Engineering Field Experience:
Industrial Archaeology Studies in England

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The practice of engineering could be described as a nascent profession when contrasted with medicine, law, academia, politics or the clergy. Engineering as a career emerged as recently as the 1800s as an outcome of newly created industry-based economies. Today the engineering profession is well established, respected, and contributes to the greater benefit of society. Bringing science, technology and creativity together, engineers conceive solutions to problems, develop new designs for products, and generate new wealth through the resultant economic activity derived from manufacturing, construction, medicine, agriculture or other industries. The variety of disciplines under the engineering descriptor continues to grow as technology becomes more advanced and complex, always looking to the future and the next new idea and its application. Yet, few students in engineering and related technology programs are given the opportunity to explore and gain understanding from the historical events upon which modern engineering practice was built. To this end, faculty members at South Dakota State University and Manchester Metropolitan University have collaborated to offer an Industrial Archaeology study abroad experience based out of Manchester England, the epicenter of modern engineering application: the Industrial Revolution.

The Need for Engineering Archaeological Field Sites

Natural science and social science disciplines such as biology, anthropology and archaeology have valued the traditional field site as significant to building the body of knowledge in their specialty. Faculty and students work together at these field sites to gather data, catalog artifacts or observations, and disseminate results through publications, presentations, and the curriculum. The relevance of history comes alive for students who have first-hand knowledge of their field and how it relates to the present and the discipline. Students benefit from organized course work at field sites as do faculty benefit from resultant research and scholarly activity. Established field sites, particularly in the biological sciences, have provided iterations of visits by students and faculty as their research value over time is not diminished.

The challenge for undergraduate engineering programs to utilize the traditional field site model within the curriculum is twofold. First and foremost is the highly structured nature of most engineering programs of study. Accreditation requirements, discipline specific specializations, and rapidly changing technology come together in an extended curriculum for most engineering students. Any variation from the prescribed set of courses or added elective credits can be a problem, delaying graduation by a semester or more, or forcing students to choose between required courses and elective credits. Second, the costs associated with field studies, especially those located abroad, are prohibitive for most undergraduate students, and engineering programs traditionally have higher fees and/or tuition rates than other academic majors. However, there is a growing call for undergraduates, particularly American students, to experience international travel and/or pursue some form of global studies. Students who have traveled overseas and studied other cultures have benefit of knowledge that can have considerable impact on future engineering design choices, environmental sustainability issues, and even socio-political decisions.

Many universities are adopting international experience and global citizenship themes in the core curriculum; South Dakota State University is among this group. However, the study abroad experience has yet to be widely adopted: only one percent of the American undergraduate population in 2002 had earned academic credit in this manner.[1] The financial constraints of overseas travel compounded with the lack of faculty participation [due to funding issues, time constraints, or teaching load issues] negatively affect study abroad programs.[2] Nonetheless, the growing importance of global issues for students is a compelling incentive for an alternative curricular solution. It is our belief that a short term international experience can provide engineering students insight into the value of historical events and technologies, thus addressing curricular and financial challenges.

The Industrial Revolution and Its Relationship to Modern Engineering

There is little doubt that the impact of technology on our lives is significant, evolutionary, and beneficial. However, the late 17th through the 19th century could be characterized as a period of revolutionary change: mechanization of manufacturing, mass transportation networks established, advances in consumer and agricultural technologies, and the sizable shift in socioeconomic boundaries. Applying the scientific method to nature and likewise the systematic solution of technical problems, 18th century England served as the crucible from which modern engineering practice was cast.[3] This confluence of technology, natural resources, and commercial enterprise was unique in the world and contributed to the establishment of engineering disciplines and the transformation of England from an agrarian culture to an industrial economy.[3] Mass production of cotton textiles, pottery, and cast iron changed daily life for the masses, redistributed wealth and power, and redesigned the urban landscape.

At the center of this whirlwind of transformation was Manchester England. Often referred to as the Cradle of the Industrial Revolution, Manchester's proximity to coal fields, canals, and railways contributed to its growth as a textile center in the 1800s. As a result, Manchester grew exponentially from about 25,000 people in the 1770s to over 350,000 by 1860. The wealth created from this economic activity had a significant impact on social and political interactions of the day. This exciting time in Manchester's history has been safeguarded by local museum archivists and, for some areas, restored by regional preservation groups. Thus, the district in and around Manchester, England contains a super-abundance of field sites relevant to the subject of engineering. These sites, initially from a pre-technological age, experienced the throes of the Industrial Revolution and are home to repositories of technological artifacts of interest to the engineering student.

