

A Study on Science Education Theory in the Late Nineteenth Century in the United States

—Focusing on John Dewey's Perspectives of Science and Science Education (1)

Yoshiei NIWANO*

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SUMMARY

In this paper, the author examined John Dewey's perspectives of science and science education. Dewey emphasized that teaching of science was to humanize science and technology, and science should be studied by problem solving method. By Dewey, teaching of science humanistically means to realize democracy as an ideal society.

KEY WORDS

Humanizing Science, Problem Solving, Laboratory School, John Dewey

1. To Humanize Science and Science Education

John Dewey, who was one of the foremost philosophers of education and influenced United States education very much, pointed out in his writings the lack of fundamental unity among the various subjects then being taught in schools, and emphasized the importance of the unity of education, he said :

[In schools] the unity of education is dissipated, and the studies become centrifugal; so much of this study to secure this end, so much of that to secure another, until the whole becomes a sheer compromise and dissipated studies¹⁾.

Dewey further suggested that the school system had to be recognized as part of the large whole of social life, and thus the disparate studies were naturally viewed in connection with social life. Dewey expressed the idea of humanizing or socializing the subject of science. After describing the function of science in the curriculum he said :

In emancipating an idea from the particular context in which it originated and giving it a wider reference the results of the experience of any individual are put at the

* Division of Science

diposal of all men. Thus ultimately and philosophically science is the organ of general social progress²⁾.

This can be understood to imply that science should not be utilized merely for the self interests of a leisure class. He thought that science should be used by education, not just to extend the resources of our physical capabilities, but in such a way as to modify the habitual attitudes of imagination and feeling, because he viewed the recent advance of science as having had the impact to modify men's conceptions of the purposes and values of life.

Science taking effect in human activity has broken down physical barriers which formerly separated men ; it has immensely widened the area of intercourse. It has brought about interdependence of interests on an enormous scale. It has brought with it an established conviction of the possibility of control of nature in the interests of mankind and thus has led men to look to the future, instead of the past. The coincidence of the ideal of progress with the advance of science is not a mere coincidence. Before this advance men placed the golden age in remote antiquity³⁾.

It was explained by Dewey that children had to experience that the function of science was systematic application of intelligence to the solution of human affairs and social problems. He severely criticized the traditional way of teaching science, asserting that since most students would never actually become scientists, it was much more important that students get some insight into the import of scientific methods rather than merely copy the results attained by previous scientific endeavor.

There is a strong temptation to assume that presenting subject matter in its perfected form provides a royal road to learning. What more natural than to suppose that the immature can be saved time and energy, and be protected from needless error by commencing where competent inquirers have left off? The outcome is written large in the history of education. Pupils begin their study of science with texts in which the subject is organized into topics according to the order of the specialist. Technical concepts, with their definitions, are introduced at the outset. Laws are introduced at a very early stage, with at best a few indications of the way in which they were arrived at. The pupils learn a "science" instead of learning the scientific way of treating the familiar material of ordinary experience. The method of the advanced student dominates college teaching; the approach of the college is transferred into the high school, and so down the line, with such omissions as may make the subject easier⁴⁾.

Dewey saw schools as miniature social groups, linking school life with the reality outside of the school, and stating that the school had to be related to life, with the necessary correlation of all studies.

Dewey's idea of "humanizing science" can be interpreted as "humanizing" or "socializ-

ing” the teaching of science.

It has a chance to affiliate itself with life, to become the child’s habit, where he learns through directed living, instead of being only a place to learn lessons having an abstract and remote reference to some possible living to be done in the future. It gets a chance to be a miniature community, an embryonic society⁵).

Dewey wanted to avoid teaching children in such a way as to give them the idea that science is a separate, abstract thing. In summary, his idea was that knowledge in science and thinking style affected change in modes to produce things. With the change in modes of production emerged the possibility of freeing men from the role of beasts of burden. Both social relations and qualities of mind were reorganized, and the content of education had to reflect this change. The temper of the scientific way of thinking that had gone so far to change human possibilities should be included as an important part of humanistic studies.

