# When Science Met People Through Education: the Mechanics' Institute Movement in the 19th Century Britain

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**Abstract:** With an emphasis on scientific literary, science education has again became closer to the interests and needs of people and sometimes expands its scope beyond the boundaries of school and the curriculum. Science educators often claim that its historical roots can be traced back to the movements of General Science and Science and Citizenship during the 1920s-40s. This study attempts to re-interpret the historical meanings of the Mechanics' Institute Movement (MIM) from the perspectives of science education. In doing so, this study first introduces the process of the emergence of MIM with a focus on its founder, George Birkbeck, and the Andersonian Institute where evening science classes began to be open to skilled workers. Then the overview of MIM is described, with examples drawn from the London Mechanics' Institute and the Manchester Mechanics' Institute. In discussing science teaching of MIM, the details taken from various mechanics' institutions are examined in terms of why, what, and how to teach sciences. This study argues that the MIM was a unique social phenomenon in which science could respond to the needs of skilled workers through education, providing science learning opportunities which were otherwise unavailable and that the MIM shared many similarities with current practice of science education, moving towards a wider career perspectives, cross-subject, community-based, and informed citizenship.

Key words: Mechanics' Institute, George Birkbeck, scientific literacy, history of science education.

## 1. Introduction

From the late 1950s with a slogan of 'scientific literary', and more recently with the social relevance of science approach (DeBoer, 1991; Roberts, 2007), today's science education is once again attempting to become closer to the interests and needs of people. To foster citizens with basic scientific knowledge and skills and the ability to make informed decisions is now, if not the most important, one of the firmly established aims of science education. The role of science education in the development of scientific literacy and responsible citizenship in a democratic society is widely supported by the science education community (e.g. Aikenhead, 2006; Reiss, 2007) and this sometimes expands the scope of science education beyond the boundaries of school and the formal curriculum (Cambell &Lubben, 2000; Falk, 2001; Song, 2006). Despite a variety of meanings and definitions of scientific literacy (e.g. DeBoer, 2000; Roberts, 2007), its ethos would be the reflection of needs, present and future, of learners; in other words, 'to meet people's needs'.

> In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. Scientific literacy also is of increasing importance in the workplace. More and more jobs demand advanced skills, requiring that people be able to learn, reason, think

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> creatively, make decisions, and solve problems. An understanding of science and the processes of science contributes in an essential way to these skills. (National Research Council 1996, *National Science Education Standards*: p. 1)

Is, then, 'scientific literacy' the twentieth century's new and more authentic attempt by science education to meet people's needs? When did science education actively seek its links with the general public, not just with future scientists? It is often claimed by science educators that the movement toward STS (science, technology and society) education first came during the 1970s 80s, especially through *Science in Society* (Lewis, 1981) and *SISCON (Science In Social CONtext) in Schools* (Addinell & Solomon, 1983) in the UK, and that these were some of the first attempts by science education to respond to contemporary social needs (e.g. Hunt, 1994; Jenkins, 2006). However, others argue that its historical root can be traced further back to the 1920s-40s when movements of *General Science* and of *Science and Citizenship* were in progress in response to then social needs in regard to revising science curricula (Fawns, 1998; Song, 1999; Jenkins, 2006). DeBoer (2000) also argues that the attempts and movements relevant to scientific literacy can be traced back to as early as the last decade of the 19th century, e.g. the 1893 Report of the National Education Association's (NEA) Committee of Ten in the US.

This study attempts to re-interpret the historical meanings of the *Mechanics' Institute Movement* (hereafter MIM), which flourished during the first half of the 19th century in Britain and opened the door of science to the working class, as the first major case in which science met the needs of people particularly through the form of education. In doing so, this study first introduces the process of the emergence of the MIM with a focus on its founder, *George Birkbeck (1776-1841)* who is known as the father of British adult education, and on the establishment of the *Andersonian Institute* where Birkbeck opened evening science classes for mechanics and artisans. Then the overview of the development of the MIM is described, with a special focus on the London *Mechanics' Institute and the Manchester Mechanics' Institute* as typical examples. In discussing its relationship with science education, together with educational and scientific backgrounds of the time, the details of the MIM are examined in terms of why-teach (aims), what-to-teach (contents), and how-to-teach (methods) sciences.