Manchester as Industrial Archaeology Engineering Field Site

This paper argues that all students of engineering need to be made aware of the distinguished history of their subject. The statement, “We are standing on the shoulders of giants,” was never more true. In the interest of increasing awareness of industrial archaeology, faculty from two institutions collaborated to provide an international field experience using Manchester England as base camp for undergraduate engineering students from South Dakota State University (SDSU) in the spring of 2004. This experiential learning opportunity provided SDSU College of Engineering students insight into the technical, cultural, and economic effects of the Industrial Revolution on 18th and 19th century England. In addition to experiencing historical technologies first hand, they also were exposed to modern mass-transportation systems, met peers at Manchester Metropolitan University, and broadened their global perspectives through interactions with the culturally diverse population of urban Manchester: encounters that served to enrich this learning experience.

Elements for a Successful Outcome

The relationship between South Dakota State University (SDSU) and Manchester Metropolitan University (MMU) was built upon a common desire to exchange ideas and information. Faculty and administrators from both institutions participated in a series of Faculty Development Seminar Abroad transactions over the past 15 years which included visiting professorships and international student exchanges. SDSU has a well-established international exchange program, currently encompassing agreements with institutions in England, Sweden, Germany, Egypt, Korea, India, and Australia. This interest in developing international experiences for students and faculty has been a high priority for SDSU’s President, Peggy Gordon Miller and the Vice President of Academic Affairs and Provost, Carol Peterson. The program was initially implemented by the now retired director of the Office of International Programs, Harriet Swedland and continues today with the new director. The results have been impressive and we continue to seek new opportunities for international experiences for our students. Thus, the Industrial Archaeology Engineering Field Site idea had solid support from the administration from the start – one of four key elements for this successful study abroad experience.

The concept for the Manchester engineering field site program was adapted from the SDSU / MMU College of Nursing study abroad program established in 1997. SDSU nursing students enrolled for a one credit seminar abroad and traveled to England during the spring semester. The two week field study allowed the nursing students to visit health care facilities in and around Manchester, meeting regularly as a group at MMU facilities to discuss their experiences with SDSU faculty supervising the trip, and journaling each day’s events. The successful experiences for the College of Nursing students, the positive reception by MMU faculty and students of SDSU personnel, and the historically significant Manchester location made a strong case for the Industrial Archaeology Engineering Field Site concept, the second important element.

The third element for our successful outcome was faculty interest. On the MMU side, we had our colleague of over a decade, Martin Whalley, a biology professor at MMU by profession who had worked with SDSU faculty to jointly offer a course for MMU and SDSU students in bioethics. However, his passion for Manchester regional history, 30-plus years work on the Bugsworth Basin restoration project and his interest in the Manchester canal system, provided unique access for SDSU faculty and students during visits to the area. Dr. Whalley's walking tour of Manchester's canal system is legendary and a de rigueur experience for visiting SDSU personnel (Figure 1). On the SDSU side of the equation, faculty members Harvey and Harriet Svec had visited Manchester numerous times over the past decade and had developed more than a passing interest in the impact of the Industrial Revolution on technological and social developments in that time period.

Figure 1. Dr. Whalley provides insight into British history and applications of technology on the Manchester Canal Tour. Here, the group views restored lock master houses along the canals.

The Svecs made a proposal to the SDSU Provosts' *New Ideas* fund to offer a one credit General Engineering special topics course in the spring 2004 semester entitled "The History of the Industrial Revolution". The project was approved and funded. Additional financial support was garnered from the College of Engineering Dean's office for any engineering student who registered for the course and support from the Engineering Technology and Management department in the form of course release time for Harvey Svec, the instructor of record. This was critical SDSU administrative support for the project and helped ensure its success.

The last piece of the success puzzle was now required – students. From the start, it had been determined that the ideal class size would be ten or fewer students as the course was being offered for the first time and the logistics of a larger group might be problematic. Marketing the course to students required personal visits to targeted engineering classes by Harriet Svec to announce and describe the study abroad course. We were able to enlist seven students from various disciplines within the College: mechanical engineering, electrical engineering, civil and environmental engineering, manufacturing engineering technology and industrial management students registered for the course. All the students were from small towns in the upper Great Plains region of the U.S. Only two students had traveled abroad before the Manchester trip, none to England previously.