Both pure and applied sciences were to be understood by everybody, because the style of thinking, the method of inquiry in approaching and solving problems should become an intrinsic part of everyday life.

Dewey’s emphasis on the teaching of science was in order to “humanize science” and “humanize technology.” He sought the cause of the failure to realize democracy as an ideal society, and stated that it could be understood that people “over-believed” science, and there appeared the gap between science and humanities. People failed to apply the thinking style of science when they approached and solved the problems they encountered. Dewey therefore concluded that science had to be thought of as the style of dealing with the various situations arising in day-to-day human affairs.

2. John Dewey’s Idea of Science Education

During the 1890’s two noteworthy schools came under the supervision of the University of Chicago: one was the South Side Academy, founded in 1892 by the University as a preparatory school: and the other was Chicago Manual Training School, founded in 1883, which became affiliated to the university in 1897. By the end of the 1890’s these two schools were placed the direction of Dewey, who was the chairman of the Department of Education. With the opening of Belfield-Blaine Hall in the fall of 1903, the schools were fused together in functional way under the name of the Laboratory School.

Dewey expected that Laboratory School could offer a new alternative method to limited and stereotyped conceptions of teaching in practice at the time.

In order to shift the trend of education away from contemporary biases that hindered the formulation of the critically grounded theory of a true profession, he turned to the idea of the classroom as a laboratory for educational experiment.

This ideal of school as a miniature social group was first carried into effect at the Laboratory School in the spring of 1896. Like any such laboratory, the aims of the Laboratory School were :

- (1) to exhibit, test, verify, and criticize theoretical statements and principles ;
- (2) to add to the sum of facts and principles in its special line.

In consequence, it was often called the Laboratory School⁶⁾.

The school was founded to apply the concepts and methods of science to institutional education, with the more specific aim of supporting research on problems connected with the psychology and sociology of education. He stated his interpretation of the role of the Laboratory School in these terms :

—the incorporation of the Laboratory School marks the necessity of training teachers, not only giving them inspiration, practical insight, and skill, but by giving them command of the most fundamental intellectual tools of the work which they are called to do.

—Speaking in terms of relationship to the University, the incorporation of the Laboratory School signifies bringing to bear the intellectual method of which the modern university is the appropriate home and embodiment, upon all the questions of education, both elementary and secondary⁷⁾.

In the Laboratory School, the teacher was expected to bear two purposes in mind :

- (1) to provide the child with opportunity to develop and use, thereby learning, great scientific truths, and
- (2) to preserve, through use, the child's instructive spirit of inquiry, to build in his mind a concept of scientific method as a practical tool and thereby guide him into the experimental, the scientific habit of mind⁸⁾.

The scientific attitude developed from kindergarten level and through elementary school was left to be of fundamental importance for the studies at the later stages. Teaching science was connected to the concern with what Dewey called social occupations, and later with such specific occupations as cooking, sewing, and carpentry.

In cooking class, scientific questions about the effects of heat on various substances, the nature of the growth patterns, and the ingredients of food were presented to the students. Children learned the value of cooking as a preparation for digestion, and conducted a general survey of what digestion is.

In sewing class, the processing of flax, cotton, and wool was examined from both raw materials and finished goods. Questions about the properties of wood and metals as well as the principles involved in simple tools and machines were raised to children by the teacher. The children were thought to be re-enacting experiences of human race through confrontation with the various problems and questions encountered through these activities.

At the beginning of the first stage of elementary education, direct use and manipulation were emphasized. Around the end of this stage there arose interests requiring more prolonged study. Physical history, including an introduction to the geological periods, the nature of atmosphere, climate, and plant and animal zones, was presented at this time, with the intention that the children be giving an idea about the earth as man's home.

