THE DEVELOPMENT OF AN AUSTRALIAN SCIENCE CURRICULUM MODEL

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ABSTRACT

THE DEVELOPMENT OF AN AUSTRALIAN
SCIENCE CURRICULUM MODEL

by David Cohen

The major purpose of the study was to develop a science curriculum model which would provide a theoretical structure for the subsequent development of science curricula in Australia. An examination of the relevance of the methodology of comparative education for comparing science education in Australia and the U.S.A. showed that there was both an actual and a perceived relevance of American educational developments for Australian systems of education. In addition, evidence was advanced which indicated that the U.S.A. was a fruitful source of significant innovations in science education. Consequently, the Australian curriculum model and a suggested mechanism for its implementation were developed by synthesizing from a series of reviews of literature largely drawn from U.S.A. sources.

The curriculum model was synthesized from a total of seventy recommendations which were developed from reviews of science education and the related areas of education, science, and psychology. These recommendations were made in areas which included the objectives of science education, procedures

from selected National Science Foundation sponsored curricula, science elements unique to the Australian culture and the findings of science education research.

The objectives of science education were shown in the model to lie in the broad purposes of education and of science. From these broad purposes were developed appropriate specific objectives, to be determined by professional educators and scientists. Science education research findings of relevance to curriculum construction were derived from six main areas, namely content, skills, learner factors, classroom practices and teacher factors, together with relevant psychological findings. Implications from NSF sponsored curricula were derived from a consideration of their process of curriculum development, philosophy and objectives, course content and organization, teacher training and evaluation.

The science curriculum model indicated factors likely to influence the teacher's utilization of the curriculum in the classroom. It also drew implications for classroom practices which may contribute to a sound science program.

Mechanisms for implementing the science curriculum model were based upon the formation of a proposed Australian Science Education Foundation. This Foundation was shown to be composed of representatives of a number of existing educator and scientist organizations. The major functions of the ASEF were to select and sponsor groups to promote and review research which may have relevance for Australian science curriculum construction, to identify the philosophy and objectives of science education, to review and promote curriculum improvement, and to maintain liaison with the existing Advisory Committee on School Facilities. Thus the ASEF operates through a number of existing organizations and coordinates their contributions to the broad improvement of science education in Australia. The outcome of these mechanisms should be to provide the basic information required by the ASEF sponsored curriculum teams.

The curriculum model, implementation mechanism, and the seventy recommendations from which these are synthesized were directed to those responsible for improving science education in Australia. The considerable progress reported in Australian science education and the recent increase in governmental interest suggest the presence of a climate favorable to the implementation of the model.

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By

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July, 1964 David Cohen

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CHAPTER I

INTRODUCTION

Australia and Its Educational Systems

The Commonwealth of Australia is an island continent with an area of 2,971,000 square miles. Australia is composed of six states, namely New South Wales, South Australia, Tasmania, Queensland, Victoria and Western Australia.

Education is the responsibility of the government of each of these states, and has been organized in each state as a centralized system. School attendance at government schools is free and compulsory, with a minimum leaving age of fifteen, but with slight variations between the states.[1]

Australian schools have recently faced the effect of the post World War II population boom. The population increased in fourteen years from 8,000,000 in 1949 to 11,000,000 in 1964,[2] in comparison to the change from 5,000,000 to 8,000,000 in the preceding thirty-one years.[3]

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[1]Australia, Department of the Interior, Australian News and Information Bureau, Australia: Official Handbook, 1963 (Canberra, 1963), pp. 234-42.

[2]Federal Bureau of Census and Statistics, Canberra, November 17, 1963, cited in "Australian Population Now 11,000,000," Australian News Weekly Round-Up, November 20, 1963, p. 1.

[3]Australian News Weekly Round-Up, November 20, 1963, p. 2.

Of the present population, 2,250,000 are school age children.[1] Dettman, reporting in the International Yearbook of Education 1961 stated that:

> The most remarkable feature of Australian education over the past decade has been the unprecedented increase in educational enrolments. Since during this time school enrolments showed a increase of more than 40% and university enrolments increased by 55%, the efforts of educational administrators have tended to be directed rather towards practical and immediate solutions to the many ensuing problems.[2]

This increase is reflected in figures shown in Table 1:

TABLE 1

ENROLMENTS AND PROJECTED ENROLMENTS IN GOVERNMENT PRIMARY AND SECONDARY SCHOOLS FOR THE WHOLE OF AUSTRALIA 1910-1975 (in thousands)[a]

Year	Enrolment	Year	Enrolment
1911	584	1950	973
1915	668	1955	1286
1920	735	1960	1612
1925	820	1963	1756
1930	922	1965	1853
1935	923	1970	2081
1940	864	1975	2361
1945	833		

[a]Extracted from Tables in "A Statement of Some Needs of Australian Education," The Teachers' Journal, XLVII (March, 1964), 27-30.

[1]"Recent Statistics," Education News, IX (October, 1963), p. 20.

[2]Henry Dettman, "Australia: Educational Development in 1960," International Yearbook of Education: Vol. XXIII, 1961 (Geneva: International Bureau of Education; Paris: Unesco, 1962), p. 17.

Australian Prime Minister Menzies described the impact of increased enrollments in government schools. He said:

> In 1960, 1,600,000 of the 2,100,000 children attending primary and secondary schools in the six States of Australia were attending government schools. This was 65 per cent more children than were in those government schools ten years earlier. Part of this increase has been due to the fact that a greater percentage of children now stay at school longer but, in the main, the increase has been due to population growth, chiefly by natural increase, though the arrival of immigrants has contributed a significant share.
>
> Clearly, to provide for these extra numbers, more classrooms have been needed and more teachers have had to be engaged and trained. The States have responded to this challenge. Their school building programmes have been greatly accelerated, new teachers' colleges have been established and the teaching force greatly augmented.[1]

In view of these increased school enrollments, administrative attention was diverted temporarily towards quantitative criteria such as providing sufficient teachers, facilities and buildings to meet the influx of entering students and to cope with increased school holding power. In the state of Victoria, for example, the number of high schools increased from forty-eight in 1950 to one hundred and thirty-five in 1959. The percentage of pupils entering grade seven who remained for a third year in high

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[1]Sir Robert Gordon Menzies, "The Commonwealth and Education: Statement by the Prime Minister: Report tabled in the Australian House of Representatives, 6th November, 1962," Education News, VIII (December, 1962), 3.

school rose from 49.7 per cent to 75.8 per cent by 1956.[1] "Unprecedented increases in enrolments have necessitated the employment of some 3,000 temporary teachers."[2]

In addition to the problems of providing adequate facilities and of securing teachers, there was also a mounting concern about educational quality. This was indicated in a report of the Ministers of Education of the various Australian states, which reads in part as follows:

> The demands of the Australian community for better education are in line with those in advanced countries overseas. When the implications of these demands are examined, certain requirements become evident for our State systems of education. Broadly speaking, these are as follows:
>
> (i) <u>There should be a variety of courses of study</u>.
>
> . . . .
>
> (ii) <u>The system should provide for all children at least between the ages of 6 and 15 years</u>.
>
> . . . .
>
> (iii) <u>Adequate opportunities for additional full-time and part-time education should be available</u>.
>
> . . . .
>
> (iv) <u>The system should ensure that every pupil can obtain an education adapted to his particular needs</u>.
>
> . . . .
>
> 8. To achieve these objectives and to provide services of a quality that will not endanger future standards of national development, the Ministers of Education are convinced that the following conditions must be met:
>
> (i) <u>The system must provide for the rapidly increasing child population sufficient school accommodation, well designed and well built</u>.
>
> . . . .