The Course

The curriculum consisted of pre-travel meetings and briefings on the Manchester region and its culture, and general information culminating in the trip to England during spring break and post-travel seminar presentations and a reflection paper. The first pre-immersion session included covering the course requirements, introduction to the Manchester area using brochures and maps, a basic travel itinerary, travel cost information, how to start the documentation process (passports and SDSU international trip forms), and a student participation survey dealing with cultural sensitivity and awareness. The survey was designed to help students begin to do some introspection about the upcoming trip. The second session prior to travel involved allowing the students to determine some of the itinerary based on information provided by the faculty team. The third pre-travel session was held two weeks prior to departure and was used to verify passports, travel insurance and other documentation, and to discuss logistics and emergency contacts.

The 10-day field experience included:

- Day 1-2: Travel from Brookings to Manchester; arrival, hotel check in and some free time to shop in downtown Manchester; walking tour of Manchester of the restored canal system, renovated cotton warehouses and factories with Dr. Whalley.
- Day 3: Travel to Telford via rail system and cab; Samuel Greg Iron Bridge, Coalbrookdale Iron Foundry, Abraham Darby Museum where iron ore was first smelted in 1709.
- Day 4: Walk to Manchester Metropolitan University to meet with Engineering faculty and students; walk to the Museum of Science and Industry including the Power Museum, Sewers Museum, Cotton Textile exhibits.
- Day 5: Travel to Stoke-on-Trent via rail system and cab to tour the Royal Daulton China factory and other nearby sites in the Potteries District.
- Day 6: Travel to York via rail system; walking tours of Yorkminster Cathedral, Roman ruins, museums and shops in York.
- Day 7: Travel to Peak district via rail system and bus: boat tour of the Lead Mines of Castleton.
- Day 8: Travel to Quarry Bank Mill via rail system: walking tours of the water powered cotton milling facilities, the Apprentice House where child laborers were kept, and museum tours with commentary on the labor rebellion.
- Day 9-10: Return trip to Brookings.

The group of students and faculty traveled well together for the duration of the trip (see Figures 2 and 3). During the first couple of days, the students did not venture out after returning to the hotel – fatigue may have been a factor as we were walking 5-10 miles each day. After meeting peers at MMU on Day 4, the students began exploring more on their own during the evening. On Day 7, a remarkable change in the students was observed. The day was originally planned to be an open schedule day, offering them an opportunity to rest or visit places not on the itinerary. The students instead chose to tour the Lead Mines of Castleton as a group. They researched train schedules, found a connecting bus and put together the day trip. The tour of the lead mine was interesting to them, but more revealing to the faculty was the student's adaptability and resourcefulness in planning a day. At our arrival in England, the students were like ducks crossing the road: one faculty member in the lead and everyone else following. By the seventh day, they were managing their trip through discussions, problem solving, and working together as international travelers. It was a remarkable transformation.

Figure 3. Students walking from the train station at York through the city center. Yorkminster Cathedral tours took the better part of 3 hours and then we could walk around the city and through the shopping district.

Figure 4. The restored train trestle at Coalbrookdale provided access to the location of the first cast iron foundry in the world.

The section that follows could be described as a short course in industrial archaeology. It is a sampling of the information gleaned from the industrial archaeology engineering field site visits in and around Manchester and was part of the experiential learning curriculum of the study abroad course that the students received. Much of this information was disseminated to the students on the walking tour of Manchester's canals, day trips near the city, or during their visit to the Museum of Science and Industry.

A Short Course in Industrial Archaeology of Manchester

Manchester is historically famous for the cotton-based textile industry. "King Cotton", so-called, drove the economy along for over a hundred years. Likewise in many parts of the world, "Manchester cloth" is still synonymous with corduroy. Other observers, however, might see the city foremost in its guise as a place of political change. A massacre of disaffected citizens at an open-air meeting in 1819 became known as "Peterloo". Charles Dickens based his novel "*Hard Times*" on the fictitious community of Coketown, in reality a thinly-disguised portrayal of Manchester, and in so doing added his weight to the campaign for social reform. Karl Marx, when writing "Das Kapital", drew upon the experience of his friend, Friedrich Engels, who had come to work in Manchester in 1842.

Whatever the perceptions, the development of efficient systems of transportation lay at the heart of all industrial progress; a progress which propelled Manchester forwards from a prosperous eighteenth century town into a major city of the British Empire. Many historians regard the first meeting between Frances Egerton, James Brindley, and John Gilbert as being among the pivotal events of the Industrial Revolution.