## 2. Background: George Birkbeck and the Andersonian Institute

In 2004, a new periodical titled the *Mechanics' Institute Review* was first published by a group of established writers and emerging talent from the Creative Writing MA and Certificate courses of Birkbeck College, University of London. The journal states that it publishes well-crafted writings of the group and follows the long tradition of the college which has been maintained ever since its establishment. The first Mechanics' Institute in London, the *London Mechanics' Institute* (hereafter LMI), was founded in 1823 by George Birkbeck. The LMI, like other Mechanics' Institutes in Britain at the time, had the primary aim of teaching the scientific principles behind the craft of artisans, then usually called 'mechanics'. The LMI later became Birkbeck College, a part of the University of London.

George Birkbeck was born to a Quaker family on 10th January, 1776, in Settle, North Yorkshire, one of the industrial areas developed during the Industrial Revolution. His father was an eminent banker and merchant in Settle and the parents were highly respected in the town. "Young Berkbick displayed signs of genius at an early age, evincing a decided partiality for mechanical and scientific pursuits. In childhood he was fond of visiting the different workshops and attempting to use the craftsmen's tools. He especially exhibited great interest in a large cotton-mill … and with precocious intelligence he endeavoured to follow the complicated machinery and to understand the manufacturing processes." (Godard, 1884: p.10). At the age of eight Birkbeck was sent to a Sedbergh School at Newton in Lancashire and remained until he was fourteen, when he became the pupil of John Dawson (1734 1820), under whose supervision later at least eighteen future senior wranglers (i.e. undergraduates who obtained the top annual mark in the final year of the Mathematics Tripos) were taught at Cambridge. Under Dawson at Sedbergh, Birkbeck could study the *Principia* of Newton. Subsequently, Birkbeck elected to study medicine and pharmacy and at eighteen he moved to Edinburgh, where he joined the Royal Medical Society and studied for a year; then he went to London to practise dissection and study anatomy; he also attended lectures on physics and chemistry there.

In 1796, he returned to Edinburgh, became a student at Edinburgh University, and joined the Society of Natural History. He became the chairs of both, the Royal Medical Society and the Society of Natural History. In 1799, he graduated as Doctor of Medicine from the University. During his university days, Birkbeck also joined a new student society, the 'Academy of Physics', which lasted for only about three years but through its network made great contributions to making science available to an ever-wider British public. The founder of the Academy was the then eighteen-year old Henry Brougham (1778-1868) who later became a lawyer and politician and went on to be Lord Chancellor of England. As a founding member of the Academy, Birkbeck maintained a close friendship with Brougham and they worked together from time to time for the spread of science into the public (Olson, 2008).

In 1799, Birkbeck became a professor of natural philosophy at the *Andersonian Institute* at Glasgow, which made a turn in his life toward science for the people. The Andersonian Institute was established to supply courses of general and scientific instruction open to all classes and to both sexes as a result of a will bequeathing his whole property by John Anderson (1726-1796) who had been the third Professor of Natural Philosophy at Glasgow University and died in 1796. Unfortunately, Anderson's property (of £ 1000) was not enough to found a separate university, thus his trustees decided to establish a Chair of Natural Philosophy (i.e. Chair of Physics). Thomas Garnett (1766-1802) was appointed to the Chair and he continued Anderson's practice of delivering experimental physics classes to adults with a great success. In 1799, Garnett left for London to take up a position at the Royal Institution, a position succeeded by George Birkbeck.

Following his predecessors' efforts of opening evening class in experimental philosophy, "Birkbeck .. When he instructed workmen how to make his needed apparatus, he was struck by the zeal with which they listened to his directions and with the 'intelligent curiosity' they showed in the working of a modern centrifugal pump. He then invited some of them to attend his lectures. His first class began with 70 students. The number of the students soon rose to over 400, thus he had to give his lectures in separate classes in a building known as Anderson's Institute." (Bishop, 1994: p.42) His lectures were full of interesting demonstrations and experiments and with simple expression and familiar illustrations which attracted the attention of workmen. In 1804, Birkbeck resigned his position in Glasgow and settled in London as a physician. Despite Birkbeck's departure, the evening classes at the Andersonian Institute maintained the tradition through his successor, Andrew Ure, later FRS, who occupied the Chair from 1804 till 1830. The lectures on the elements of mechanical science continued up to the time of the formation of the

Glasgow Mechanics' Institution (GMI) in 1823. Among the prominent students of the Andersonian Institute were William Thomson (later Lord Kelvin), his brother James (later a professor of engineering at Glasgow University), and Lyon Playfair (later a professor of chemistry at Edinburgh University) (Bishop, 1994).