At the second period of elementary education, the study of science for eleven-year-olds was divided into two major areas :

1. Physiography (related to the study of history) :
2. Experimental science both biological and physical.

This shift of emphasis in the method was occasioned by the fact that children at this stage developed an interest in the value of divided science to use in investigation.

The third stage (from age thirteen) moved toward more specific studies, including general courses in biology and the physical sciences. The evolution of animal life beginning with simple forms and ending with the physiology of human being was offered to the pupils. This was preceded by an analysis of the children's gymnastic as connected with the physiology of the body. The children might choose, for example, the general subject of walking which would then be related to the moving joints of the limbs. In the physical science, topical studies were made of such phenomena as light, heat, gravity, and electricity. Experiments that emphasized the role of theory and generalization were performed. The study of photography was initiated as a basis for understanding basic concepts in the physical sciences, extending to the principles which govern the formation of shadows, and including the history of the various scientific theories about the nature of light.

The goal of the science taught at this stage was to give children a mental image of the physical and biological processes of change and growth as a continuous round of freeing and using energy. Many topics were studied in a spiral fashion.

The emphasis on structure rather than isolated scientific principles, on modes of inquiry and inductive methods of learning, and on the use of various materials and media that appeared with a nationwide curriculum reform movement beginning in the late 1950's greatly influenced curriculum contents and instructional strategies.

In the new science curricula, the processes of scientific inquiry are emphasized, with the process and scientific knowledge considered inseparable. The new science programs are laboratory-centered, to investigate unknowns, with the activities designed for students to approach frontiers of science. Various ways are introduced to students to develop their skills of scientific inquiry and investigation.

The weaknesses of the new programs are that they are independent courses, usually one school year in length, in biology, chemistry, and physics without consistent, sequential development. Furthermore many of the early programs were designed with college-bound students in mind, so that average or below-average students have been neglected until more recently.

A science education researcher, J.D. Novak, made these comments on the situation at the

end of 1960's :

In education the pendulum that makes periods of change has swung from side to side; we have been through a decade when scholars in science have dominated curriculum reform and school programs have benefited. Now the pendulum may be in transit to a pole where focus on students and their capacities will be central in science curriculum design. There is an acute need for training new curriculum workers who have sufficient competence in science to maintain the gains achieved through the contributions of scientists and who can add a new dimension of instructional technology and learning theory to improved curriculum designs. Those of us who have cast out lot to the field of science education must accept this as the major challenge in the improvement of school science teaching⁹⁾.

The weaknesses of the new science curricula, including neglect of the general high school student population and lack of sequential development, have been gradually improved through the renewed emphasis in the 1970's on "unified science".

Jerrold Zacharias, father of the PSSC physics curriculum, has written :

The division of science at the secondary school level into biology, chemistry, and physics is both unreasonable and uneconomical. Ideally, a three-year course that covered all three disciplines would be far more suitable than a sequence of courses which pretends to treat them as distinct. Today a three-year course would be difficult to fit into the educational system, but much of this difficulty might be overcome if such a course existed¹⁰⁾.

Already in the early 1970's unified science programs were in operation at various high schools around the United States. Some characteristics of these programs are as follows :

1. Unified science courses are not just upgraded general science courses.
2. Most of the present unified science programs are essentially "homemade".
3. Unified science courses can be used satisfactorily with students of different degrees of academic competence and at many different grade levels.
4. Most senior high schools that have introduced unified science courses continue to offer traditionally organized science courses as well.
5. These programs offer adequate college preparation ("It's good college preparation, too").
6. Most unified science courses are built around a family of major themes or "big ideas," not as subject-matter sequences.
7. Many courses employ a flexible modular design¹¹⁾.

During the late 1960's students became less interested in pursuing science as a career, and could not identify the role of science in the world of human affairs and problems. Also, American people at this time became very much concerned about the societal implications

of the scientific enterprise. Science had neglected to study such very real problems as those of air pollution, overpopulation, and depletion of natural resources. The question of the relationship of research to the totality of man within the universe had been sorely neglected, with the result that a new trend to humanize the sciences has appeared.