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[1]Victoria, Department of Education, <u>Report of the Committee on State Education in Victoria</u> (Melbourne: A. C. Brooks, Government Printer, 1960), p. 21.

[2]<u>Ibid</u>., p. 128.

(ii) The system should provide teachers in sufficient numbers.

. . . .

(iii) Teachers must be adequately trained.

. . . .

(iv) To make maximum use of the teaching strength there should be adequate staff in schools for clerical and other non-teaching duties.

Schools should be properly furnished and equipped.[1]

Prior to the report of the Ministers of Education, governmental concern had been indicated by the appointment in New South Wales, Victoria and Queensland (the three most populous states) of committees to investigate and report to the State governments on their respective educational systems. In New South Wales, the "Terms of Reference" of the Survey Committee were as follows:

1. To survey and to report upon the provision of full-time day education for adolescents in New South Wales.

2. In particular, to examine the objectives, organization and content of the courses provided for adolescent pupils in the public schools of the State, regard being had to the requirements of a good general education and to the desirability of providing a variety of curriculum adequate to meet the varying aptitudes and abilities of the pupils concerned.[2]

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[1]"A Statement of Some Needs of Australian Education," The Teachers' Journal, XLVII, p. 23.

[2]New South Wales, Department of Education, Report of the Committee Appointed to Survey Secondary Education in New South Wales (Sydney: V. C. N. Blight, Government Printer, 1962), p. 5.

As a result of the deliberations of the respective committees, the Report on Secondary Education in New South Wales (Wyndham Report) was submitted in 1957 to the state Minister of Education,[1] and the Report of the Committee on State Education in Victoria (Ramsay Report) was submitted to the Victorian Minister of Education in 1960.[2] The final Queensland report has not yet been released (1964), although an interim report was presented to the Queensland government.[3] These reports reflected a renewed concern for the development of new curricula, as noted in the 1962 International Yearbook of Education:

> In association with the structural changes in secondary education in New South Wales and the proposed changes in Queensland, considerable changes in the secondary school curriculum have been recommended in each state.[4]

Some of the recommendations in the various reports pertained to science education. A new science curriculum was recommended in the New South Wales report. Stanhope reported that "the most significant event in the history of school science in New South Wales came in February 1962

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[1]New South Wales, Department of Education, Report of the Committee. . ., p. 5.

[2]Victoria, Department of Education, Report of the Committee. . ., pp. 6-7.

[3]H. G. Watkin, "The Reform of Secondary Education in Queensland," The Australian Journal of Education, VI (October, 1962), 108-185.

[4]R. G. Jeffrey and Warwick Eunson, "Australia: Educational Developments in 1961-1962," International Yearbook of Education: Vol. XXIV, 1962 (Geneva: International Bureau of Education; Paris: Unesco, 1963), p. 22.

following upon the implementation of the major recommendations of the Wyndham Committee."[1] The event referred to was the introduction of science as a subject for compulsory study for the first four years of secondary school. The course comprised the study of biology, chemistry, geology and physics integrated to produce a single course.

Further evidence of the change in science in the secondary schools is provided by the introduction of a new physics course in Victoria which was recommended by a special committee known as the Standing Committee for Physics. This new course for grades 11 and 12 is an adaptation of the materials produced by the American Physical Science Study Committee and was recommended after the Standing Committee considered two possible approaches for the development of the course, namely:

(a) To construct entirely new courses with revised aims and content:

(b) To examine the American Physical Science Study Committee (P.S.S.C.) course and to determine its suitability for Victorian schools.[2]

Miller wrote that "when the sheer magnitude of the task in the former became apparent the choice fell to the latter."[3]

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[1]R. W. Stanhope, "New South Wales," Conasta XII: Science Education in Australia Today," ed. M. L. Yaxley (Tasmania, May, 1963), p. 14.

[2]G. D. Miller, "New Senior Physics Course in Victoria," Education News, IX (October, 1963), 6.

[3]Ibid.

As a preliminary to further and more systematic improvements in science education, following the ninth annual conference of the Australian Science Teachers' Association (CONASTA IX) in 1960, it was decided to obtain a thorough appraisal of science education throughout Australia. The Australian Science Teachers' Association (ASTA) obtained the support of the Australian Council of Educational Research (ACER) and The Victorian Employers' Federation, and initiated the first Australia-wide survey of science teaching conditions and facilities. In this status study, every Australian secondary school principal received a comprehensive questionnaire soliciting information concerning students, teachers, laboratories and equipment. Punched card procedures are being utilized to analyze the information. While no information has been released concerning this study, it is anticipated that the data will provide a useful basis for subsequent work.

Need for the Study

The foregoing statements show that there is a concern for the improvement of school curricula in Australia. The concern for improvement of science curricula is further emphasized by the recommendations of the Australian Science Teachers' Association. Yaxley reported that:

> The Australian Science Teachers' Association (ASTA) recently recommended that an Australian Educational Foundation should be established to foster the development of integrated and structured courses that will be adopted in all States of the Commonwealth.
> . . . .

> The basic aim is to have a team of experts in science education professionally engaged in the construction of better syllabi. First-rate teaching and learning aids could then be produced more economically because there would be some prospect of sales on a national basis rather than, at present, on a State basis. The population of Australia is becoming more mobile and we want to make it easier for a pupil from one State to take up his or her education in another State.
>
> . . . .
>
> Many of us are dissatisfied with the actual science courses recommended because they emphasize factual knowledge and do not adequately present the true meaning, scope and structure of science as a discipline and as a part of our culture. This problem is not restricted to Tasmania and I do not imply that the majority of teachers would object to a change in this direction. The situation arises because those who prepare the courses (myself included) have to do so after school hours. The courses are carefully considered but they are thrown together rather than developed scientifically. It is this unsatisfactory state of affairs that has inspired the move for an Australian Educational Foundation.[1]

Action relative to the Association's concern is shown by the recommendations adopted at the eleventh annual convention of the Australian Science Teachers' Association (CONASTA XI). The document produced reads in part as follows:

> Because
> (a) there is general dissatisfaction amongst science teachers with science syllabuses and methods of examining;
> (b) our population of experienced and capable academics, teachers and educators is small and widely scattered,
>
> there is a need for the people to be professionally engaged in syllabus construction in Australia.

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[1]Murray L. Yaxley, "Some Aspects of Science Education in Tasmania," <u>Duquesne Science Counselor</u>, (June, 1963), p. 59.

IT IS THEREFORE RECOMMENDED THAT:

> An AUSTRALIAN EDUCATIONAL FOUNDATION should be established to foster the development of integrated science courses, by a national group of representatives of all those interested in science education.
>
> AND FURTHER that such courses should be used, tested and modified where necessary before being published and distributed to the States for adaption should they wish to their individual use.
>
> The Council of the Australian Science Teachers' Association is requested to take this matter actively in hand with the appropriate bodies.[1]

Subsequently, in a statement submitted by the Australian Science Teachers' Association to the Australian and New Zealand Association for the Advancement of Science (ANZAAS) Council meeting in January, 1964, a national approach was suggested as a possible solution to the problems of science education:

> The Australian Science Teachers' Association foresees that improvements in science education will result from the continuation of a variety of activities within each State and Territory, but it also foresees that certain major improvements can come about only through co-ordination of efforts at a national level.
>
> It will only be by the establishment of an Australian Science Education Foundation, similar in nature and purpose to the National Science Foundation in the U.S.A. and the Nuffield Foundation School Science Teaching Project in Great Britain, that the major deficiencies associated with the teaching of science will be precisely defined, and a balanced attack made on all aspects of the problem.