## 3. The London Mechanics' Institute and the Manchester Mechanics Institute

> The large room of the Crown and Anchor Tavern, one of the very largest in the Metropolis, was engaged for the occasion, and at the time appointed for taking the chair, it was completely filled. It was said to hold 2,500 persons; certainly more than 2,000 were present. We were glad to perceive that they consisted chiefly of that class for whose good the institution is intended, namely, *working mechanics;* and that they showed, by their conduct and demeanor, that they comprehended fully the serious magnitude of the object for which they were assembled, and came to the consideration of it with minds warned apparently to enthusiasm in its support; yet keenly intent on examining and scrutinizing well the means by which they were to be invited to realized the promised good. It was a meeting of men resolved both to *think and act for themselves* … (original italics, *Mechanics' Magazine*, 15 November 1823, p. 177)

As depicted in the report of the occasion by *Mechanics' Magazine*, the opening of the London Mechanics' Institute (hereafter LMI), the first of its kind in London, was very much cheered and supported by the intended audience and supporters of the time. When the LMI was formally inaugurated in 2nd December 1823, Birkbeck was invited as its first president and he held the position till his death in 1841. However, the successful opening of the LMI was not straight-forward and was only possible after a long and bitter dispute over the issue of "should an appeal be launched for subscriptions for the well-to-do?" Among the four founding members of the LMI, at a meeting in preparation of its establishment, the two from the *Mechanics' Magazine*, J. C. Robertson (editor) and Thomas Hodgskin (associate editor), opposed this idea, while Francis Place and Birkbeck (as the chair of the meeting) supported for the proposal. In particular, Hodgskin, who became in later years one of the pioneers of English socialism, vigorously opposed the proposal, later saying "men had better be without education … than be educated by their rulers" (re-quoted from Kelly, 1992, p.119). The agreement for subscriptions from the well-to-do was finally reached with a condition of writing into the constitution that two-thirds of the managing committee must be working men. The same issue arose for this issue was shared by many other subsequent Mechanics' Institutes and was important because it would after all shape profoundly 'why, what, and how to teach' after the establishment. The following *Preamble of the revised Rules and Orders* of LMI illustrates the compromised result of the debate (Kelly, 1957, pp.88-89).

> **OBJECT OF THE INSTITUTION**
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> I. The object proposed to be obtained is the instruction of the Members in the principles of the Arts they practice, and in the various branches of science and useful Knowledge.
>
> II. The means proposed are
>
> 1. The Voluntary association of Mechanics and others, and the payment of a small Annual or Quarterly Sum by each.
> 2. Donation of Money, Books, Specimens, Implements, Models, and Apparatus.
> 3. A Library of References, a Circulating Library and Reading Room.
> 4. A Museum of Mechanics, Models, Minerals, and Natural History.
> 5. Lectures on Natural and experimental Philosophy, Practical Mechanics, Astronomy, Chemistry, Literature and the

Arts.

6. Elementary Schools (for adults) for teaching Arithmetic, Algebra, Geometry, and Trigonometry, and their different applications, particularly to Perspective, Architecture, Mensuration and Navigation.
7. An Experimental Workshop and Laboratory.

In 1858, among the changes to the University of London's structure resulting in an opening up of access to the examinations for its degree, the LMI became the main provider of part-time university education. In 1866, the LMI was renamed as the Birkbeck Literary and Scientific Institute. In 1904, Birkbeck's first official Students' Union was formed and described by Sidney Webb (a former student) as 'the kind of evening instruction for the intelligent workman that is unique in the world. No other city has anything to equal it' (http://www.bbk.ac.uk/about_us/history/1900s?isPrintable=1). In 1907, the Birkbeck Literary and Scientific Institute was renamed the Birkbeck College, the present official name. In 1920, the Birkbeck College became a School of the University of London dedicated to the teaching of evening and part-time students, and in 1926 it received the Royal Charter. In 1966, the Ashby Report recommended that the Birkbeck College continue to provide education for mature students in full-time employment. In 1988, the Department of Extra-Mural Studies of the University of London joined the Birkbeck College, and became the Centre for Extra-Mural Studies and later the Faculty of Continuing Education.

