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Practical Work in British School Science during the Second Half of the 19th Century

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ABSTRACT

This study examines how practical work in science was introduced in British schools and became an important part of school science activities during the second half of the 19th century. Firstly, the establishment of a national education system in Britain is reviewed. Secondly, a general development of school science teaching is summarized with a special attention to students' enrollment in science subjects. Thirdly, the practical work in elementary schools are discussed in relation to the introduction of Object Lessons in curriculum. Then, the situations of practical work in science in secondary schools, particularly in Organized Science Schools and some famous public schools, are illustrated. Finally, the overall development until present days is critically discussed in relation to the types and aims of practical work in science.

Key words: practical work, Britain, school science, 19th century, Victorian science

Ⅰ. Introduction

On May 1st, 1851, Queen Victoria opened the *Great Exhibition* in the Crystal Palace built in Hyde Park, London. The Great Exhibition was probably the most important, if not the first, single event through which Great Britain realized her status in science and technology as second-best, and began to review critically the whole system of supporting science and technology, including the educational system of science.[1] The circumstance of the *Great Exhibition* in 1851, in which Great Britain realized the great advance by rival countries - particularly France and Germany -, was similarly repeated almost a century later in the USA when her rival, the USSR, succeeded in launching the first earth-orbiting satellite *Sputnik* in October, 1957.

On the other hand, at the very beginning of the new century (i.e. January 1901), the

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1) In 1867 when the great International Exhibition was held in Paris, a more direct alarm and warning of the failure of Britain was given towards the technical education movement through an important letter from Lyon Playfair, who was among the British jurors, to Lord Taunton of the Schools Inquiry Commission. Playfair's conclusion was an urgent necessity for a governmental inquiry into the question of how foreign workers were acquiring intellectual preeminence and how nations were applying this scientific skill to national industries (Cardweel, 1972: 111-112).

Association of Public School Science Masters(APSSM)[2] came into being. The year 1902 is also considered to be the beginning of important steps towards a unified system of education in England. The Education Act of 1902 co-ordinated all forms of education under local education authorities, and this swept away the old *ad hoc* system which had been inherited from the days of *laissez faire* (Argles, 1964: 56,59).

Between these two important dates (i.e. the second half of the 19th century), important foundations for school science education were established in Britain. For example, science became an importance part of elementary and secondary school curricula; the examination systems for science subjects were introduced; the government provided the grants for science teaching and for practical work in science subjects, and science teaching became a branch of professional occupations.

Throughout the 20th century, there have been many valuable historical accounts of the practical aspects of science teaching in British schools. For example, Sutcliffe(1929) provided a brief historical summary of the introduction of student laboratories from the 17th century to the 19th century in England. Armstrong(1946) outlined the growth of experimental physics teaching from the 17th century to the 1930s. More recently, Nott(1997) provided a comprehensive account on the introduction of the laboratory into English schools during the period between the late 19th century and the beginning of the 20th century. He paid particularly attention to illustrate the roles of school laboratories as the working places for professional scientists - i..e. science teachers. Jenkins(1998) also outlined the growth of laboratory teaching since the late 19th century and examined the roles of the practical work in school science until the introduction of the National Curriculum during the 1980s and 1990s. These studies in general have provided comprehensive descriptions and theoretical arguments of the educational and philosophical backgrounds of the growth of practical work in school science.

It is, however, still not clear, from these studies, what were the actual situations of practical work in school science during the second half of the 19th century. There have been relatively few details reported, compared with well-summarized general arguments on the topic. In addition, the previous studies largely provided historical accounts on a few more selected areas (particularly, school laboratories), rather than on the multiple aspects of the practical work.

With this background, the present study attempts to provide a more comprehensive picture of the practical work in school science during the period, largely corresponding to Victorian ear, that is the second half of the 19th century, particularly through providing more details, which have not been widely reported, across the various aspects of the topic.

Ⅱ. The 19th Century: the Establishment of a National System for Education

At the beginning of the 19th century, there was no organized system of elementary education

2) It later became Science Master's Association(SMA), and then the Association for Science Education(ASE).

Journal of the Korean Association for Research in Science Education
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in England and Wales. Despite some educational provision by charity schools (e.g. Sunday Schools) from the 18th century, many children of the working class never went to school at all or spent only two or three years at school. During the first half of the 19th century, elementary education was mainly provided by two voluntary societies, the *National Society for Promoting the Education of the Poor in the Principles of the Established Church* founded in 1811, and the *British and Foreign School Society*[3] named in 1814 (Turner, 1927: 107).

The 19th century was the century of Select Committees and of Royal Commissions on Education (Jones, 1924: 10), and of the introduction of a series of important Educational Acts.

The Reform Bill of 1832 brought up the question of education, for it was realized that an illiterate electorate would be a source of danger to the country. In 1833, Parliament voted £ 20,000 for the purposes of education[4] and the money was administered through the two voluntary societies. The grant was renewed annually until 1838.

In 1857, influenced by the fact that government's grants to schools increased very rapidly beyond the government's capability[5], the *Newcastle Commission*[6] was appointed to consider ways of providing 'sound and cheap elementary instruction'. One of the Commission's recommendations was *Payment by Results*, and this system was formally introduced by the *Revised Code of 1862*. Thus, grants to schools, and hence the salaries of the staff, depended on the results of an individual examination of the pupils. This system of *Payment by Results* affected the whole system of elementary education for many years. The examinations consisted of specific tests in the 3R's (i.e. reading, writing and arithmetic), in six gradations of difficulties, known as Six Standards[7] (Turner, 1927: 108). The curriculum for each standard was clearly laid down, and this undue emphasis on only instrumental subjects directed attention to bring pupils up to a certain mean standard of attainment. Consequently, the teaching became monotonous, and the whole atmosphere of the school became one of dead uniformity (Turner, 1927: 109). Table 1 shows the content of 'Arithmetic' of the *Revised Code of 1879*, in which some elements of science, i.e. measurement, could only be found in Arithmetic of Standard IV.