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[1]"Conasta XI Statement on Changes and Developments: The Effect of Our Teaching Upon Our Pupils; Being the Text of a Statement Agreed to by Members of the Eleventh Conference of the Australian Science Teachers' Association, held in Melbourne, May 1962," p. 4. (Mimeographed; in the files of the Association.)

Without such a body of national standing, efforts are likely to be undirected, unco-ordinated and wasteful of the resources available.

We, the Australian Science Teachers' Association ask that the A.N.Z.A.A.S. Council and its members should promote the establishment of an Australian Science Education Foundation.[1]

The potential importance of the work of the Australian Science Teachers' Association was indicated by the subsequent action of the Australian College of Education (ACE). The Australian College of Education in 1963 deferred work on a special science project "until a current inquiry by the Science Teachers' Association of Australia was completed."[2,3] At the same time, the Australian College of Education passed the following motion:

The Australian College of Education has noted that children, moving from one State to another, suffer serious difficulties and handicaps, particularly in secondary education, in organisation, standards, and curriculum. In view of the increasing numbers of families who are moving interstate, this meeting of the Australian College of Education requests THAT the

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[1]Australian Science Teachers' Association, "The Needs of Science Education in Australian Schools," The Australian Science Teachers' Journal, X (May, 1964), 42.

[2]The Australian College of Education, Fourth Annual Report and Proceedings of the Fourth Annual Conference: 17th-21st, May 1963 (Melbourne: The Australian College of Education, 1963), p. 18.

[3]The Australian College of Education is a professional organization whose aim is "to bring together those who have shown excellence as educators or who have had above average success in the field of education. Candidates for Membership, therefore, must have had made a contribution over and above that implied by the possession of the basic qualifications, and must give evidence of continuing professional development."

> authorities responsible in each State should examine the possibilities of providing a closer correlation (without imposing undue uniformity) between the standards and organisation in the various States.[1]

Consequently, these two influential Australian professional organizations have expressed a need for:

1. some degree of uniformity in curricula in the states of Australia and

2. the formation of a national group to develop new science curricula.

In view of these expressed positions and the interest prevalent amongst educational leaders and science teachers for curricular changes, there is a need for the development of a sound theoretical framework to assist those engaged in the task of preparing a science curriculum with national implications.

Purpose of this Study

The major purpose of this study was to develop a science curriculum model which may provide a structure for the subsequent development of science curricula in Australia. The model was formulated to meet the anticipated needs of Australian science education. The model would have practical use in determining science objectives, selection of curriculum materials, teaching procedures, evaluation techniques, and administrative functions in the school systems of Australia.

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[1]The Australian College of Education, Fourth Annual Report, . ., p. 9.

Design of this Study

This study was designed as a synthesis investigation. Science education in Australia and the U.S.A. was examined through personal observations and by a review of research studies, curriculum developments, and professional literature. The findings and inferences drawn from these observations and reviews were then synthesized to produce a science curriculum model applicable to Australia.

The following problems were investigated relative to the reviews of research studies, curriculum developments, and professional literature.

1. What is the relevance of educational developments in the U.S.A. for Australia?

2. (a) What are the aims of science education in the U.S.A.?

   (b) What are the implications of the aims of science education in the U.S.A. for developing curricula in Australia?

3. (a) What are the findings of research in science education and psychology relevant to curriculum construction? What are the implications of the findings of science education and psychological research for developing a curriculum model for Australia?

   (b) What are the implications from the professional literature of science education for developing a curriculum model for Australia?

4. (a) What are the factors which have influenced the recent developments in science education in the U.S.A.?

   (b) Which of the factors which have recently influenced developments in science education in the U.S.A. are applicable to Australia?

5. What are some of the distinctive features of selected NSF sponsored science curriculum projects in the U.S.A. which have direct application for science curriculum development in Australia?

Basic Assumptions

1. The science curriculum consists of the educational experiences provided as an integral part of the formal organization of the Australian school systems.
2. The research studies, curriculum developments, and professional literature, to a large degree provide a valid picture of science education in the U.S.A.
3. Certain elements characteristic of science education in the U.S.A. are applicable to science education in Australia.

Limitations of the Study

The study is limited to the observations and reviews which the writer was able to make. It was further limited in that only certain of the longer established NSF science curriculum projects were examined. The study was not concerned with research and developments at other than secondary level except as they may impinge on the Australian curriculum model.

It is also pointed out that it is recognized that there may be inherent limitations of transferring successfully innovations from one culture to another. Kandel pointed this out in that:

> It has long been recognized that a system to education cannot be transferred from one nation to another because the strong cultural differences between any two nations are too great. . . . The obverse of this principle is that each nation has or should have the educational system that it desires and finds most suitable to it.[1]

Kandel's statement, however, does not negate the usefulness of transposing appropriate elements from one educational system to another. This is implied in Wolfle's statement that:

> The great general principles of science and its methods of acquiring new knowledge, most of the detailed facts, and the methods and attitudes that characterize good scientific work are much the same regardless of political or geographical boundaries.[2]

Organization of Thesis

This Chapter has presented the problem, described the context of the problem and indicated the need for the study. Additionally, the design of the study, assumptions, and limitations were presented. The study was premised on the relevance of the findings of the literature and research of the U.S.A. for the development of a science curriculum for Australia. The methodology of comparative research is utilized in Chapter II to compare their educational systems

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[1] I. L. Kandel, "The Methodology of Comparative Education," International Review of Education, V, No. 3 (1959), 275.

[2] Dael Wolfle, "Elements of Effective Science Education," Science Education News (September, 1963), p. 3.

and so to establish the relevance of comparisons for developing an Australian science curriculum model. In Chapter III, the objectives of education, science and science education and their sources in U.S.A. and Australia are reviewed. Chapter IV presents a review of the professional literature and research in science education in Australia and the U.S.A., and Chapter V reviews the contemporary science curriculum scenes in the two nations. Chapter VI describes the characteristics of an educational model. On the basis of the definition so derived, and from the recommendations established in the preceding chapters, an Australian science curriculum model is synthesized, and a technique for implementing the recommendations is developed.

CHAPTER II

RELEVANCE OF EDUCATIONAL COMPARISONS BETWEEN U.S.A. AND AUSTRALIA

The purpose of this chapter was to show the relevance of the findings from the educational literature and research of the U.S.A. for the development of an Australian science curriculum model.

Comparative Education Methodology

The appropriateness of "the methodology of comparative education is determined by the purpose that the study is to fulfil."[1] According to Kandel, the finest product of a comparative study results from an ability to analyze one's own system and to add something to the philosophy underlying it.[2] In this thesis, an effort was made through an analysis of Australia's educational systems and from an analysis of U.S.A. practices to develop a science curriculum model which would be a contribution to Australia's basic philosophy of education. As a prerequisite for such an analysis, Kandel named a number of areas requiring scrutiny. Kandel stated:

> In order to understand, appreciate, and evaluate the real meaning of the educational system of a nation, it is

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[1] I. L. Kandel, "The Methodology of Comparative Education," <u>International Review of Education</u>, V, No. 3 (1959), 271-272.