> Birkbeck College is now, as the London Mechanics' Institution was a century ago, first, a partially self-governing association of students, and, secondly, as institution for part-time adult education of those who are actually at work in commerce and industry, in journalism, in the Civil Service, or in the schools. (Burns 1924, p.13)

Ever since its establishment in 1823, the Birkbeck College has been widely known for its contribution to part-time and adult education and, later, its socialist-oriented perspectives. The Birkbeck College is still being advertised on its own homepage as "London's only specialist provider of evening higher education" (http://www.bbk.ac.uk/). As well as having some famous figures, like Sidney Webb (the co-founder of LSE) as a student and T. S. Eliot as a teacher, it has also been a home to many notable scientists, especially in the field of crystallography. This is in part a consequence of the socialist movement by scientists as most of the great scientific achievements by Birkbeck people, either as professors or as students, were strongly linked with the tradition firmly established by J. D. Bernal, who was a pioneer of X-ray crystallography as well as a leader of the British communist movement in the early 20$^{th}$ century (Werskey, 1978; Brown, 2005). In part as a result of the influence of Bernal, the Birkbeck College maintained its strong tradition of scientific research and activity, through the work of such major scientists as Patrick Blackett, Rosalind Franklin, Lancelot Hogben, James Lovelock, Roger Penrose, William Stanley and Alfred Russell Wallace (Books LLC, 2010).

Among the fourteen institutes opened in 1824, following the six opened in the previous year, the Manchester Mechanics' Institute (hereafter MMI) shows the development of the MIM in Britain. As one of the mechanics' institutes in the industrial counties of the North of England, MMI was established by a group of businessmen, industrialists and scientists, among them John Dalton (of atomic theory), to ensure that factory workers could learn the basic principles of science for their jobs. After a series of changes of name (Manchester Municipal School of Technology and then Manchester Municipal College of Technology), in 1966 the MMI became UMIST (the University of Manchester Institute of Science and Technology) and in 2004 became a part of the University of Manchester through merger with another long-standing institution, the Victoria University of Manchester which itself originated from Owens College, the first civic university in England, established in 1851 (Jones 1988). The case of the MMI shows how a mechanics' institute established in the first half of the nineteenth century could evolve successfully into a prestigious university specializing in science and technology. The following Preamble of the MMI's Rules and Orders beautifully illustrates the 'intended' mission, instructional methods and contents of a mechanics' institute of the time, although it was not at all easy for these to be fulfilled given the situation at the time.

**Preamble of the Manchester Mechanics' Institution**

This society was formed for the purpose of enabling Mechanics and Artisans of whatever trade may be, to become acquainted with such branches of science as are of practical application in the exercise of that trade, that they may possess a more thorough knowledge of their business, acquire a greater degree of skill in the practice of it, and be qualified to make improvements and even new inventions in the Arts which they respectively profess. It is not intended to teach the trade of the Machine Maker, the Dyer, the Carpenter, the Mason, or any other practical business, but there is no Art which does not depend, more or less on scientific principles, and to search what these are, and to point out their practical application, will form the chief objects of this institution. The mode in which it is proposed to accomplish these purposes is, in the first place, by the delivery of Lectures on the various sciences, and their practical application to the Arts of these lectures. Mechanical Philosophy and Chemistry will, of course, be leading subjects; and when their general principles, and those of other important Sciences have been made known, more minute and detailed instruction upon particular branches of Art, will form the subjects of subsequent lectures. It is intended that a suitable Library shall be formed for circulation and reference, and that there shall be a collection of Models, Instruments, together with an experimental Workshop and Laboratory. It is hoped, also, that instruction may be given in the elements of Geometry, in the higher branches of Arithmetic, and in Mechanical and Architectural Drawing. (Quoted from Hudson, 1851, p.56)

## 4. The mechanics' institutes movement and science teaching

What were main social backgrounds of the MIM in the early years of the nineteenth century in Britain? As an indicator showing the degree of adult literacy, the average percentage of people who could sign their names in the marriage register was quite low, for example 58% (66 % of men and 50% of women) in 1840 (Kelly, 1957, p.332). Together with low adult literacy rates, the provision of elementary education was also very limited. For instance, the average percentage of children aged 5-15 not attending school was 53% in Liverpool in 1835 and 35% in York in 1836 (Kelly, 1957, p.336).

Mechanics' institutions were in fact one of the various forms of further education in England, that were prevalent in the $18^{th}$ and $19^{th}$ century, along with Sunday Schools, Adult Schools, the Working Men's Colleges, the Young Men's Christian Association, Night Schools and Evening Classes under Government inspection, the extension of University teaching, Free Public Libraries and the National Home Reading Union (Sadler, 1908). The backgrounds of the origins of these further education institutions were the Industrial Revolution and the following changes of educational needs.

