets (*nine times* revised) of the volume; that proofs of text and engravings are sent repeatedly to authors in all parts of the civilized world, as well as to special revisers outside of this office, besides being carefully examined here; that it is necessary to know at any moment the exact stage of every separate publication, and to secure by persistent vigilance the final preparation of all in time for the publication of the annual volume of *Transactions*; and that this volume must be ultimately examined for Errata, and indexed with fullness and accuracy – this outline of the work, I say, will sufficiently indicate the continuous, varied and onerous labor which it involves [11].

Moreover, during the publication process each written paper or industrial idea/discovery went through several stages. Most frequently it began with a talk given at one of the AIME meetings. Sometimes the conversation that followed was taken down by dictation. In the earlier years of AIME, written papers were then serialized in EMJ. The revised paper (and sometimes the discussion) were then edited, typeset and printed in TAIME (see Figure 2). This publishing

system distributed the first "draft" new knowledge rapidly for a wide audience then the second peer-reviewed and edited version that represented professional consensus. EMJ reflected the spoken world of developing knowledge and TAIME was more a repository of accepted and codified knowledge.

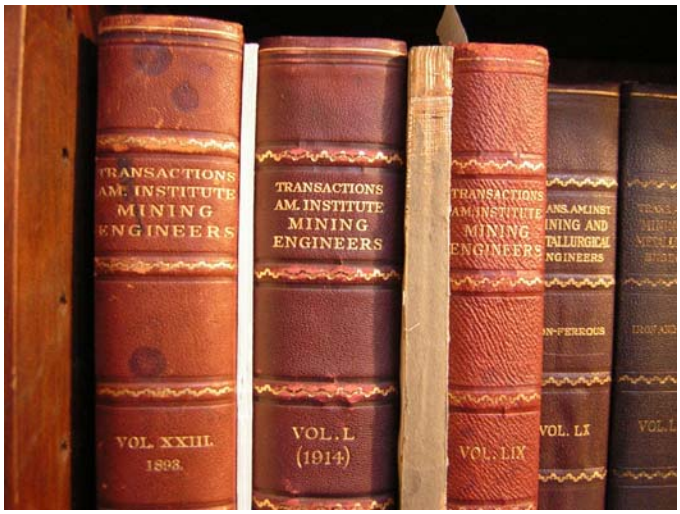

Figure 2 – Volumes of the *Transactions of the American Institute of Mining Engineers* (TAIME).

This system worked well. For instance, one of the major problems with the most immediacy in the 19th century was railroad rails that shattered, causing accidents and killing many. The news articles and images had an impact and focused the public on solving the problem. A concerted effort to end this problem was begun at the founding of AIME in 1871. There are hundreds of pages of papers and recorded discussions that took place surrounding this topic and eventually an appropriate form of steel was discovered, ending the large number of ongoing railway accidents due to shattered rails.

20th Century: Group Knowledge

In 1911 Raymond retired and no longer could one man hold the reins – the age of the "Renaissance Personality" was over. Raymond's process of publishing, which had adhered to a very high standard, was restructured, restructured and then restructured again. First, a Committee of Publications was established and it created a new procedure: each paper would have two readers and if there is a difference of opinions, the discrepancy would be resolved by a third. All readers commented and make recommendations on printed forms. The work that had formerly been done by one man and one woman was now done by a committee of sixty readers.

AIME grew both in size and in the number of disciplines it contained: as industry developed new fields, those new fields specialized and broke off, sometimes spawning new fields themselves. In 1919, the name "Metallurgy" was added: AIME became the American Institute of Mining and Metallurgical Engineers. In 1922, a Petroleum Division was added and in 1925 the Petroleum Division started to publish their own transactions. In 1946, the Petroleum Division physically left AIME's New York City headquarters and moved to Dallas, closer to its base of operations. In 1956, the name Petroleum was added: AIME became the American Institute of Mining, Metallurgical and Petroleum Engineers.

These changes in divisions and disciplines were accompanied by changes in the society's structures and publication processes. In 1942 a new publishing plan was created: seven subsidiary Publications Committees were developed to decentralize the society both geographically and by discipline. The papers were vetted by the local expert committees and the by a main publications committee that would create a "uniformity of standards and an equitable balance in the allotment of publication space and financial resources of various groups." (p. 439, 1947). In the bound volumes of TAIME, all published papers were mixed – no attempt was made to organize them into fields or divisions until 1927. After 1927, the papers appeared in separate volumes, one each for petroleum, metals, iron and steel, and coal. Papers that did not fit into those divisions were still published in occasional mixed volumes.

Much of the historical data in this section was taken from *Annual Volume Seventy-Five Years of Progress in the Mineral Industry 1871-1946,* a historical volume compiled in 1947. This 817 page volume of TAIME includes historical summaries of the development of mining geology, iron and steel, nonferrous metallurgy, coal mining, petroleum, and mineral industry education. It also records the history of AIME, including photos and biographies of all of the officers and the proceedings of the 75th Anniversary Celebration. Interestingly, although women are still unrepresented within the society, on page 810 there is an acknowledgement to two women on the Institute staff who compiled the biographies and the data for the history. It specifically mentions that Katharine S. Lovell as "the only person who will ever be able to say, with truth, that she has read every word in the book – and she has read them twice. The volume itself attests to the high quality of her work." [12].

The End of AIME

Towards the end of the 20th century, much of the heavy industry in the United States was moving abroad to countries with more financial incentives such as government support, lower wages and fewer environmental controls. In 1973 the AIME business office decentralized. The mining division moved to Salt Lake City, then Colorado. The metallurgy division moved to Pittsburgh. In 1974 another society was added – Iron and Steel Society –and the four Societies (mining, metallurgy, iron and steel and petroleum) separated their incorporation in 1984. Only the Society of Petroleum Engineers continued growing. AIME today consists of the four member societies: the Association of Iron and Steel Technology (AIST), the Minerals, Metals and Materials Society (TMS), the Society for Mining, Metallurgy and Exploration (SME) and the Society of Petroleum Engineers (SPE). Most of the annual mining and metallurgical conferences today are in Australia, London, China, Chile, Canada, Italy, Singapore and Amsterdam. The headquarters of AIME, with the URL http://www.aimehq.org/, is now in Littleton, Colorado. Interestingly, AIME presently has two staff members, both women.

Conclusion

Today, there are no publications listed on the AIME website. The organization formed and grew as needed, created and dissolved divisions as needed, codified and shared knowledge as needed, and then ceased to exist when the majority of heavy industry moved abroad. Big Steel would not have been possible without the sharing of written knowledge. That knowledge began in individual people but was communicated, modified, augmented and codified by intensive an intensive publication program for over one hundred years. The publications of AIME were a vital part of the development of the iron and steel industries as well as other, related industries, but now are largely a record of the past. The gradual decline in mining and in the steel industry in the United States gradually brought this intensive publishing process to an end.

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6. Johnson, Carol. "The Evolution of Illustrated Texts and Their Effect on Science: Examples from Early American State Geological Reports." *Leonardo: Journal of the International Society for the Arts, Sciences and Technology*, MIT Press (41:2), 2008.

7. Ivins, William M., *Prints and Visual Communication*, (Cambridge, MA: MIT Press, 1978), p. 3. Ivins posits that we cannot now "see" the importance of visual communication because is has become so familiar to us.

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9. By "Renaissance personality" I mean a person who functions in well a wide variety of fields rather than in a single field.

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