[2] <u>Ibid</u>.

> essential to know something of its history and traditions, of the forces and attitudes governing its social organization, of the political and economic conditions that determine its development.[1]

Using Kandel's statement, the writer developed three bases upon which to analyze the educational systems of Australia and the U.S.A., namely:

> 1. The history and traditions of the two countries, U.S.A. and Australia, particularly as reflected by their respective constitutional and governmental provisions for education.
>
> 2. The forces and attitudes governing their social organizations, examining especially the role of education and the types of educational administration practiced.
>
> 3. The political and economic conditions that have determined the development of each of the two nations.[2]

In terms of each of these three bases, the educational systems of U.S.A. and Australia were compared.

Comparability of Constitutional and Governmental Provisions for Education

Constitutional Similarities

Remarkable similarities between the history and traditions of the two nations stem back at least as far as the framing of the Australian constitution. Hunt wrote:

> Parallels between federation in Australia and America were constantly pointed out in the course of the Australian

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[1]I. L. Kandel, Comparative Education (New York: Houghton Mifflin Company, 1933), p. xix.

[2]Ibid.

> federal movement. Some of these comparisons were merely superficial or were more notable for the divergences than for the similarities which were involved, but others were deeper and more significant.[1]

For example, in the U.S.A. the establishment of the Constitution in 1787 was the prelude to many important issues concerning the division of authority between federal and state governments. Some clarification of the Constitution was provided by the adoption in 1791 of the Bill of Rights, comprising the first amendments to the Constitution. By virtue of the Tenth Amendment, those powers not specifically delegated to the federal government by the Constitution, nor prohibited to the States, were reserved for the States. One of the powers so reserved was education.

In Australia, education was treated in a parallel fashion. Hunt stated:

> With a few additions the powers entrusted to the Australian parliament were those which had been delegated in America to Congress. Without serious dissent it was decided to reserve to the states all powers not assigned by the constitution to the federal government, as had been done in the American Tenth Amendment.[2]

This evidence suggests that constitutional differences between the two nations are not sufficiently different to invalidate educational comparisons.

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[1]Erling M. Hunt, American Precedents in Australian Federation (New York: Columbia University Press, 1930), p. 11.

[2]*Ibid.*, p. 14.

Similarities in Governmental Provisions

Despite the state responsibility for education mentioned previously, there have been many evidences both in U.S.A. and in Australia of national concern for education as reflected in a number of federal legislative enactments which provided for education.

Federal concern for education in the U.S.A.

Interest of the U.S.A. Government in education can be traced back to the pre-constitution instruction of military service trainees in 1777.[1] Most of the earlier educational Acts provided grants of land for the support of public schools;[2] in fact, seventeen of the first fifty-one Congresses considered proposals for the support of public education from the proceeds of public land.[3]

Continued Federal concern for education was evidenced by the nearly 1500 bills relating to education

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[1]U.S., Congress, House, Committee on Education and Labor, Federal Educational Policies, Programs and Proposals: A Survey and Handbook 86th Cong., 2d Sess., 1960, prepared by Charles A. Quattlebaum (Washington D.C.: U.S. Government Printing Office, 1960), p. 7.

[2]*Ibid*., p. 9.

[3]U.S., Congress, House, Committee on Education and Labor, Federal Aid for Education: A History of Proposals Which Have Received Consideration by the Congress of the United States (1789-1960) 87th Cong., 1st Sess., 1961, prepared by Helen A. Miller *et al*. (Washington, D.C.: U.S. Government Printing Office, 1961), facing p. 72.

considered by the 85th Congress. Among the eighty educational laws enacted by this Congress was the National Defense Education Act (NDEA). This Act, with its billion dollar budget, provided substantial support for improving science education.[1] The NDEA has been described as "a monumental legislative reaction to the great national concern with education."[2] The Act instituted a four year, state administered program for supporting education in mathematics, science and modern foreign languages. Financial assistance was given under Title III of the Act for the acquisition of laboratory and other special equipment, the remodeling of laboratories, and for providing improved supervisory services.[3]

Acts such as the NDEA have resulted in charges of the initiation of "policies of far-reaching effect as mere incidents of some particular attempt to induce an immediate and particular efficiency."[4] Nevertheless, the Federal

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[1]U.S., Congress, House, Committee on Education and Labor, Federal Educational Policies. . ., p. 7.

[2]Sidney C. Sufrin, Administering the National Defense Education Act (Syracuse, N.Y.: Syracuse University Press, 1963), p. 9.

[3]U.S., Congress, Senate, Committee on Labor and Public Welfare, The National Defense Education Act of 1958: A Summary and Analysis of the Act, 85th Congress, 2nd Sess., 1962, prepared by the Staff of the Committee (Washington, D.C.: U.S. Government Printing Office, 1962), pp. 3-4.

[4]U.S., Congress, House, Committee on Education and Labor, Federal Educational Policies. . ., p. 188.

Government has consistently avoided a comprehensive policy statement on education. However, the late President Kennedy clarified the role of the Federal Government in education in these terms:

> Although the resources and leadership of the Federal Government are essential to this effort, it is States and local communities that have the primary responsibility of supplementing the family effort in protecting and promoting the interests of children and youth. The Federal Government's challenge is to aid the States and local communities in this role.[1]

Federal concern for education in Australia

The relationship of the Federal and State governments in Australia with respect to education parallels that of the U.S.A. This was evidenced by a recent statement of Prime Minister Sir Robert G. Menzies, who said:

> The Commonwealth Government, too, is deeply interested in education and contributes a great deal in one way or another towards its financial support.
>
> . . . .
>
> Under the Australian Constitution, some matters are the responsibility of the Federal Government and some are the responsibility of the State Governments. Education is a matter that falls in the States' sphere of responsibility, not because of any lack of importance but because it is believed that State Governments are in a better position to assess local needs and provide for them. The proper role of the Commonwealth in this matter is to co-operate with the States, but not to take over their functions. Where the Commonwealth's

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[1]U.S., Congress, House, General Subcommittee on Education, Hearings, Youth Conservation Corps, 88th. Congress, 1st Sess., 1963, prepared by Adam C. Powell (Washington, D.C.: U.S. Government Printing Office, 1963), p. 20.

> responsibilities in other directions have involved it in some educational or training programme, it has tended wherever possible to make use of existing State facilities rather than establish institutions of its own. This is as it should be.
>
> So far as financial support is concerned, the Commonwealth's approach has been to build up the States' general financial resources. In this way, funds that are provided federally are spent on education, no less than they would if they were given as direct grants for this purpose. The difference is that, as things are, the States decide the purposes.[1]

One recent educational Act, however, specified the purpose for which Federally allocated money was to be spent. This Act had great significance for science education. Senator Gorton, Minister-in-Charge of Commonwealth Activities in Education and Research, in March 1964, issued a statement which was read by the Prime Minister (Sir R. G. Menzies) in the House of Representatives. The plans he proposed were to put into effect the pre-election promises of 1963 "to assist the provision and equipment of science teaching laboratories in secondary schools."[2] Gorton outlined arrangements made with the State Ministers of Education for the allocation of a total of $11.2 million annually, on proportionate non-discriminatory bases to each state, and to Government and non-Government schools. Administration of the sums available to Government schools will be by the

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[1]Menzies, <u>Education News</u>, VIII (December, 1962), p. 4

[2]Senator John Gorton, "Provision of Science Buildings and Equipment in Secondary Schools," Statement made in the Senate, and read by the Prime Minister in the House of Representatives at 8 P.M. on 5th. March, 1964, Canberra, Australia. Unpaged. (Typewritten copy in files of the writer).

recipient states "subject to the conditions that it can only be spent on the provision of science teaching laboratories in secondary schools or in the provision or capital expenditure for such laboratories,"[1] and that the State budgets clearly identify both the source of the funds and the items purchased.