The swift economic change which took place at the time of the Industrial Revolution created large communities which, educationally, were almost destitute. Philanthropic effort set itself to

> grapple with their needs. Again, the Industrial Revolution brought to the front numbers of vigorous workpeople who felt their lack of early schooling and were eager for the opportunities of intellectual self-improvement afforded by the evening class. Thirdly, great numbers of these men, in order to satisfy their curiosity about industrial processes and to enhance their technical skill, craved scientific information, much of which could conveniently by given in evening classes held when the day's work was done. (Sadler, 1908: pp.3–4)

Following initial successes in Edinburgh, Glasgow, and London, similar Mechanics' institutes began to be established at great speed across Britain. Especially in England a whole cluster of institutes grew up in suburbs: at least 13 new institutes were established in 1824 and 70 in 1825. By 1826 there were over 100 (Kelly, 1992, p.122). According to Hudson (1851), after a steady growth in number, by 1850 there were about 700 mechanics' institutions or similar organisations and over 120,000 members, which is impressive considering the fact that all these arose from the voluntary efforts of workers and the well-to-do without government support. In 1850, in mechanics' institutions across the UK, there were over two millions book loans, about 5,800 lectures delivered, and 408 news rooms (Hole, 1853, p.10). In terms of size, while there were some large institutions with over 500 memberships, the great majority of them were small; there were 551 institutions with under 200 memberships in 1851 (Kelly, 1957, p.330).

The MIM was not confined to Britain. The ideas and success of the Andersonian Institute and the LMI attracted the attention and imagination of foreign countries, particularly English speaking ones, in a quite remarkable fashion. For example, in the US, the Franklin Institute in Philadelphia was formally established early in 1824, the Maryland Institute of Baltimore in 1825, the Boston Mechanics' Institution in 1827. The spread of the British model of mechanics' institutes went on to other Commonwealth regions like Canada (e.g. the Montreal Mechanics' Institute, 1828), Australia (e.g. the Mechanics' School of Arts at Sydney, 1833), New Zealand (e.g. the Mechanics' Institution at Port Nicholson, 1842), and India (e.g. the Calcutta Mechanics' Institute, 1839; the Bombay Mechanics' Institution, 1848) (Hudson, 1851). Some historians of education (e.g. Keane, 1988) refer to this expansion of the MIM across the world as the international "useful knowledge" movement and to the Mechanics' Institutes as its international agencies.

The MIM was at its peak around the middle of the 19th century. Entering into the second half of that century, its initial moving force, i.e. the diffusion of useful knowledge among workingmen, began to fade away. While some mechanics' institutes disappeared, many of them morphed into institutions with different functions and names. For example, as explained above, the MMI was able to maintain its science and technology orientation and to evolve into a world class university specialising in science and technology. In case of the LMI, it was also able to keep the tradition, not of science and technology but of adult education, and to become a higher education institution specializing in humanities and social sciences with an ongoing tradition of evening classes open to the general public. Some of the mechanics' institutes also maintained their tradition of professional development and remained as further education institutions; the York Mechanics' Institute which became York College would be a typical example (Cheetham, *et al.*, 2008). Many other mechanics' institutes became libraries or were given to public libraries after the Public Libraries Act was passed in 1850.

## Why Teach

The *Preamble of the Rules and Orders* of the LMI stated "The object proposed to be obtained is the instruction of the Members in the principles of the Arts they practice, and in the various branches of science and useful Knowledge." (Kelly, 1957, p.88). The object of the LMI was repeated in the preamble of MIM, stating "… for the purpose of enabling Mechanics and Artisans of whatever trade may be, to become acquainted with such branches of science as are of practical application in the exercise of that trade, that they may possess a more thorough knowledge of their business, acquire a greater degree of skill in the practice of it, and be qualified to make improvements and even new inventions in the Arts which they respectively profess. …" (Hudson, 1851, p.56).

Thus, the primary 'intended' aim of the LMI and the MMI was to teach its members (i.e. mechanics and artisans) scientific principles and useful knowledge relevant to their job. However, this intended aim gradually attenuated as more and more non-working class people joined the institutions (e.g. Kelly, 1957), principally based on the belief that "… there is no Art which does not depend, more or less on scientific principles" (Hudson, 1851, p.56). This career-supportive aim of the MIM is well matched with today's idea of scientific literacy and appeared in the *National Science Education Standard* quoted earlier: "… everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. Scientific literacy also is of increasing importance in the workplace. More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems" (National Research Council, 1996, p.1).