Starting at Manchester city center, a short journey by bus brings the student to Worsley Delph. Here a former quarry, now almost completely overgrown, marks the exit point for two tunnels, cut into the face of a cliff and from where thousands of tons of coal were to be extracted, until closure of the mines in 1887 (Figure 5) . The landowner, Francis Egerton, Third Duke of Bridgewater, saw canals in Continental Europe and immediately realized their potential in an industrial context.[4] Thus the first ever arterial canal came about, designed by arguably the greatest engineer of the Canal Age, James Brindley. An arterial canal is defined as one which crosses one or a series of valleys, often with the aid of such features as tunnels, cuttings, embankments and aqueducts, as distinct from a lateral canal which is constructed alongside the banks of a river and thus has a relatively easy course.[5] Brindley's canal fulfilled all these criteria throughout its lockless length. When it came to the tunnels, these were driven into the mines themselves, coupled with a remarkable system of ventilation and a mechanism for the "flushing out "of loaded boats.

Figure 5. Worsley Delph. The canal arms, left and right center of picture, can be discerned, progressing towards a sandstone cliff. From here, a system of underground canals, eventually totaling 42 miles, was cut on four different levels. The brown color of the water derives from ochre, a hydrated oxide of iron.

The Duke, then in his early twenties and being assisted by his agent, John Gilbert, had an astute head for business. A packhorse on a bad road carried 140lbs. A single horse, drawing a wagon along the same road, might manage a ton. A horse, walking the Bridgewater Canal towing path (Figure 6), built to the specification of Brindley, pulled 25 tons with comparative ease. The price of coal and thus of energy for the industries of Manchester fell by 50%, a significant business and productivity advantage.

Figure 6. Near the Manchester terminus of the Bridgewater Canal, what remains of a huge coal yard is now used as a car park. Recent plantings of trees soften the outlines of brickwork, and also provide shade for two residential boats. The building with the tower is the former Congregational Chapel (1858), one of the few religious buildings to survive in the district.

Many techniques used for the building of canals were directly applicable to the later concept of railways; most notably perhaps, the use of cut and fill, perfected by a second master of canal construction, Thomas Telford (1757-1834). Here spoil, excavated from one place could be moved forwards to fill depressions in the landscape, thereby facilitating a run of more or less level track. Thus a total of 4,000 miles of canal, achieved by the canal builders from 1760 to 1820, was later to be surpassed by the railway engineers, who laid an 18,000 mile network of track, between the years 1830 and 1880.[6] George Stephenson and his son, Robert, acted as civil engineers and locomotive builders for the Liverpool to Manchester Railway (see Figure 7). The walking tour of the Manchester Canal System impresses upon the student the extensive effort and creative application of technology to build this system. Innovations included crossing marshy country, west of Manchester at Chat Moss, with an embankment, built on layers of brushwood thrown into the peat. A locomotive trial at nearby Rainhill, open to all who could raise an entrance fee, was also won by the Stephensons. The railway, as built and 40 miles in length connected Manchester with the port of Liverpool, then center of the lucrative UK-North America trade.

Figure 7. The intersections of three railway crossings pass over the former busy northern terminus of the Castlefield canal complex.

A journey by canal of about 22 miles, eastwards from the entrance to the Rochdale Canal at Castlefield, takes the student to the largest inland port ever to be built on the British narrow canal system . Bugsworth Canal Basin at the head of the Peak Forest Canal developed as place where limestone and limestone products, such as quicklime and slaked lime, were transhipped from tramway wagons to horse-drawn narrowboats. The canal terminated in Bugsworth Basin because the builders encountered a hard band of gritstone, directly in the path of the channel. This feature was later exploited as a highly-prized source of building stone and setts, then used for surfacing roads. The output of the basin reached between 600 and 800 tons per day during the 1880s. A pall of smoke hung continuously over the village, as gangs of wagons, carrying limestone or coal, were emptied into the charge holes at the top of the kilns (Figure 8). The engineer for the undertaking, Benjamin Outram (1764-1805) was forced by the difficult geology to construct an extra length of tramway, as opposed to canal channel, in the direction of the quarries of the Derbyshire Peak District.[7]