Administration of funds for non-governmental schools is to be handled by a seven man "Advisory Committee on Science Facilities" with the following terms of reference:

(a) to advise on the standards to be recognised by the Commonwealth in assisting in the construction and equipping of science teaching laboratories;

(b) upon reference from the Minister, to advise upon requests for assistance received from individual schools;

(c) to serve as an expert body to which schools developing proposals for improving their science teaching could look for advice as to the best means of meeting their particular needs.[2]

This Commonwealth activity was unique in that it was the first occasion on which a specific subject area has been allocated federal aid. This Act bore some similarities to the National Defense Education Act of 1958 of the U.S.A. However, support for facilities without first perfecting a philosophy for sound and well researched programs of science

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[1]Senator John Gorton, "Provision of Science Buildings and Equipment in Secondary Schools."

[2]Canberra Press Release Copy, 25th. March, 1964, Canberra, A. C. T., Minister-in-Charge of Commonwealth Activities in Education and Research, Senator Gorton. (Mimeographed.)

education may not be directing attention to the most basic and most needed priorities of science teaching improvement.

The above evidence of Federal concern in Australia for education in general, and for science education in particular, indicates similar trends in governmental provisions to those in the U.S.A. Based upon governmental provisions in the U.S.A., the following provisions are recommended to facilitate the implementation of curriculum change suggested in the science curriculum model:

Recommendations:

2.01. A governmental agency, the Australian Science Education Foundation (ASEF), should be established for the support and encouragement of significant efforts to improve science education.[1]

2.02. The ASEF should comprise representatives selected from such organizations as: Australian Academy of Science, Australian and New Zealand Association for the Advancement of Science (ANZAAS), the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian Atomic Energy Commission (AAEC), the Australian National University, the Australian Council for Educational Research (ACER), the Australian Industries Development Association (AIDA), the Australian Science Teachers' Association (ASTA), the Commonwealth Office of Education, the Australian College of Education, the Australian Teachers' Federation, and state Education Departments.

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[1]A similar recommendation is made by the Australian Science Teachers' Association in its statement on "The Needs of Science Education in Australian Schools," submitted to the ANZAAS Council Meeting, January, 1964 (See Chapter I).

2.03. The Australian Science Education Foundation should generate studies to identify factors such as a philosophy for science education in Australia, the objectives of science education, overseas curriculum practices with implications for Australia, and science elements unique to the Australian culture; and should support research related to such factors as the determination of appropriate content and skills for science curricula, and factors related to the learner, the teacher, and classroom practices.

2.04. Federal funds should be allocated in Australia through the ASEF for the development of science curricula of national importance.

2.05. Further allocations of federal funds to schools for the improvement of science laboratories should be made dependent upon receipt of evidence of their utilization of sound programs of science education as a major criterion.

Comparability of Role of Education and of Educational Administration

The second basis developed from Kandel's prerequisites for the analysis of educational systems developed at the beginning of this chapter requires an examination and comparison of the roles of education and of the types of educational administration in Australia and in the U.S.A.

Role of Education

The role of education may be deduced from statements of the aims of education. In developing a set of aims for secondary education in Australia, Connell first considered two sources from U.S.A., namely the works of Inglis and the Report of the NEA Commission on the Reorganization of Secondary Education. Connell wrote:

> Most of those who thought and wrote in this field in most countries of the world, adopted this [American] approach, and most subsequent analyses, when they have not been actual modifications or developments of the statements of Inglis and the Commission, have usually been along closely similar lines.[1]

As an example of the similarity of Australia's educational aims to those developed in the U.S.A., Connell cited the aims expressed in the Wyndham Report.[2] These resembled the two sets of aims specified in the statements of Inglis and by the NEA Commission.

Further evidences of perceived similarities in the role of education in the two nations are provided by the relatively high number of Australian faculty[3] and students[4] visiting the U.S.A., the success of the teacher exchange program set up by the Fulbright Scheme,[5] and the increasing utilization of selected U.S.A. curriculum project materials in Australia. For example, despite its relatively small population, in 1961-62 Australia ranked ninth in the number

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[1]W. F. Connell, The Foundations of Secondary Education (Melbourne: Australian Council of Educational Research, 1962), p. 50.

[2]Ibid.

[3]American Council on Education, A Fact Book on Higher Education, A Report Prepared by the Office of Statistical Information and Research (Chicago: American Council on Education, 10/1/62), p. 268.

[4]Open Doors 1961 (New York: Institute of International Education, 1961), p. 25.

[5]Victoria, Department of Education, Report of the Committee. . ., p. 29.

(128) of visiting faculty and scholars in the U.S.A.;[1] in addition, there were 401 Australian students in U.S.A. in 1961.[2]

Curriculum project materials from the U.S.A. now being used in Australia include the adapted PSSC materials mentioned previously which were initiated following a visit by Professor Gilbert Finlay from the University of Illinois who spent two weeks in Melbourne and Sydney in September 1961. Finlay was a guest of the Australian Council of Educational Research invited to provide details of the PSSC course to Australian science educators. Following the adoption of these PSSC materials in Victoria, other states (e.g., Queensland) are also showing interest in these. The Chemical Bond Approach (CBA) chemistry course materials were introduced in 1962 to participants at a Summer School at the University of New South Wales attended by seventy high-school chemistry teachers.[3] BSCS materials have also been introduced into Australia. In 1964, with the backing of the Education Department of Victoria, four of the largest secondary schools in the state are having trial runs of the

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[1]American Council on Education, A Fact Book. . ., p. 268

[2]Open Doors 1961, p. 25.

[3]"Foreign CBA Programs: Australia," CBA Newsletter, No. 12 (February, 1962), p. 3.

various versions of BSCS materials. At Essendon Grammar School, a private school in Victoria, the AAAS "Process Approach" science materials are currently being tested.[1]

Thus it can be seen that American science curricula are gradually being tried under Australian conditions. This is further evidence of the perceived similarity of roles of science education in the two nations. In view of this perceived relevance of roles in the U.S.A. for Australia, and of science education in particular, steps should be taken to facilitate the selection, adaptation and adoption of appropriate U.S.A. materials for Australian usage. With this in mind, the following recommendations are made:

Recommendations

2.06. A Science Resource Center should be established in each Australian state for the purpose of obtaining, reviewing and displaying specimen materials of all NSF supported projects developed in the U.S.A., in addition to other relevant materials from the U.S.A. and other countries.

2.07. Mechanisms should be sponsored by the ASEF in each Australian state for the continual review of developments of other states and of contemporary developments significance in other countries of the world, particularly the U.S.A. Such mechanisms may include provisions for:

(a) attendance at NSF sponsored workshops of Australian science educators;

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[1]Letter from Mervyn L. Turner, Chief Research Officer of the General Research Department of the Australian Council of Educational Research, Hawthorn, Australia, April 15, 1964.

(b) regular visits to Australia of directors and other senior officers of U.S.A. science curriculum projects:

(c) study tours in the U.S.A. by science education leaders and officers of the state Education Departments responsible for science education;

(d) appointment of an Australian educational attaché in the U.S.A. to advise Australians on contemporary educational developments in the U.S.A.