The trend to humanize curriculum has resulted in a multidisciplinary approach to instruction. This approach applies basic laws of science to a variety of problem situations in subjects other than science. Science teachers work in teams with teachers from other disciplines and help students relate principles of science to current social, political, and economic problems.

The multidisciplinary approach serves two purposes. First, it brings new depth to all disciplines. Second, it reminds us of science's relation to the political, economic, and social affairs of humankind. The major goal of science teachers in the 1980s will be to provide students with basic problem-solving skills they will need to cope with an often dehumanizing technical society¹².

One more trend in education to appear on the scene has been to the "Back to Basics" movement. The "Back to Basics" movement in American education which has attracted a great deal of publicity is a reaction to the observation that the general academic performance of pupils, especially the minimum competency standards in reading and mathematics as well as classroom discipline, has declined somewhat over the years. The "Back to Basics" movement in the mid 1970's has sometimes been characterized as merely a return to the exclusive teaching of the 3 "R's", but it is the author's opinion that the movement contains more than 3 "R's." Inadequate student reading ability causes a serious problem in grade 7-12 according to all the groups queried.

However, according to a survey conducted by *Science and Children* in June, 1978, science is no longer considered as a fundamental subject of knowledge nor as a high-priority area. This shift of focus from process/inquiry, as featured in the curricula, to content/skills and factual knowledge stems from the much-publicized results of minimum competency testing.

The great variety of operational definitions of basic education in use have led to the current trend towards diversity of curricula emphasis.

This is reminiscent of Dewey's assertion of the humanization of science and technology previously mentioned. Is science basic? This is a question that has yet to be answered. It is the author's opinion that whether science education is basic or not is still a matter of great controversy in the United States.

3. John Dewey's Idea of Teacher Education

Dewey conceived of the dynamics of the classroom as the interaction of teacher, pupil, and subject matter. From an educational viewpoint, Dewey maintained that, without care,

both pupil and subject matter might incur mistaken treatment. The logically organized finished products of inquiry might be contained as the subject matter in the textbooks. By mere recitation of the organized products the children had been cheating of their insight into the exciting processes of inquiry and questioning that went before.

The teacher's effectiveness depends on his ability to interpret the meanings of his subject and to develop insights into the process of inquiry that led to its creation. The teacher who truly understands the significance of his subject may help students, through acts of appreciation, to share the sense of discovery of the creators of knowledge¹³⁾.

In *How we think*, Dewey wrote that :

—the teacher can take advantage of unexpected questions or unanticipated incidents. —The teacher must have his mind free to observe the mental responses and movements of the student members of the recitation group. —Unless the teacher's mind has mastered the subject matter in advance, unless it is thoroughly at home in it, using it unconsciously without the need of express thought, he will not be free to give time and attention to observation and interpretation of the pupils' intellectual reaction¹⁴⁾.

To summarize, Dewey insisted that the teacher should be a serious student of his subject, and should strive to advance his students learning experiences. The teacher was expected to lead children to identify and solve problems, and learn how to discover knowledge. The teacher had to create in the classroom a democratic problem solving group. He would teach his children to use scientific methods to solve problems within their group. He himself had been seen in the role of problem solver.

Problem solving based upon the materials gathered by both the teacher and his pupils was emphasized in science courses. Young teachers were given resource units instead of structured curricula, and taught how to create units which the students would need.

The science teachers at the Laboratory School were themselves experts in their fields. Also, in accordance with portrait of the teacher set forth by Dewey, they had to be active students of "the mind of the child", in other words, "students of the psychology of the learning process." They had to be sensitive to the experiences appropriate for children at different ages, and imaginative in their efforts to get children to appreciate the excitement of scientific inquiry.