Extra grants were first offered in 1867 to schools which taught one or more Specific Subjects of secular instruction beyond the 3R's; but it was under the *New Code of 1871*[8] that a special

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3) This was reformed and re-named from the *Royal Lancasterian Society* which was set up in 1808 by the nonconformist supports of Joseph Lancaster.
4) However, the sums would only be paid when at least half of the cost (of school building) had been raised by private subscription. This was a serious shortcoming, for the poorest areas, where needs were greatest, were least able to put up their share (May, 1998: 9).
5) For example, the grants were £150,000 in 1851 but they had risen to £541,233 by 1857 (May, 1998: 26).
6) This Royal Commission was under the chairmanship of the Duke of Newcastle.
7) Generally, the Standards corresponded to the years of school life. For example, Standard I included children aged between six and seven, while Standard VI included those aged between eleven and twelve. In 1882, a Standard VII was introduced (May, 1998: 28).
8) This was possible largely through the influence of the writings of contemporary influential persons, such as Herbert Spencer and T. H. Huxley.

Table 1. An extract of 'Arithmetic'* of the *Revised Code of 1879*

Standard I	Standard II	Standard III	Standard IV	Standard V	Standard VI
Notation and numeration up to 1,000. Simple addition and subtraction of numbers of not more than four figures, and the multiplication table, to 6 times 12.	Notation and numeration up to 100,000. The four simple rules to short division (inclusive).	Notation and numeration up to 1,000,000. Long division and compound addition and subtraction (money).	Compound rules (money) and reduction (common weights and measures).+	Practice, bills of parcels, and simple proportion.	Proportion, vulgar and decimal fractions.

Notes: * 'The work of girls will be judged more leniently than that of boys.'
+ 'The 'weights and measures' taught in public elementary schools should be only such as are really useful; - such as Avoirdupois Weight, Long Measure, Liquid Measure, Time Table, Square and Cubical Measure, and any measure which is connected with the industrial occupations of the district.'

grant for individual scholars who passed in two Specific Subjects[9] in addition to the 3R's was introduced. The establishment of this special grant marks an important stage in the evolution of science teaching. The curriculum of elementary schools from 1875 to the closing years of the century consisted of the following three divisions (Turner, 1927: 100-101):

① Obligatory Subjects (i.e. the 3R's, together with some other subjects[10]),
② Class Subjects[11] (optional for the whole school above Standard I), and
③ Specific Subjects (taught to individual scholars in Standards IV to VI).[12]

9) These subjects included geography, grammar, algebra, geometry, natural philosophy, physical geography, natural sciences, political economy, and languages.

10) In 1871 'Plain needlework and cutting out' was involved (only for girls) as a Obligatory Subject. But when the Class Subjects were introduced by the *Code of 1875*, it was classified as a Class subject (Education Department, 1897: 56-58). By the *Code of 1895*, Object Lessons (together with Suitable Occupations for Standards I-III) was added to the Class Subjects. But, by the *Code of 1896*, Object Lessons was made obligatory as the First Class Subject in Standards I, II and III (Committee of Council on Education, 1899).

11) When the Class Subjects were first introduced by the *Code of 1875*, they consisted of Grammar, History, Elementary Geography, and Plain Needlework. By the *Code of 1882*, the recognised Class Subjects were stated to be English, Geography, Elementary Science, History, and Needlework (for girls). Welsh (in Wales) by the *Code of 1893* and Domestic Economy (for girls) by the *Code of 1894* were added to the Class Subjects. Besides, Drawing had been a Class Subject during 1886-7 and it was taught in 240 schools in 1886 and in 505 schools in 1887. (Committee of Council on Education, 1899: 116).

12) See Education Department, 1897: 58-63.

Before 1870, it would be fair to argue that there was no national system of education in Britain.[13] The *1870 Education Act*, known as *Forster's Act*, was a belated recognition by the state that the voluntary elementary education given by the two organizations were quite unable to cope (Brock, 1996: X, 953). It empowered school boards, if they so chose, to frame by-laws to compel attendance, but many failed to do so. Ten years later(i.e. through the *1880 Education Act*), however, the framing of such by-laws became compulsory, and thus made a significant impact on the number of children in school. Thereafter, all children in England and Wales were required to attend school until the age of ten, while children aged between ten and thirteen might leave once they had reached Standard V. In 1893, the school-leaving age was raised to eleven, and it was raised again to twelve in 1899 (May, 1998: 29). In terms of actual teaching in schools, however, the *Technical Instruction Act of 1889* and the *Local Taxation (Customs and Excise) Act of 1890*, which made the Residue Grant, so called 'Whisky Money', would be one of the most significant events which gave a real impact on the ways of teaching in schools, particularly science and industrial subjects(Ministry of Reconstruction, 1919: 3).

Ⅲ. School Science Teaching during the 19th Century

The increase of various technological activities at the beginning of the century stimulated a demand for workers who were knowledgeable about how these things worked and how to work them, and about the scientific principles that underpinned them. One of the responses to this need was the establishment of Mechanics' Institutes in major cities and towns throughout the country.[14] Lectures were given on the principles of areas of science such as Mechanics, Heat, Light, and Chemistry. Practical work in classrooms and lecture halls consisted of lecturers demonstrating the facts of science in front of the audience. Thus, although the apparatus used were generally simple, demonstration work and apparatus were introduced into science education before the introduction of the laboratory as a teaching space. (Nott, 1997: 49-50). In addition to class teaching, lecture, and demonstration, the Mechanics' Institutes also usually held exhibitions in which many educational items as well as new development from the industry were displayed. For example, Table 2 shows the articles shown at an exhibition held at the Manchester Mechanics' Institute in 1839 (Tylecote, 1957: 306). After the vast expansion between 1820s and 1840s, however, the movement of Mechanics' Institutes had been fading away since the 1850s, and its original aim, to teach scientific principles, was replaced by a more broad and liberal one to teach nearly all subjects, including social activities.