(e) subsidy of systematic trials of curricular innovations under Australian conditions.

Types of Administration

A major difference between the education systems of Australia and the U.S.A. lies in their methods of school administration. In the U.S.A., there is a commitment to local control of education; whereas in Australia, all six states maintain basically centralized educational administrations.

It will be shown that effects of this difference on science education are superficial rather than actual, and consequently will not invalidate the application of comparative education methodology. It will further be shown that the difference is accountable in terms of the historical development of the two systems.

Local administration in U.S.A.

In the U.S.A. the need for local systems of education was implied by the requirements for administering the township sections allocated by the 1785 Northwest Ordinance.

These ordinances, preceding the Constitution, were passed by the Congress of the Confederation in 1785 and 1787 and represent the first provisions of federal aid to education. This aid was provided through the reservation of the sixteenth of every thirty-six blocks in each six-mile-square township in the Northwest Territory. The income obtained from these lands or the sale of them was to be used for the development of public education in the township. Although providing funds from federal action, the effect of these Ordinances was to cause local administration of these funds. These funds were insufficient to provide for the continued administration of the public education facilities that were developed.

Generally, finance for these systems was problematical, and lotteries and charges for licences for liquor, theater, and marriage were used to defray expenses and so avoid the need for a property tax.[1] This method proved to have merely delayed the enactment of more realistic financing measures. Although there was much opposition to the introduction of statewide compulsory district tax laws, several states followed the leads of New Jersey (1820) and Missouri (1824) by enacting optional laws, which required ratification at the local level. It was Massachusetts, under the dynamic

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[1]William E. Drake, The American School in Transition (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1960), p. 199.

leadership of Horace Mann, which in 1837 passed the state law setting up a state-organized public school system. By 1875, all states in the Union had appointed public school officers.

It is at this local level that control of public education in the U.S.A. is still retained. State legislatures have, in general, delegated the control of schools to local school boards. Conant gave some credit to President Thomas Jefferson for the development of this local pattern. However, he tended to discount Jefferson as the instigator. Conant wrote:

> In one other respect, the success of Jefferson as a politician influenced American public education profoundly, Jefferson and his followers were highly suspicious of centralized government.
>
> . . . .
>
> For several generations after Jefferson's death, this distrust of central government hampered the state authorities in the work of improving schools. Not that the characteristically American system of local control of public schools (today there are some 40,000 independent school boards) can be attributed to Jefferson, but the political success of Jeffersonian democracy was surely one important factor in the development. . . . His plan envisaged local schools, locally controlled and supported largely by local taxes.[1]

Subsequently, Jefferson's plans for local education administration have received widespread support in the U.S.A.

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[1]James B. Conant, Thomas Jefferson and the Development of American Public Education (Berkeley: University of California Press, 1962), pp. 10-11.

Centralized administration in Australia

As described earlier, education in Australia is state administered. Kandel failed to appreciate the raison d'être of this centralized educational administration. He attributed the centralized control there to "an accident of history rather than for political reasons."[1] Elsewhere, Kandel had written:

> There are centralized systems in democracies, such as Ontario and the Australian Provinces, which seem to have no raison d'être in the political or social theories of these States, but appear to be accepted in the interests of efficiency and perpetuated through inertia.[2]

However, Hans described the rationale for the administrative structure of Australian education in terms of its geographic features. He expounded this theory further in the following:

> As a striking example of the dominating influence of geographic factors of a modern nation we may take Australia. This continent, almost equalling Europe in area, contains the second-largest desert in the world. The whole area is divided as follows: 21 per cent of the continent is suitable for close settlement by Europeans, 42 per cent is arid, 34 per cent suitable for pastoral purposes and 3 per cent for tropical agriculture. In these conditions the population is either congregated in a few urban centres or widely scattered in the bush. The six capitals of the six states: Sydney, Melbourne, Brisbane, Adelaide, Perth and Hobart, contain 47 per cent of the total population

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[1]I. L. Kandel, The New Era in Education: A Comparative Study (Cambridge, Massachusetts: The Riverside Press, 1955), p. 69.

[2]Kandel, Comparative Education, p. 76.

of Australia, the rural population on the other hand is sparsely distributed throughout the country. Whereas in England the density of the rural population is 120 per square mile, in Australia it is only 1 per square mile. In these conditions Australia was compelled by geography to develop two quite different systems of education: one for the large towns, another for rural districts.

. . . .

The conditions in the outlying rural districts are entirely different. The rural schools are small one-teacher institutions with ten to forty pupils. Secondary schools are all concentrated in urban communities. Only small intermediate schools for the ages twelve to fifteen are available in the country. In addition many farms are so far from the nearest rural school that daily attendance is impossible. Left to themselves these families would be quite unable to educate their children beyond reading and writing. As all six states have accepted in their legislation the principle of equality of educational opportunity, the government has had to take both the administrative and financial responsibility into its hands. Thus the highly centralised systems of Australia, so contrary to the historical traditions of the English-speaking countries, are the direct result of geographical conditions. In the absence of local authorities the state was the only agency which could provide the means and organisation of correspondence and travelling teachers. Thousands of isolated boys and girls receive their education through correspondence and occasional visits by travelling inspectors.[1]

Rayner supported this view:

In educational literature centralisation has often been condemned; whilst there can be no doubt that there are some directions in which educational decentralisation is increasingly desirable, it seems that no system could have served so well in maintaining a reasonably good standard of general education during the pioneering work of opening up a new continent. . . .Underdeveloped and rural areas could not offer salaries as high as those

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[1]Nicholas Hans, Comparative Education (London: Routledge and Kegan Paul Ltd., 1951), pp. 65-66.

> paid in the cities, and hence, in some other countries, they received the poorer teachers. The Australian system makes it possible to spread educational opportunities more uniformly.[1]

Butts commended the equality of educational facilities resulting from Australia's centralized system:

> I have nothing but praise for your efforts to provide equal educational facilities throughout a state system. To find good buildings and well-prepared and well-paid teachers in the poorest and most remote sections of a State as well as in the wealthiest and most densely populated areas is, I believe, a remarkable achievement. I would not find this same equality in the United States.[2]

From the above, it is seen that in terms of Australia's unique population distribution, the centralized administrative structure for education affords a high degree of equality of educational opportunity.

Effects of Different Types of Administration on Comparability of Science Education

The marked differences in administrative structures of education in the two nations is not reflected in differences in the extent of adoption of science curricula. In Australia, state centralized administration results in statewide science curricula. However, local control in the U.S.A. is not always reflected in the use of locally devised curricula.

For example, the fact of local option in curriculum selection in the U.S.A. has been exercised in a direction

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[1] S. A. Rayner, Correspondence Education in Australia and New Zealand (Melbourne: Melbourne University Press, 1959), pp. 9-10.

[2] R. Freeman Butts, Assumptions Underlying Australian Education (New York: Bureau of Publications, Teachers College, Columbia University, 1955), p. 12.

which has resulted in widespread acceptance of a few National Science Foundation (NSF) sponsored science curricula. This degree of acceptance has tended to produce a measure of uniformity in curricula akin to a centralized administrative educational system such as that in Australia. For example, the PSSC physics is being used by 4,000 (25% of) high school teachers throughout the U.S.A.[1]

Curricula emanating from nationally conceived groups in other areas are likewise being accepted in increasing numbers, as evidenced in Table 2.