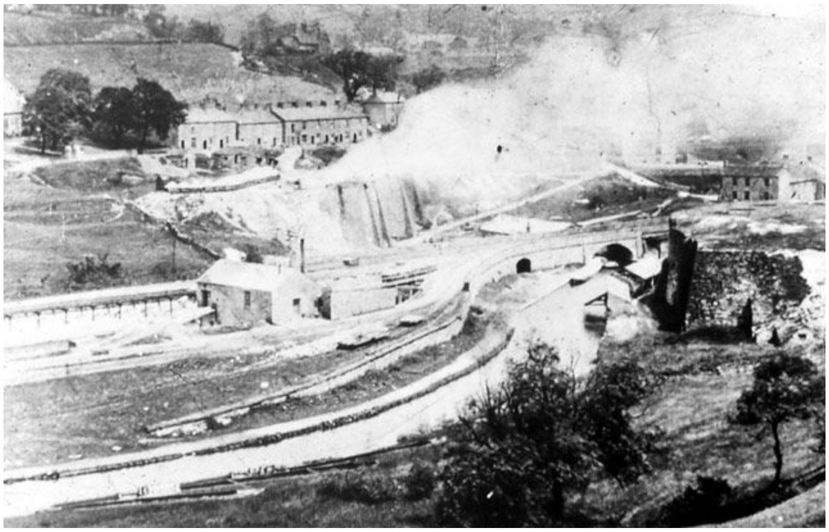

Figure 8. Bugsworth Canal Basin in the village of Bugsworth, Derbyshire (c. 1880), was characterized by smoking limekilns, busy boat traffic and the regular arrival of gangs of tramway wagons, bringing limestone from the quarries of the Derbyshire Peak District.

The Peak Forest Canal Tramway and Bugsworth Basin remained operational, well into the twentieth century. Indeed, the last wisps of smoke only left the charge holes of the kilns in 1923; to be followed in 1926 by the last load of stone, down the tramway and out by boat. Scrapping and destruction of much of the system followed, accompanied by the demolition of most of the buildings. There matters lay until 1958, when what might be called an eccentric couple in modern parlance, Percy John and Bessie Bunker, re-discovered the site and vowed to restore it. The Inland Waterways Protection Society has continued with that aim since September 1968. The whole site, officially an Ancient Monument and restored under the watchful eye of English Heritage, is due to be re-opened to boats in March 2005. As in the case of Castlefield and Worsley Delph, Bugsworth Basin provides unique opportunities as a field site for engineers.

Outcomes from the Industrial Archaeology Field Site Experience

After returning home, the students were required to write a paper detailing their observations and lessons learned from the experience. Additionally, they made a presentation to the general public in an open seminar late in the spring semester and several students gave interviews for local and regional newspapers. In discussions with the students immediately following the trip, the overall consensus indicated they learned much about engineering and technological history as it related to their disciplines and they enjoyed the travel abroad experience as a whole. They were especially appreciative of the fact there was no significant language barrier to overcome and that they felt safe traveling as a group with faculty members who had intimate knowledge of the Manchester area. Some were concerned about the costs associated with the trip beforehand, around $1700 including tuition, but afterwards all agreed the money was well spent. The students indicated they would be much more likely to consider future travels abroad after this positive experience.

Although a survey on cultural sensitivities was included as part of the course, the instrument lacked any test of validity or reliability. With only seven students in the group, no generalizable conclusions could be drawn from the students' responses pre and post travel.

At issue is whether the students responded to the survey with political correctness in mind or actually as a result of in-depth introspection. The survey was used as an avenue to involve students in thinking about the international experience and international culture. It should be noted that, although different, British culture is a western culture not significantly different from that of the Midwest in terms of socio-economic conditions. The students comfort level with overseas travel was increased while in Manchester, however it should be noted that as we re-entered the United States and encountered security and customs, the students reverted to a more dependent behavior pattern until we had arrived at our regional airport.

Summary

The industrial archaeology engineering field site experience will have some long term impact on the students and it is our intention to stay in contact with them. The value of 'knowing where we come from to better understand where we are going' was not lost on this group of students. Their future perspectives have been altered, hopefully in a positive fashion, and it will take some time for the full import of the study abroad experience to manifest itself.

For SDSU and MMU faculty, the effort expended in bringing this course to a successful outcome was extensive yet valuable. It is our hope to offer this course again in the near future. Once again, financial barriers must be overcome, time and workload constraints much be managed, and a willing group of students with an openness to travel abroad must be identified. The rich history of engineering and technological developments associated with the Industrial Revolution contained within such an accessible region in and around Manchester is an inviting reward for engineering students and faculty alike.

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