Science was a late starter among school subjects, as it was in the university. The teaching of

13) Well over a million working-class children between the ages of six and ten years received no education whatsoever, and it is estimated that a further half-million aged between ten and thirteen also never attended school.

14) For more details, see *The History of Adult Education* (Hudson, 1851), *George Birbeck: Pioneer of Adult Education* (Kelly, 1957), and *The Mechanic' Institutes of Lancashire and Yorkshire before 1851* (Tylecote, 1957).

Table 2. Various kinds of articles in the first exhibition held at the Manchester Mechanics' Institute (from the Annual Report of 1839)

31	Models of Steam Engines.
79	Models of useful Machines and ingenious Mechanical Contrivances.
20	Models of Ships, Packets, Boats, etc.
400	Specimens of beautiful Manufactures, and of superior workmanship in the Arts.
12	Models of Public Buildings.
40	Specimens of Papier Mache and Cabinet Work.
19	Time-Pieces and Clocks.
90	Philosophical Instruments.
160	Ancient and Modern Curiosities.
1,050	Medals, Coins, and Plaster Casts of Medallions.
59	Landscape Paintings.
35	Painted Portraits.
64	Historical and Allegorical Paintings.
13	Paintings illustrative of Natural History.
290	Engravings.
140	India Ink and Coloured Designs and Drawings.
28	Specimens of Glass, painted and stained.
30	Busts.
20	Figures in Marble and Plaster of Paris.
200	Natural Curiosities.
300	Botanic Specimens.
7,000	Mineralogical and Geological Specimens.
1,120	Birds.
100	Quadrupeds and Reptiles.
4,000	Shells.
10,000	Insects.
1,000	Coralines.

science in elementary schools began to get under way in the 1840s, through the influence of remarkable men such as Richard Dawes, J. S. Henslow and Henry Mosleley (Layton, 1973). However, the progress was quickly checked in 1862 through the introduction of a system of *Payment by Result*. Although, this system was modified about ten years later to take some account of science, as pointed out in Devonshire Commissioners's report of 1872, the situation of science teaching in (teacher) training college and elementary schools was far from satisfactory (Ingle & Jennings, 1981: 15).

Table 3 and Table 4 show the extent of the change of school science teaching during the late 19th century, particularly compared with other major subjects. As shown in Table 3,[15] Elementary Science, together with Object Lessons, was the fastest expanding Class Subject,

15) Committee of Council on Education, 1899: 116.

specially compared with other, more traditional, subjects, such as English, Geography, Needlework. On the other hand, Table 4 shows the steady growth of all major branches of science - i.e. Mechanics, Botany, Chemistry and Magnetism and Electricity.[16] The dramatic decrease of Latin illustrates a clear contrast.

Ⅳ. Practical Work in Elementary School Science

A general provision of elementary education in England and Wales was expanded so much during the first quarter of the century, from the passing of the *Elementary Education Act, 1870.*[17]

London School Board, which was formed after the first election in November 1870, experimented with ways of encouraging teachers to make it a central feature of science lessons. The most important experiments were (i) the introduction, in 1885, of a Peripatetic System of teaching mechanics (and, later, physics and chemistry), and (ii) the introduction of evening classes for teachers (Waring, 1985: 124).

Table 3. Number of departments in day schools where class subjects were taught

Year ending 31 August	English	Geography	Elementary Science	History	Needlework (Girls)	Welsh	Domestic Economy (Girls)	Object Lessons	Student Occupations
1884	19,080	12,775	51	382	5,929	-	-	-	-
1885	19,431	12,336	45	386	6,499	-	-	-	-
1886	19,688	12,055	43	375	6,809	-	-	-	-
1887	19,917	12,035	39	383	7,137	-	-	-	-
1888	20,041	12,058	36	390	7,424	-	-	-	-
1889	20,151	12,171	36	386	7,620	-	-	-	-
1890	20,304	12,367	32	414	7,758	-	-	-	-
1891	19,835	12,806	173	750	8,026	-	-	-	-
1892	18,175	13,465	788	1,627	7,655	-	-	-	-
1893	17,394	14,256	1,073	2,209	7,612	-	-	-	-
1894	17,030	15,250	1,215	2,972	7,675	1	-	-	-
1895	16,272	15,702	1,396	3,597	7,396	8	316	-	-
1896	15,327	16,171	2,237	4,143	7,219	18	471	1,079	360
1897	14,286	16,646	2,617	5,133	7,397	31	633	8,321	392
1898	13,456	17,049	2,143	5,780	7,252	12	784	21,882	176

16) Committee of Council on Education, 1899: 114-115.

17) During the time, the attitude of the nation as a whole towards elementary education underwent a surprising change. The value of a good school had become more widely appreciated, and parents evinced an increasing desire to secure the benefits of efficient teaching for their children. This change in public opinion had made possible much which the zeal of educational reformers, the goodwill of local authorities, the liberality of subscribers, and the experience and devotion of the teachers, would otherwise have been powerless to effect (Education Department, 1897: 8).

Table 4. Number of day scholars presented in science and some other Specific Subjects