It is apparent from Table 2 that despite the local freedom of choice of the school boards, the increasing tendency to utilize NSF supported curricula has provided an informal system producing a uniformity of science curricula across the U.S.A. This is similar to that of the formally-imposed curricula of the centralized systems of education in Australia. Whether formally or informally produced, the resultant systems are comparable. Bakke stated:

> As factors influencing human behavior, the formal and informal systems are not separable.[2]

In view of the extent of adoption of the NSF supported curricula, which imposes an administrative structure

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[1]ESI Quarterly Report Winter-Spring 1964 (Watertown, Massachusetts: Educational Services Incorporated, 1964), p.4.

[2]E. W. Bakke, Bonds of Organization (New York: Harper and Brothers, 1950), p. 144, cited by Keith David, Human Relations in Business (New York: McGraw-Hill Book Company, Inc., 1957), p. 98.

TABLE 2

NUMBER OF TEACHERS UTILIZING SELECTED NSF SUPPORTED CURRICULUM PROJECT MATERIALS

	1959-60	1960-61	1961-62	1962-63	1963-64	Total Number of Teachers in Area[e] (1963)
Physics (PSSC)[a]	560	1100	1800	3000	4000 (estimated)	16731
Biology (BSCS)[b]	(Materials Written)	118	541	950		33102
Chemistry (CBA)[c]	"		200		-	21346
Chemistry (CHEM Study)[d]	"	24	158	700	1700[f]	

[a]ESI Quarterly Report, p. 4.

[b]CBA Newsletters

[c]BSCS Newsletters

[d]CHEM Study Newsletter

[e]U.S. Registry of Junior and Senior High School Science and Mathematics Teaching Personnel. Established by the National Science Teachers Association (NEA) and National Council of Teachers of Mathematics (NEA); supported by a grant from the National Science Foundation, 1963.

[f]Letter from Richard J. Merrill, Executive Director, CHEM Study, to writer, dated July 7, 1964.

on science curricula from outside the local community, there is a similarity in the administrative patterns of science curricula which validates and facilitates comparisons between educational administration in Australia and the U.S.A. for the purposes of this thesis. This suggests that procedures utilized by the NSF and its curriculum projects have relevance for Australian conditions. Consequently, the following recommendations are presented:

Recommendations

2.08. Australian science curricula, including all necessary accompanying materials, should be developed in Australia by procedures similar to those in the U.S.A. which utilize the best manpower and practices known.

2.09. These curricula should be made available for voluntary selection and adaption by the schools of Australia.

Comparability of Political and Economic Conditions

The third basis developed from Kandel's requirements for a comparison of educational systems requires a comparison of the political and economic conditions of Australia and the U.S.A.

Political Conditions

Fundamentally, these two nations bear close political similarities by virtue of their respective commitments to democratic ideals. Connell expressed the Australian viewpoint thus:

> An integral part of the Australian tradition and of our present way of life is a belief that we are democratic people. We are attached by conviction and by sentiment to our democratic institutions and we view any threat to them as an attempt to subvert something fundamental in our existence. We habitually use the democratic way of doing things as an expression of praise, and frown upon ideals which work in a contrary direction.[1]

Contemporary political conditions largely reflect the respective national constitutions. The analogous constitutions of the two nations date back to the framing of the Australian constitution in the 1880's. Hunt quoted freely from various conferences which preceded Australian federation, and showed how American precedents were often decisive in their influence on Australians responsibility for framing the constitution. Hunt wrote of some constitutional similarities:

> The superficial resemblance of the Australian to the American Constitution is obvious. Both organize a federal government. Both separate that government into three branches. Both establish a legislature composed of a house of representatives elected on a popular basis and a senate in which the states are equally represented. Both provide for a supreme or high court and empower the federal legislature to establish a system of inferior federal courts. Both constitutions delegate large powers, many of which are the same in the two documents, to the federal government, reserving the powers not so delegated to the states composing the union. Both carefully guarantee the integrity of these states and preserve to them large and essential powers.[2]

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[1] W. F. Connell, The Foundations of Secondary Education, p. 35.

[2] Hunt, p. 5.

Even similar wording was used in the Australian Constitution where the American precedent was useful. Hunt further reported:

> When words in the American Constitution exactly fitted the needs of Australian draftsmen, and had been demonstrated to be effective, they were adopted, but when they needed modification, either to meet different conditions or because they had proved vague or inadequate, they were modified or discarded without hesitation. American judicial decisions in such matters as irrigation, interstate commerce, and the regulation of Sunday observance, actually influenced votes.[1]

These constitutional similarities gave rise to basic political similarities in Australia and the U.S.A. Despite the constitutional similarities, a political difference between the United States and Australia is manifested by virtue of the differences in the role of internal politics on education in the two countries. In Australia, political influence is minimal. Rayner wrote:

> By contrast with the United States, education in Queensland is only one of a dozen or more governmental functions. In political campaigns, the members of the governing party campaign on their record as a whole rather than on the work of one department; the result is that educational issues are not raised in elections as in the United States where thousands of candidates for public office are concerned with education alone.[2]

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[1]Hunt, p. 256.

[2]S. A. Rayner, "The Administration of Pupil Personnel Services: A Comparative Study of Services in the United States and Queensland, Australia" (unpublished Ph. D. dissertation, University of Illinois, January, 1955), pp. 16-17.

What Rayner reported for Queensland is equally applicable to other states. Consequently, it is unlikely that political considerations alone will affect science education curricula in Australia.

Economic Conditions

A comparison of the economic conditions of the two nations is complicated among other factors by the different methods of reporting educational expenditures, by the great differences in populations and geographical distributions of the people, by differences in stages of industrial developments of the two countries, and by differences in currency. In spite of these complications, since Cramer and Browne have stated that "the economic resources of a country affect greatly the level of educational opportunities which can be provided,"[1] the economic comparison remains important. Referring to the situation in Australia, Cramer and Browne added:

> We have a continent about the same size as the United States, but with only 9 million people [1956] within its borders. The task is to carry effective education to a widely scattered population, and thus the educational planning must be on a different basis from that in many other countries, since the educational expenditure, limited in total amount by the small population, has to be spread over such an enormous area.[2]

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[1]John Francis Cramer and George Stephenson Browne, Contemporary Education: A Comparative Study of National Systems (New York: Harcourt, Brace and Company, 1956), p. 8.

[2]Ibid., p. 10.

So great are the financial problems faced by the State departments of education in Australia today, that this was the basis of a special document "compiled under the direction of the Australian Educational Council, which comprises the Ministers of Education of all states of the Commonwealth of Australia."[1] The critical state of the finances available for Australian education was made clear in the following statement in the above mentioned document:

> The problems dealt with in this statement are those whose solution depends substantially upon financial considerations. At present these constitute the greatest challenge to the nation's educational future.
>
> . . . .
>
> There is a wide gap between the needs and demands of the community and what State Governments can provide.
>
> . . . .
>
> The Governments of the various States have allocated to their Education Departments a large and increasing proportion of their moneys and consequently some progress has been made in meeting basic educational requirements. This allocation has been made, however, in competition with demands for other services which cannot continue to operate satisfactorily without additional funds.[2] Further--and despite the increased allocation--the objectives as laid down by the Council have not been fully attained, and there have been many indications of the Community's impatience at the slowness of the rate of progress reported.[3]

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[1]"A Statement of Some Needs of Australian Education," The Teachers' Journal, XLVII (March, 1964), 23.