As mentioned earlier, the primary aim of science teacher in the high school should be the formation of scientific habits of mind. The physics teacher had to have interest in techniques of measurement and experiment, but the focus on these techniques as ends in themselves should come later, specifically in the training of scientific specialists.

The method of experimental inquiry and testing which give intellectual integrity, and power in all fields, rather than those which are peculiar to his speciality, are what the

high school teacher should bear in mind¹⁵⁾.

It is the author's opinion that Dewey stressed "student-center, problem-oriented, hypothesis-generating modes of education and saw teachers as part of the process for adapting the society to changing conditions."¹⁶⁾

4. Change in the Teacher's Role

What will be some of the specific changes in the expected role of the teacher? The ability to manage and supervise the classroom will be required of teachers. Recently, there has appeared a new kind of interaction between teacher and student, signally an emphasis on classroom dynamics.

The teacher gives the students a great deal of discretion about the learning task, in the classroom, and there exists teacher-student interdependence, because the teacher gives the resources and the guidance for the discretion. More effective teacher-student communication has been much needed as a way to solve problems of classroom management and coordination. There are two conditions necessary to accomplish the task of learning in the classroom.

- (a) the teacher must be the authority figure and must successfully exercise the power of that office, and
- (b) students must accept this authority and agree to achieve the norms and standards set and to abide by them¹⁷⁾.

For example, if we apply Dewey's social problem solving to a modern situation, "the idea is the problem-centered core."

The modern exemplification of Dewey's social problem solving is the "problem-centered core," and the management of such classrooms differs significantly from that of either individualized or conventional group instruction. —the teacher is expected to play the role of a participating, "nearly equal" member of the class¹⁸⁾.

(to be continued)

References

- 1) John Dewey, *The School and Society*, Chicago, University of Chicago Press, 1915, p. 72.
- 2) John Dewey, *Democracy and Education*, New York, Free Press, 1916, p. 230.
- 3) Ibid., pp. 224-225.
- 4) Ibid., p. 220.
- 5) John Dewey (1915), p. 18.

- 6) Katherine C. Mayhew and Anna C. Edwards, *The Dewey School*, New York, Atherton Press, 1965, p. 3.
- 7) John Dewey, "Significance of the School of Education," *The Elementary School Teacher*, Vol. 4, No. 7, 1904, pp. 441-453.
- 8) Katherine C. Mayhew and Anna C. Edwards (1965), p. 283.
- 9) Joseph D. Novak, "A Case Study of Curriculum Change.....Science Since PSSC," *School Science and Mathematics*, 69 : 1969, pp. 383-384.
- 10) Glenys G. Unruh and William M. Alexander, *Innovation in Secondary Education*, New York, Holt, Rinehart and Winston, 1974. p. 71.
- 11) Ibid., p. 72.
- 12) John D. McNeil, *Curriculum.....A Comprehensive Introduction*, Boston, Little, Brown, and Company 1977, p. 239.
- 13) Arthur G. Wirth, *John Dewey as Educator*, New York, John Wiley & Sons, 1966, pp. 61-62.
- 14) John Dewey, *How We Think*, Chicago, Henry Regnery Company, 1971, pp. 274-275.
- 15) John Dewey, "Symposium on the purpose and organization of physics teaching in secondary schools," *School Science and Mathematics*, Vol. IX, No. 3, 1909, p. 292.
- 16) Bruce Joyce, "Conceptions of man and their implications for teacher education," *The 74th Yearbook of the National Society for the Study of Education*, Chicago, University of Chicago Press, 1975, p. 123.
- 17) Beatrice A. Ward and William J. Tikunoff, "Utilizing nonteachers in the instructional process," *The 78th Yearbook of the National Society for the Study of Education*, Chicago, University of Chicago Press, 1979, p. 284.
- 18) Mauritz Johnson and Harry Brooks, "Conceptualizing classroom management," *The 78th Yearbook of the National Society for the Study of Education*, Chicago, University of Chicago Press, 1979, p. 18.