Year ending 31 August	Specific Subjects											
			Science									
	English Literature	Latin	Physical Geography	Mechanics	Animal Physiology	Botany	Principles of Agriculture	Chemistry	Sound, Light and Heat	Magnetism and Electricity	Shorthand	Domestic Economy (Girls)
1872	11,085	32	1,036	-	901	-	-	9	(8)	←	-	357
1873	19,817	46	658	-	25	-	-	14	(70)	←	-	600
1874	26,881	36	1,088	37	660	45	-	41	(115)	←	-	844
1875	39,211	65	2,087	-	966	58	-	26	(11)	←	-	1,211
1876	34,931	452	8,553	299	5,936	483	-	27	(20)	←	-	3,307
1877	44,790	616	18,936	584	13,032	913	-	-	-	-	-	10,919
1878	58,966	654	23,126	884	15,866	928	-	-	-	-	-	24,636
1879	80,137	864	29,459	1,621	20,506	1,332	-	-	-	-	-	37,409
1880	113,193	881	34,288	2,109	24,725	1,853	-	-	-	-	-	50,797
1881	127,313	1,006	34,382	2,458	25,886	1,903	-	-	-	-	-	55,993
1882	140,772	956	34,207	3,933	27,683	2,149	-	-	-	-	-	59,812
1883	109,485+	720	22,521+	4,136	29,027	2,672	422	368	196	1,133	-	49,037
1884	-	454	-	3,380	22,857	2,604	1,859	1,017	1,253	3,244	-	21,458
1885	-	365	-	3,766	20,869	2,415	1,481	1,095	1,231	2,864	-	19,437
1886	-	342	-	4,972	18,523	1,992	1,351	1,158	1,334	2,951	-	19,556
1887	-	363	-	6,348	17,338	1,589	1,137	1,488	1,158	2,250	-	20,716
1888	-	371	-	7,292	16,940	1,598	1,151	1,808	978	1,977	-	20,787
1889	-	350	-	9,651	15,893	1,944	1,199	1,531	1,076	1,669	-	22,064
1890	-	360	-	11,662	15,842	1,830	1,228	2,007	1,183	2,293	-	23,094
1891	-	347	-	15,559	15,050	2,115	1,231	1,847	1,085	2,554	814	27,475
1892	-	260	-	18,000	13,622	1,845	1,085	1,935	1,163	2,338	3,605	26,447
1893	-	247	-	20,023	14,060	1,968	909	2,387	1,168	2,181	5,650	29,210
1894	-	226	-	21,532	15,271	2,052	1,231	3,043	1,175	3,040	8,293	32,922
1895	-	250	-	23,806	17,003	2,483	1,196	3,850	914	3,198	10,332	36,239
1896	-	186	-	24,956	18,284	2,996	1,059	4,822	937	3,168	10,479	39,794
1897	-	112	-	26,110	19,989	3,377	825	5,545	1,040	3,431	11,090	45,881
1898	-	224	-	27,009	22,877	4,031	870	6,978	1,155	3,905	12,665	51,259

* By the Code of 1875, grammar, history, and elementary geography were, from 31 March, 1876, to be considered the Class Subjects. Algebra, euclid, and mensuration became "Mathematics".

\+ By the Code of 1882, English and physical geography were, from 30 April 1883, added to the Class Subjects. Mathematics were divided into "algebra" and "euclid and mensuration". Euclid and mensuration again, by the Code of 1890, were recognised as separate subjects.

←Between 1872 and 1876, "sound, light and heat" and "magnetism and electricity" were considered as one subject, "physics". The numbers in the brackets of "sound, light and heat" show the data of the physics during this period. Physics were then divided into the two subjects from 1883.

Reflecting a growing concern about practical science, a one-off, small-scale, experiment was tried in 1882. Thomas Twining obtained permission to circulate Lecture Boxes in seven board schools at fortnightly intervals for the boys in the 5th and higher standards,. Each Lecture Box contained text, diagrams and apparatus for one of ten lecture-demonstrations on physics, chemistry, natural history or physiography based on his *Science Made Easy* series. Although the experiment appeared to be very satisfactory, no further action was taken.

In the mean time, the *Technical Education Sub-committee*, which was set up following the *First Royal Commission on Technical Instruction*(1881-4), recommended that the Peripatetic plan of teaching mechanics, which had already proved very successful in Liverpool and Birmingham, be tried out in one London district. Following the approval of the Board, W.H. Grieve was appointed as 'science demonstrator', and he was to visit each of twenty-one schools once a fortnight, taking with him the necessary apparatus and equipment. The lecture-demonstration was watched by the class teacher, who then repeated the lesson during the intervening period. On leaving, Grieve gave the teacher a list of questions which boys were to answer in writing before his next visit. The scheme was very popular and satisfied the Technical Education Sub-committee. In 1887, the committee proposed the appointment of three additional demonstrators for schools in the Board's other three divisions (Waring, 1985: 125-7).[18] [19]

On the other hand, the London School Board appointed a special committee to enquire into the curriculum of the schools. The committee recommended that in Junior and Senior schools there should be given graded Object Lessons[20]. As a result of the recommendation, Object Lessons were given by enthusiastic teachers, who endeavoured to show the relationship between scientific facts and problems of everyday life (Turner, 1927: 110-111).

In 1878, thanks to the influence of J. H. Gladstone(1827-1902), the London School Board issued a syllabus of Object Lessons for the youngers pupils and of elementary science for the optional subjects of the *Whitehall Code* and the more specialized subjects for the examinations of the Department of Science and Art(DSA).[21]

In 1889, Twining provided a *Suggestive Scheme* for science teaching in elementary schools.[22] His scheme basically consisted of two parts: the first part of simple Object Lessons covering

18) The three demonstrators appointed were Mr. G. E. Blanche, Mr. A. Hubble and Mr. S. R. Todd (Turner, 1927: 113).

19) After five years of experiments, however, it became clear that more was needed to help teachers to overcome their anxiety about the practical work. At the demonstrators' request, the Board sanctioned the establishment of regular courses of eight or ten sessions and in addition gave three month's leave of absence every year to enable them to attend summer schools at South Kensington. Doubts were growing about the effectiveness of lecture-demonstrations for achieving the desired ends with pupils, that is, a linkage between 'hand and eye training' and 'mind training'. To achieve this linkage, it was argued, pupils themselves needed to perform experiments (Waring, 1985: 128-9).

20) The object lesson has its origin in the view of some educationists, such as Heinrich Pestalozzi (1746-1827), that children learn through their senses, and should be led from the known to the unknown, and from the concrete to abstract. The method was considered particularly suitable for teaching science, and consisted of bringing into the classroom either natural or man-made objects, each of which would form the basis of a lesson (May, 1998: 20-22).