On the other hand, the common spirit of establishing mechanics' institutes was a reflection of and a forward step taken from Birkbeck's rather philanthropic feeling at the Andersonian Institute.

> I behold, through every disadvantage of circumstance and appearance, such strong indications of the existence of unquenchable spirit, and such emanations from 'the heaven lighted lamp in man', that the question was forced upon me, Why are these minds left without the means of obtaining that knowledge which they so ardently desire, and why are the avenues of science barred against them because they are poor? It was impossible not to determine that the obstacle should be removed… (Birkbeck, 1799: re-quoted from Kelly, 1992, p.119)

## What to Teach

At the Andersonian Institute, the first mechanics' institute, there were various self-supported classes covering a wide range of subjects with natural sciences as the core: Natural Philosophy, Chemistry, Mathematics, Algebra and Arithmetic, Writing, Book-keeping, Grammar and Geography, French, Drawing, Elocution, Principles and Practices of Surgery, Practical Chemistry, Midwifery, Practice of Medicine and Anatomy, and Materia Medica (Hudson, 1851, p.38). The Preamble of the MMI (1824) also says "… in the first place, by the delivery of Lectures on the various sciences … Mechanical Philosophy and Chemistry will, of course, be leading subjects; and when their general principles, and those of other important Sciences have been made known, more minute and detailed instruction upon particular branches of Art, will form the subjects of subsequent lectures. … It is hoped, also, that instruction may be given in the elements of Geometry, in the higher branches of Arithmetic, and in Mechanical and Architectural Drawing." It seems that at least at the beginning of some institutions the lectures, particularly on the basic sciences, were mostly delivered by then famous scholars: for example, at the LMI in 1824: Mechanics by Prof. Millington, Chemistry by Mr. Phillips, Geometry by Mr. Dotchin, Hydrostatics by Dr. Birkbeck, Application of Chemistry to the Arts by Mr. Cooper, Astronomy by Mr. Newton, Electricity by Mr. Tatun

(Hudson, 1851, pp.49-50).

On the other hand, according to the list provided by the Vice-President of LMI, Charles Toplis, to the Select Committee on Arts and Manufactures in 1835, the subjects and membership were as follows: English Grammar (73), Writing (40), Arithmetic (36), Mathematics (20), Practical Geometry (45), Drawing (39), Drawing the Human Figure (2 classes, 38), Modeling (av. attendance 12), Landscape Drawing (30), French (av. attendance 40), Latin (av. attendance 12), Shorthand (occasionally, av. attendance at last class 50). There were also mutual improvement classes in Literary Composition, Chemistry, Experimental Philosophy, Geography, Natural History, and Phrenology (Kelly, 1957, p.132). About two decades after its establishment, the list of the major classes (1840-49) of the Edinburgh School of Arts illustrates which subjects were popular: Natural Philosophy, Chemistry, Mathematics, English, Drawing, Modeling, Arithmetic, French, Natural History, Political Economy, and Singing (Hudson, 1851, p.76).

The examination of subjects in various mechanics' institutes (e.g. of the Andersonian Institute around 1800, the MMI in 1824, the LMI in 1835) shows that the 'intended' contents can be largely grouped into five groups: that is, basic sciences (e.g. natural/experimental/mechanical philosophy, chemistry, natural history, geography) as the main one, mathematics (e.g. arithmetic, (practical) geometry, algebra, mathematics), vocational subjects (e.g. mechanical/architectural drawings, modeling, midwifery, shorthand), language and liberal arts (e.g. English (grammar), French, Latin, political economy), and leisure (e.g. landscape/human figure drawing, singing). In fact, according to the data on lectures delivered in the MMI (1835-1849), it is apparent that there was a substantial decrease in the number of lectures on physical science (from 60% during 1835-39 to 38% during 1845-49) alongside a considerable increase in the number of lectures on literature and education (from 13% during 1835-39 to 37% during 1845-49) (Hole, 1853, p.30).

It is frequently claimed that the decline of the MIM after the 1850s was largely due to the increase of non-scientific subjects, resulting in a loss of its original impetus. It is, however, necessary to consider the change of the MIM's social roles after the introduction of the DSA (Department of Science and Education) Examination and elementary education systems during the second half of the 19th century (e.g. Inkster, 1976; Song & Cho, 2002; Morris, 2003). In addition, the higher education system in England and Wales was being expanded, beyond the boundary of Oxbridge and London, with the establishment of a series of civic universities, including Manchester in 1851, Leeds in 1874, Bristol in 1876, Birmingham in 1880, Liverpool in 1881, Reading in 1892, and Sheffield in 1897 (Jones, 1988). Since the middle of the 19th century, the overall system of education in Britain became better established and more available to a wider spectrum of the society.