Standards I to III, and the other part of the basic knowledge of natural sciences covering Standard IV and above. (See Table 5)

In 1895, the *Code* made Object Lessons compulsory in Standards I to III of elementary schools. This led to a considerable increase in the number of children taking Elementary Science as a Class Subject in the upper standards (Turner, 1927: 149).

As the main value of Object Teaching, the following three principal uses were emphasized: (i) to teach the children to observe, compare, and contrast; (ii) to impart information and (iii) to reinforce the other two by making the results of them the basis for instruction in Language, Drawing, Number, Modelling, and other Handwork. Among the above uses, the first use was considered to be the most important. Some other educational advantages were also recognized, such as, to encouraging children to contact directly with nature, to make children by encouraging the exercise of brain, hand and eye, and to develop a love of nature and an interest in living things.[23]

The educational principles of the Object Lessons were sound enough. In practice, however, Object Lessons frequently degenerated into boring rote learning; while the list of such lessons given throughout the term (often to be found in school log books) indicate that there was rarely any coherent relationship between one session and the next (May, 1998: 20-22). Table 6 shows the syllabus for Object Lessons for Standard VII which were in use at the end of the century.[24]

Table 5. Twining's *Suggestive Scheme* for Elementary Science (Twining, 1889)

Standard I, II and III	A Course of simple Object Lessons, adapted to cultivate habits of exact observation and reasoning and to prepare the way for the Elementary Science of the Upper Standards. Each Standard was to include portions of the following subjects :— (a) The chief tribes of Animals, their leading features, habitats, and uses. (b) Plants, their growth and uses. (c) Common substances, their properties and uses.
Standard IV	Notions of Mechanical Physics.
Standard V	Notions of Heat and Chemistry.
Standard VI	Outlines of Physiology.—Applications of the acquired scientific knowledge to the concerns of common life. Food.
Standard VI	Rationale of Common Things, continued.

21) The method of the Object Lessons had been used in the early part of the nineteenth century and such lessons were given at other schools besides elementary ones. For example, the boys of University College School worked through Miss Mayo's book *On Objects* about 1832, but the work was not satisfactory and was abandoned (Sutcliffe, 1929: 86).
22) It was suggested by the chairman of the *Committee on 'Subjects and Modes of Instruction'*, appointed by the School Board of London.
23) Committee of Council on Education, 1899: 704-705.
24) Committee of Council on Education, 1899: 715-716.

Journal of the Korean Association for Research in Science Education
Vol. 22 No. 5(Special Issue), pp. 970~990 (2002)

Table 6. Measuring, weighing, and testing (for Object Lessons)

A two-foot rule.
Measurements of length—first by eye, then with rule.
Easy measurements of a square—first by eye, then with rule.
Easy measurements of rectangles.
The wire-gauge.
Callipers.
Scales and weights.
Weighing of common objects—first by hand, then with scales; weigh in ounces only.
Weighing letters.
Plumb-line.
Spirit level.
Steam—observations on boiling water; condensation of steam, etc.
Mercury—weight of; cf. drop of mercury and drop of water; effect of heat on mercury.
Alcohol—effect of heat on it; its evaporation.
Thermometer, its manufacture.
Thermometer—uses; readings in ice, in boiling water, under the tongue, in schoolroom.
A candle—its composition. The wick.
Candle under bell-jar over water; candle in narrow-necked bottle.
Chalk—where found; its origin.
Chalk—its treatment with acid.
Chalk—its reduction to quicklime with blow-pipe ; lime-water.
Sugar heated in test-tube; wood heated in test-tube.
Sulphur heated in test-tube; lead heated in test-tube.
Magnet and iron fillings.
The compass.

V. Practical Works in Secondary Schools Science

In the year following the DSA's establishment in 1853, 'Science Schools' were proposed in Birmingham and Aberdeen, and the teachers' salaries were guaranteed. In 1856, some Science Schools (and Navigation Schools) were opened in several cities in Britain. Examinations were held and prizes awarded. However, by 1859, the only Science Schools existing at this time were at Aberdeen and Bristol, and these were not largely attended.[25][26]

To encourage the establishment of schools giving regular systematic instruction in science, the DSA offered attendance grants in 1872 to those institutions which adopted schemes set forth in the *Science and Art Directory*. In this way arose the 'Organized Science School' (Turner, 1927:

25) Royal Commission on Scientific Instruction and The Advancement of Science Vol. I, Appendix I, 4, 1872.

26) The term Science School was at this time applied to any school, or a part of school, which earned DSA's grants. By 1867 there were 212 Science Schools and 10,230 students.

76-77). The method of aiding Organised Science Schools (later, called School of Science) was somewhat different. These schools increased steadily, for example, 10 in 1886, 112 in 1894, 141 in 1896, and 169 in 1897.

These schools had grown up to meet the need for scientific instructions of a more advanced kind. They included not only 'higher grade' elementary schools, but also many private and grammar schools which had been tempted to adopt a predominantly scientific curriculum. The Regulations required schools to give not less than thirteen hours a week to an obligatory course of not more than five hours mathematics and, in addition, chemistry, drawing and practical geometry (Turner, 1927: 115). (see Table 7.)[27]

Nearly at the end of the century, 1897, the Education Department published a huge volume of *Special Reports on Educational Subjects*. The committee of the Special Inquiries summarized the contemporary state of British Education and provided a detail surveys of school education in many foreign countries. The first report[28] included the results of an experiment in the co-

Table 7. Courses for organised science schools

First year	Second year	Third year
Mathematics (1st Stage). Freehand Drawing (2nd Grade Art). Practical Geometry. Chemistry, Inorganic (1st Stage) with practical work. Physics: Sound, Light and Heat (1st Stage) ; or Magnetism and Electricity, frictional and voltaic (1st Stage) ; or Physiography (1st Stage).	Elementary Mechanics, including the physical property of liquids and gasses (1st Stage). Physics: Sound, Light and Heat (1st Stage) ; or Magnetism and Electricity, frictional and voltaic (1st Stage) ; or Physiography (2nd Stage). Mathematics (2nd Stage and (if possible) 4th Stage). Practical Geometry (Plane and Solid), Chemistry, Inorganic (2nd Stage), with practical work. Animal Physiology (if possible), (1st Satge).	No definite course. But students should have a sound knowledge of the first stage of mathematics, Elementary Mechanics, Physics, and Chemistry, as well as sound knowledge and facility in Practical Geometry, Mechanical Drawing and Frehand Drawing. With continuous study in Mathematics and ist stage of Animal Physiography, students can have 'Specialization' in the following branches: 1. Physics and Chemistry and Metallurgy. 2. Theoretical and Applied Mechanics, Steam and Machine Construction, and Drawing. 3. Theoretical and Applied Mechanics, and Building Construction, and Drawing. 4. Biology. 5. Physiography, Geology, Mineralogy, and Mining.

27) Department of Science and Art of the Committee of Council on Education, 1890: 34-36.
28) Education Department, *Special Reports on Educational Subjects, 1896-1897*. London: HMSO, 1897.

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education of boys and girls, particularly from the trial in Secondary Day School attached to the Battersea Polytechnic. The school curriculum was divided into three divisions, and the subjects taught and the time allocations to the subjects were slightly different according to the division. Table 8 shows brief information on the school calender and the subjects. It is clear that in this school, some science classes (i.e. Physics, Chemistry, and Mechanics) included some amount (1.5 - 2.5 hours) of laboratory work.

During the last decade of the century, the liberal grants made for the equipment of science lecture rooms and laboratories in secondary schools seemed to influence, quite effectively, the ways of teaching physical science. The proportion of physical science lessons which had no connection with practical work was greatly reduced, as shown in Table 9. It was further claimed by C. W. Kimmins[29] that there was very little theoretical instruction given in public secondary schools in London which was not definitely associated with suitable practical work (Kimmins, 1901: 131).

At the beginning of the 19th century, there was no science teaching at the great schools. The subjects of study were largely limited to the classics. During the first half of the century there were a number of new foundations of public rank.[30] These schools were untrammelled by

Table 8. School calender and the subjects taught - secondary day school, battersea polytechnic (Education Department, 1897: 209-210)

School Hours :	Morning - 9.30 to 12.30, Afternoon - 2 to 4.30 (No school on Saturdays)
School Year, 1896-7 :	First term - September 15th (Tuesday) to December 23rd (Wednesday) Second term - January 5th (Tuesday) to April 14th (Wednesday) Third term - April 27th (Tuesday) to July 23rd (Friday)
Subjects of Study :	*(Mechanical Division)*
(hours per week)	Mathematics (5), Mechanics (3.5), Physics (3.5), Drawing (4), English subjects (4), French (2), Manual training (4.5), Drill (1).
	(Science Division) Mathematics (5), Mechanics (2.5), Physics (3.5), Chemistry (4.5), Drawing (3), English subjects (4), French (2), Manual training (2), Drill (1).
	(Elementary Division) Mathematics (5), Physics (3), Chemistry (2.5), Drawing (3), English subjects (5), French (3), Art (2), Manual training or domestic economy (3), Drill (1). (N.B.-The subjects of physics, chemistry, and mechanics include from 1.5 to 2.5 hours laboratory work.)

29) He gave a lecture on the teaching of science in schools as part of a series of "Education in the Nineteenth Century" at the Summer Meeting held at Cambridge in August 1890. He was then the Secretary to the London Society for the Extension of University Teaching and the Inspector of Science Teaching to the Technical Education Board of the London County Council.

30) Among these were Mill Hill (1807), King's College School (1829), University College School (1830), Cheltenham College (1841), Marlborough (1843), Rossall (1844), Wellington (1853), and Clifton (1862) (Turner, 1927: 27).

Table 9. Percentages of physics and chemistry students taking practical work in public secondary schools in London (1893-1896)

	1893-4	1894-5	1895-6
Percentage of those receiving theoretical instruction in physics taking practical work in this subject	17.1	26.2	66.8
Percentage of those receiving theoretical instruction in chemistry taking practical work in this subject	31.7	43.7	58.1

outworn statutes and traditions, and began by providing a more modern type of curriculum, such as, mathematics, modern languages, some sciences (Turner, 1927: 87-88). Secondary education at the time was based on the classics, and science was only rarely regarded as a valuable addition to the curriculum. Nevertheless, by 1870, some form of science had appeared on timetables of many public and grammar schools, although, as in the classics, it usually took the form of book learning. Fortunately, a few individuals were far-sighted enough to appreciate the value of experimental work (Ingle & Jennings, 1981: 15)[31].

Particularly, Rugby was regarded to be ahead of the other major schools. Here, science teaching was introduced in a tentative way as early as 1849. However, it was not until the appointment of J. M. Wilson(1836-1931)[32] that more active and regular teaching of science was practised at Rugby. With a strong support from the headmaster, Dr. Temple, Wilson started to give science lessons in the cloakroom of the town hall and, shortly afterwards, a new science laboratory was built. Wilson later said "I taught in the cloak room on the ground floor in the Town Hall, which was furnished with tables and chairs and a cupboard containing apparatus for illustrating elementary optics, hydrostatics, mechanics and heat, and some good electrical apparatus." The number of boys receiving some training in science was increased during the 1860s, and the facilities available for practical work were also extended (Meadows & Brock, 1975: 103-104).

The special commissioners appointed under the *Public Schools Act of 1868* made a significant influence for the teaching of science, by strongly recommending that the older public schools should build laboratories and should also appoint at least one science master for every two hundred boys. They also suggested that one hour per week should be devoted to natural science, and that two main branches of science should be studied.[33] When the Devonshire Commissioners published their survey of public and endowed schools in 1875, "among the 128 Endowed

31) Rugby and Queenwood College were among the first schools to build laboratories and to emphasize the importance of practical work in science teaching.

32) Although he was a fairly typical public school master, his mathematical studies at Cambridge - he was a Senior Wrangler - led him to an interest in science. As a mathematics master, his primary duty was the teaching of mathematics, but he proposed and gave occasional lectures in science with a great enthusiasm (Meadows & Brock, 1975: 103).