## How to Teach

As shown in the *Preamble of the revised Rules and Orders* of LMI (1823), the proposed means of instruction of the institution included lecture, experiment and exhibition as ways of instruction with the library, museum, elementary school, workshop, and laboratory as its facilities. A similar list of means of instruction appeared in the *Preamble of the Manchester Mechanics' Institution* (1824): "… The mode in which it is proposed to accomplish these purposes is, in the first place, by the delivery of Lectures … It is intended that a suitable Library shall be formed for circulation and reference, and that there shall be a collection of Models, Instruments, together with an experimental Workshop and Laboratory." That is to say, the 'intended' ways of teaching science in the MIM were quite diverse including lecture, experiment, exhibition, library, models, instruments, a workshop, and a laboratory. Aside of no mention of IT and the Internet, which were obviously not available at that time, these are not very different from today's ways of teaching science.

Laboratories were equipped with a range of apparatus. For example, the Liverpool Mechanics' Institution in 1832 possesses the following list of physics-related apparatus: (Mechanics) Atwood's machine, inclined plane, wheel and axel, etc.; (Hydraulics) Force and lift pump, Archimedean screw, etc.; (Hydrostatics) Rotary blowing engine; (Pneumatics) Air pump, guinea and feather apparatus, brass hemispheres; (Optics) Magic Lantern; (Electricity) Cylindrical machine, battery of five jars, etc. ; (Galvanism) Troughs and piles (re-quoted from Bishop, 1994, p.44).

Besides regular instructions, exhibitions held on special occasions also played an important role for science teaching, in this case to a wide audience not just to their members. For example, at the MMI's exhibition in 1839, over 26,000 items of 27 categories were displayed (Tylecote, 1957, p.306). The MMI's first exhibition was opened "on the 27th of December, 1837, and remained open nearly six weeks, and was visited by upwards of 50,000 persons" (Hole, 1853, p.78). At the following annual meeting of the MMI, Sir Benjamin Heywood expressed his feeling toward the exhibition:

> Where shall I begin in the enumeration of its happy influences? Shall I speak of the spirit which animated those who undertook its preparation and arrangement, of the days and nights of labour they devoted to it; of the readiness and kindness with which contributions of all kinds were offered to it by thousands and tens of thousands, … It was delightful to see the countenances, beaming with pleasure, of the working-men, their wives, and their children, … I could not help feeling, …, how false an estimate those have formed, who dare not trust their collections to public inspection. ... Oh! Let it be known throughout the country, let it open doors that have hitherto been closed, let our own town be the first to profit by the example, and let us see our National History Society, our Royal Institution, our Botanic Garden, our Zoological Garden thronged, as your exhibition has been with working-men and their families. Treat the working-man with generosity and confidence, and he will repay you with honesty and gratitude…" (Hole 1853, pp.78-79)

At the beginning of the MIM period, due to the lack of its supply system, the provision of instruction materials was very limited even when funds became available. The issue was not seriously challenged until the foundation of the *Society for the Diffusion of Useful Knowledge* (hereafter SDUK) in London in 1826. The SDUK was founded by Lord Brougham (1778-1868), an old friend of Birkbeck from the days of Edinburgh University, as the ally of the mechanics' institutes and similar organisations intended for the education of the working classes. The SDUK, mainly through the efforts of Brougham as the president and Charles Knight as the publisher, provided cheap educational literature for the self-educated masses. Among them, the *Library of Useful Knowledge* (a biweekly 32-page focusing on scientific topics published from 1827), the *Penny Magazine* (a weekly 8-page miscellany of literature, history, science and arts, illustrated by woodcuts, published from 1832), and the *Penny Cyclopaedia* (published in 27 volumes, launched in 1832 and completed in 1844) were mainly achievements for 'popular science' (Tuner, 1927; Kelly, 1992; Lightman, 2007). It is, however, believed that, despite a remarkable success at the initial stage (e.g. nearly 30,000 copies of the *Library of Useful Knowledge* and 200,000 sales of the *Penny Magazine*) these failed to match the needs of 'intended' readers, being too scientific and too difficult for the average working man, and resulted in a steady decline in sales (Kelly, 1992).