33) Public Schools Commission, *Report*, 11-18 & 28-33 (quoted in Turner, 1927: 90).

Schools ..., Science is taught in only 63, and of these only 13 have a Laboratory, and only 18 Apparatus, often very scanty".[34)]

However, since the *Public Schools Act of 1868*, efforts were made at several of the great schools to give a certain amount of scientific instruction to all boys. Owing to the large number of pupils and the few science masters, the teaching often took the form of lectures supplemented by experimental demonstrations. At Clifton, for example, all the boys attended a certain number of lectures and, as a voluntary study, boys were allowed to work in the chemical laboratory. The work there consisted mainly of qualitative analysis, and the time spent varied from four to ten hours per week.[35)]

At the time, the bulk of the laboratory teaching was practical chemistry and more particularly simple chemical analysis. In addition, the practical work was often not experimental in the real sense. The lecture illustrations by the master tended to become merely verifications of the statements he had previously made (Turner, 1927: 137-138). Nevertheless, science practical works were generally encouraged, and sometimes given with a more appropriate sense of real science - i.e. practical work by students themselves - in a few schools. The following quotations from *Devonshire Commissioner's Report* illustrate this[36)]:

> *Communication from Professor G. Carey Foster (*December, *1870)* - "May class of practical chemistry in University College School began, I believe, in 1859. ... The course of instruction was of this kind. At the beginning of each lesson each pair of boys was supplied with certain materials and apparatus, and as soon as they were all in their places, I described, as fully as I could, the experiments I wished them to make, but without telling them what results to expect. When they had done this, I made them examine, during the same or the next lesson, the products of the operations they had gone through. ... Throughout the course I purposely avoided the use of any text book as I specially wished that the knowledge the boys got in the class should be, as far as possible, the result of *their own* observations and experiments."

During the second half of the century, the curriculum of schools was largely determined by the requirements of the various examining bodies.[37)] In the later decades of the century the matriculation examination of London University became used as a leaving examination in schools by many pupils who had no intention of proceeding to a university course. At this time

34) Devonshire Report, I. (quoted in Meadows & Brock, 1975: 111).
35) *Sixth Report of Royal Commission on Scientific Instruction*, C. 1279, 1875, 36-49 (quoted in Turner, 1927: 137).
36) quoted in Turner, 1927: 138-139.
37) The first examinations for the Indian Civil Service and for Home Civil Service were held about 1855. More importantly, Oxford Local Examinations were instituted in 1857, and the Cambridge Local Examination was first held in 1858. The joint board, Oxford and Cambridge Schools Examination Board, was established in 1873, as a result of the Head Master's Conference of 1870.

the preparation of boys for examinations in science was carried out by means of lectures and the reading of text books. Even in those schools provided with special laboratories, practical work was regarded as a privilege and reserved for the advanced pupils[38] (Turner, 1927: 100-101).

The matriculation examination of London University exerted an enormous influence on the curriculum of schools. The University was severe in its demands, and consequently, London degrees were held in high esteem. At the beginning of the examination in the late 1830s, the requirements consisted of five compulsory subjects[39], one subject of modern languages[40] and two branches of Natural Science. In 1888, the requirements were changed to include one of the experimental science.[41] Then, in 1899, the requirements were changed again[42] and the regulations required that "the subjects shall be treated wherever possible from an experimental point of view".[43]

Towards the end of the century, the situation of science teaching in public schools was being improved. However, the study of science still did not seem to enjoy popularity among the students. For example, in the City of London School, in 1891, the Science Side was founded, following the foundation of the Modern Side in the previous year, and a grant of £1,000 for the accommodation in the teaching of Natural Science and a further grant of £500 a year for scientific and technological education, were arranged. In the following year, a physics master (O. G. Jones) was appointed with the task of equipping and organizing the new Physics Laboratory. At this time, the school numbered 710, of whom only 20 were Science (Douglas-Smith, 1937: 293-294). The following reminiscences of the year 1890 by a student (C. S. Myers), who claims to have been the first member of the Science Side, also illustrate the difficulties of the time:

> "My last year at the School was spent under Pollard's headmastership. But I had already begun to specialize. I was becoming more and more attracted to natural science, although still attached to classical studies... I decided to ask permission to

38) For example, at Taunton, the first two years of the science course were spent in studying mechanics from text books, and the pupils took the Oxford Local Examination in that subject. The third year was devoted to Chemistry lectures and demonstrations by the master, and in the fourth year the boys were allowed to perform certain manipulations for themselves. At the end of this year the pupils took the London Matriculation Examination. (from: Rev. W. Tuckwell, *The Method of Teaching Physical Science in Schools*. Paper read before the British Association at Exter, August, 1869 - quoted in Turner, 1927: 101).

39) Greek, Latin, Mathematics, English History and Modern Geography.

40) either French or German.

41) The requirements were (1) Latin, (2) one language (Greek, French, German etc.), (3) English Language with English History and Geography, (4) Mathematics, (5) Mechanics and Hydrostatics and (6) one of the branches of experimental science (Chemistry, Heat and Light, Magnetism and Electricity).

42) The requirements were (1) Latin - two papers, (2) English - two papers, (3) mathematics - two papers, (4) general elementary science - two papers, and (5) any one of following languages or science - Greek, French, German, etc. elementary mechanics, elementary chemistry, elementary heat and light, elementary electricity and magnetism, elementary botany - one paper.

43) *London University Calendar, 1898-99*: 5 (quoted in Turner, 1927: 102-103).

prepare under Durham's tuition for an Entrance Scholarship examination at Cambridge in Natural Science. Henceforth I was excused much of my ordinary class work. I worked with Durham in physiology as well as in chemistry and physics. As boys in such circumstances always do, I discovered quickly enough that Durham knew little more physiology than I did, and that Durham was always reading my text-book a few chapters ahead of me. But he was a kind, if not extremely competent teacher, and took endless trouble with me. I was, of course, the sole member of his class; indeed I may thus in a sense, and with no little pride, claim to be the first boy on the Science Side which was established on my departure." (quoted in Douglas-Smith, 1937: 294)

Despite enthusiasm from the teacher as well as the student, thus, the science teaching at the City of London School at the beginning of 1890s still suffered from the lack of popularity among the students, and from the lack of qualified teachers for each specialized areas of science.

According to Jenkins(1979), there were few school laboratories before 1870 and these were nearly all chemistry laboratories. Chemistry is the science which requires glassware, water disposal and other services, and therefore needs a special space (Nott, 1997: 50). Compared with chemistry, physics laboratories were not considered to be more difficult. Due to its wider variety of experimental activities, it was thought that practical works in physics were not readily accommodated within a single laboratory. Physics equipment was often both delicate and expensive (Jenkins, 1998: 36).

During the last quarter of the century, resources were provided on a significant scale to support the provision and equipping of school science laboratories. The outcome was a growth in the number of laboratories, as shown in Table 10. Around 1,100 school science laboratories were built between 1877 and 1902 (Jenkins, 1998: 39).[44]

English school laboratories were modelled on university laboratories, which themselves had been modelled on German university laboratories. Similarly, the practical work was modelled on the university experiences of the teachers, rather than a consideration of the need of the pupils (Nott, 1997: 51).

Table 10. School laboratories recognised by the DSA

Year	Chemistry	Physics	Biology
1880	133	-	-
1900	669	219	17
1901	772	291	26
1902	758	320	34

44) quoted in Jenkins, 1998: 39.

Ⅵ. Conclusions

The purpose of the practical work during the second half of the nineteenth century might be well summarized by the following quotation from the *1882 Code*, which illustrated the nature of science teaching expected:

> It is intended that the instruction of scholars in science subjects ... shall be given mainly by experiments and illustration. If these subjects are taught to children by definition and verbal description, instead of making them excercise their powers of observation, they will be worthless as means of education. It cannot, therefore, be too strongly impressed on teachers that nothing like rote learning will suffice... (quoted in Uzzell, 1986: 150)

Despite a great advance of practical work in British schools during the period, as Nott(1997) pointed out, the practical work tended to be demonstrations, confirmatory rather than investigative, and a narrow training in skills. In principle, the provision of sophisticated laboratories and their equipments alone could not be the solution for practical work in school science. H. E. Armstrong emphasized the importance of using everyday things rather than ready-made apparatus and workshops, rather than laboratories.

> Commence experimental studies at the very earliest possible moment, so that children from the outset may learn to acquire knowledge by their own efforts, so that observing and experimenting become habits.
>
> As to appliances, there is a very wrong idea that very special and expensive accommodation must be provided. This is not the case. There must, however, be space in which the work can be done; there must be a workshop, and much should be done with home-made apparatus. Use ordinary article, medicine bottles, jam pots, saucepans ...; invaluable opportunities are lost by providing everything ready made. (quoted in Nightingale, 1962: 329)

In the UK, practical work has particularly enjoyed its prestige as one of most important aspects of school science for the last half a century, since the introduction of Nuffield schemes. And its importance has become even more appreciated through the introduction of the National Curriculum, under the name of Investigation.

In their recent comparative historical review of science teachers' attitudes to the aims of practical work, Swain *et al.*(1998) found that some of the aims (i.e. to encourage accurate observation and description, to promote a logical reasoning method of thought, to arouse and maintain interest and to make phenomena more real) had been consistently highly rated by the teachers in all three periods (that is, 1962, 1979 and 1997). These aims were argued to just reflect a main core feature of science itself (i.e. to study natural phenomena to find out patterns in the natural world). However, it was also clearly shown that the changes of the popularity of the aims reflect the changing fashions of school science practical work throughout the period - that is, standard exercise(1962), discovery experiments(1979) and investigations(1997).

Wellington(1994) classified practical work in school science into the following five types: teacher demonstration; class practice; a circus of experiments; investigations; and problem-solving activities. Woolnough & Allsop(1985) also gave another classification with three types, i.e. exercise, experience and investigation (Wellington, 1998: 12). Watson et al.(1998) described six kinds of investigations with different structural characteristics: classifying and identifying, fair testing, pattern seeking, investigation models, exploring, and making things or developing systems. They also showed a surprising domination of 'fair testing' (82%), to the exclusion of other kinds (11%, together with 7% of 'No response or insufficient detail').

In addition, a recent policy recommendation publication for British science education, *Beyond 2000* (Millar & Osborne, 1998) identified key problems of current school science curriculum, particularly, on practical work, as follows:

> There is a lack of variety of teaching and learning experiences leading to too many dull and uninspiring lessons. Sometimes routine practical work is used where other learning strategies might be more effective. Even investigations, as innovative practice introduced by the National Curriculum itself, is in danger of succumbing to routine teaching as a consequence of perceived assessment requirements. (Millar & Osborne, 1998: 6)

In other words, many recent studies, like those mentioned above, suggest that, although the practical work in Britain have changed its nature towards investigative work and continuously enjoy popularity, the dominant use of a certain particular type of the practical work diminishes its great values, for example, to motivate pupils, to cultivate scientific thinking and to encourage meaningful understanding of science.

In this perspective, the following summary of the situation of science teaching in the early days of the 20th century would provide a valuable retrospective lesson for today's science education:

> ... The Report of the Prime Minister's Committee on Natural Science called attention to the importance that had been attached to laboratory work since the heuristic method was preached in the closing years of the 19th century. It was warned, in the report, that there was a danger in over estimating the importance of laboratory exercises and that in many cases the time spent in such work was more than the results justify. The Committee therefore suggested that the demonstration lesson has its place, and that the time often spent in the repetition of laboratory exercises may be employed to some extent in the giving of definite informational

lessons which shall bring home to the pupil some of the important applications of science in everyday life. (Tuner, 1927: 157)

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