## Discussion and Implications

The MIM has not really been studied in the field of science education but in other disciplines, like the histories of science, of adult education and of technical education (e.g. Hodgen, 1925; Tylecote, 1957; Inkster, 1976; Laurent, 1984; Kelly, 1992). Since the details of George Birkbeck (i.e. Godard, 1884; Kelly, 1957) and of the MIM (e.g. Hudson, 1851; Hole, 1853) are well-documented elsewhere, the main focus of this study has been on how to understand the MIM from the perspectives of science education. So far, studies of science education, even those that deal with its history, have not attempted to include the works of Birkbeck and the MIM (e.g. DeBoer, 1991 & 2000; Rudolph, 2008; Donnelly, 2009), possibly based on the belief that they simply do not belong to the territory of science education. From a traditional point of view, science education used to be something to do with school science, that is curricula, textbooks, teachers, students, assessments and so on. However, as mentioned earlier, today's science education does not confined to traditional boundaries of 'school' and 'science', especially from the perspectives of scientific literacy. In this sense, the meanings and implications of the history of MIM can be re-examined and interpreted from the perspectives of science education.

The first half of the 19th century in Britain was full of a belief in workmen's self-esteem and their eagerness for scientific knowledge and principles as well as philanthropists' good-will and support for their wishes. Even elementary education during the period was not available to workmen, and there was no other place but the Mechanics' Institutes for them to get some sorts of scientific knowledge needed in their working places. The combination of workmen's desire and gentlemen's sympathy, together with such a social condition, provided the social background of the MIM, which is truly one of the rare cases of voluntary educational movement on such a large scale. It is also interesting to note that this kind of self-education movement came not from 'soft' areas, like reading or music, but from 'hard' ones: science and applied mathematics. One of the key reasons why this voluntary movement of science education lasted so long, more than a half of a century, must be that it managed to meet the needs of its audience. There were on-going negotiation, and frequently debates, on how to maintain active participation from workmen and to secure a steady influx of donations from the upper classes, on what was to be taught, and on how to support the teaching and learning of science. These have been and still are the essential questions for any meaningful and effect teaching of science.

In addition, it was not until 1871 that the Cavendish Laboratory at Cambridge with its first professor, James C. Maxwell (1831-1879), opened for the provision of the systematic teaching of experimental physics. It was only twenty years before that Natural Science could get its place as a separate subject in the Cambridge Tripos examination. Science teaching at younger universities, representatively at University College and King's College in London, came earlier but only after the 1830s. Not surprisingly, science teaching in elementary and secondary schools developed later than in higher education institutions, mostly well after the 1850s (e.g. Turner, 1927; DeBoer, 1991; Bishop, 1994). It is thus fair to claim that the teaching of science at mechanics' institutes preceded any formal science teaching in Britain.

In sum, the MIM was a unique social phenomenon in which science could respond to the needs of skilled workers through education, providing science learning opportunities which were otherwise impossible. As we have seen so far, despite huge gaps in history and social conditions, the MIM seems to share many similarities with today's practice of science education focusing on scientific literacy, thus moving towards a wider career perspective, cross-subject, community-based, and informed citizenship. Of course, the 'intended' mission of the MIM was not easily accomplished in practice, due to mismatches between initial and actual aims, curricula and learners. The nature of the MIM could be better understood in its wider historical contexts, such as its relationships with pre-existing more professional and upper-class organisations (e.g. *Lunar Societies, Literary and Philosophical Societies, the Royal Institution*), contemporary friendly organisations (e.g. the SDUK), and later introductions of DSA examinations and the elementary and higher education systems (Turner, 1927; Cardwell, 1972; Roderick & Stephens, 1972; Bishop, 1994). The MIM can also be regarded as the historical precedent for later waves of science education focused on people and society (i.e. movements of General Science / Science and Citizenship during the 1920-40s, STS during the 1970-80s, and more recent SSI approaches) which appeared alternatively with more discipline-oriented counterparts of the swinging pendulum of the history of science education. The period of the MIM was, in fact, followed by the period of securing science subjects in British school curricula during the second half of the 19th century, representatively through the works of T. H. Huxley, H. E. Armstrong, and the British government and Royal Commissions (such as, *Royal Commission on Scientific Instruction and the Advancement of Science* (1871-5)) which was more discipline-oriented (e.g. Turner, 1927; Layton, 1973; Bishop, 1994; Song, 1999).

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