[2]The percentage of the total government expenditure by the six Australian States on education rose from 12.6% in 1952-53, to 17.1% in 1960-61.

[3]"A Statement of Some Needs of Australian Education," The Teachers' Journal, XLVII, 23.

Much of the increased educational allocation has been absorbed by the needs of the unprecedented increase in school population referred to in Chapter I. A comparison of national and state expenditures on education reveals that Australia and its six states would need vastly increased financial support for its educational systems, to bring expenditure to figures comparable with those in the U.S.A. This may be evidenced by examining the percentage of the gross national product spent on education and from the amount spent per inhabitant on education. In 1960-61, the six Australian states spent a total of £ A184 million (comprising £ A142 million on education and £ A32 million on school buildings.)[1,2] On this basis, the percentage of the gross national product spent on education in that year was 2.71 per cent. In the same year the gross national product in U.S.A. was $503,443 million and the educational expenditure $27,300 million. Consequently, 5.42 per cent of the gross national product in U.S.A. was spent on education.[3] This American percentage is exactly double the percentage spent in Australia in the same year.

In terms of expenditure on education per inhabitant, in 1960 the United States of America spent $27,300,000,000

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[1]Menzies, Education News, VIII (December, 1962), 4

[2]£1 (Australian) = $2.24 (U.S.A.)

[3]U.S., Department of Health, Education, and Welfare, Office of Education, Progress of Public Education in the United States of America 1962-63 (Washington, D.C.: U.S. Government Printing Office, 1963), pp. 2-3.

or $151 per inhabitant, compared to the 1962 Australian expenditure of £191,000,000 (approximately $428,000,000 or $43 per inhabitant.)[1,2]

Each set of comparative costs indicates that educational expenditures in the U.S.A. are far higher than those in Australia. This is in spite of the higher distribution costs one would expect in Australia for education, as indicated by the population distribution shown in Table 3:

TABLE 3

SOME COMPARATIVE STATISTICS FOR
U.S.A. AND AUSTRALIA

	Australia	U.S.A.
Area	2,971,000 sq. mi.	3,554,600 sq. mi.
Population 1964	11,000,000	186,000.000
Population density	3.6 persons/sq.mi.	50 persons/sq. mi.
School-age children	2,200,000	37,504,000
Public school teachers	59,600	1,260,000

These figures reflect the facts that one-third of Australia is virtually uninhabited, and another one-third of the area has only a sparse population. Over fifty per cent of the people live in the States' six capital cities, and nearly

[1]Extracted from "Statistics of Public Expenditure on Education," Table VI in International Yearbook of Education Vol XXIV, 1962, pp. 496-98.

[2]The discrepancy between the amount of £A191 million quoted here and that of £184 million quoted by the Prime Minister in the previous paragraphs appears to be due to inclusion in the former of a Commonwealth expenditure of £A6.62 million on scholarships and international education.

sixty-five per cent of the people live in the dozen most populous cities (compare Table 4). Ninety-six per cent of the population lives on about sixty per cent of the land.

TABLE 4

POPULATIONS OF THE TWELVE MOST POPULOUS AUSTRALIAN CITIES[a]

City	Population	City	Population
Sydney	2,215,970	Newcastle	208,905
Melbourne	1,956,400	Wollongong	131,758
Brisbane	635,500	Geelong	91,666
Adelaide	593,500	Launceston	56,837
Perth	431,000	Canberra	63,313
Hobart	118,828	Ballanat	54,913

[a]"Population," Australia in Brief (Canberra: Australian News and Information Bureau, 1963), p. 5.

The problem of providing equal educational opportunity for the sparser elements of the population requires correspondence tuition, School of the Air, one teacher (rural) schools, and similar facilities. These costly techniques of providing equal educational opportunity for children in outlying areas add considerably to the cost of education.

With the limited availability of educational funds in Australia, financial priorities for providing minimal physical facilities obviously severely restrict the availability of funds for improving educational quality. School curriculum and educational research must consequently become to some extent secondary considerations. This is in contrast with that of the U.S.A. where Taylor reported that

> . . .with the economic resources of a country richer in resources that any other in the world, we have an opportunity to achieve more than any other country in the world. . . . We have the opportunity to educate every child in the United States up to the limit of his talents. We have the financial and educational resources. We also have the opportunity to resist the easy way of accepting our own natural and cultural resources without doing anything with them. We have the opportunity, each one of us in our schools and colleges, to take the higher road, to look for new ways of teaching, to look for new forms of knowledge, to look for a higher level of achievement and aspiration on the part of our students.[1]

These comparisons indicate that U.S.A. in a much better financial position than Australia to support education. The influence of expenditure on facilitating educational innovation is referred to by Firman. He wrote:

> Using "adaptability"--the rate at which the school employs newer instructional and curriculum techniques as they are discovered--as a global criterion of school quality, researchers have shown the relationship of many generalized variables to quality. Their studies indicate a strong positive relationship, for example, between expenditure level and the adaptability criterion.[2]

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[1]Harold Taylor, "Americans in Transition," The Impact of Contemporary Scientific and Technological Developments Upon the American Economy, Report of Proceedings of the Science-Economics Workshop Sponsored by Joint Council on Economic Education in Cooperation with the National Council for the Social Studies and the National Science Teachers Association, Sarah Lawrence College, Bronxville, New York, August 3-22, 1958 (New York: Joint Council on Economic Education, 1958), p. 9.

[2]William D. Firman, "The Relationship of Cost to Quality in Education," (unpublished talk presented to the Committee on Educational Finance, National Education Association, St. Louis, Missouri, April 8, 1963), p. 8. (Mimeographed.)

Consequently, with such a difference in financial resources available to education in the two countries, the adaptation and utilization by Australia of curricula which have passed the test of experimentation in the U.S.A. appears to have merit. As it would not be practicable to examine innovations in all school districts,[1] selection could be limited to the wealthier of these. These districts were shown in a study by Mort and Cornell to be highly inventive. Mort and Cornell found "wealthy school districts play an important part in the inventing of adaptations and experimentation with them"[2]

The above evidence indicates that Australia can profitably adapt and utilize successful American innovations, since conditions in the U S.A. are more amenable to educational innovation. Methods of facilitating such innovations have been suggested by Brickell as a result of his study in New York State. Two of his findings appear to have relevance for Australian science education, namely:

> (1) The most persuasive experience a school person can have is to visit a successful new program and

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[1]In 1931-32 there were 127,531 school districts in U.S.A. By 1957-58, this number had decreased to 47,594. Iowa had the most districts (3,303), Nevada the fewest (17). Michigan had 2,500 districts. Figures from Biennial Survey, p. 23.

[2]Paul R. Mort and Francis G. Cornell, American Schools in Transition: How Our Schools Adapt Their Practices to Changing Needs (New York: Bureau of Publications, Teachers College, Columbia University, 1941), p. 139.

to observe it in action. . . . Recommended new programs must be demonstrated so that they can be observed in action.

(2) Anything abnormal, unreal, or artificial in the circumstances surrounding an observed program--that is to say, anything appreciably different from conditions in the visitor's own school system--can rob a visit of persuasive effect. Implication: Recommended new programs must be demonstrated in schools quite similar to those from which visitors come.[1]

Brickell's study suggests the need in Australia for the demonstration of new science programs in action in classrooms in typical schools.

Comparability of U.S.A. and Australian Education: Summary and Conclusions

From the above discussion utilizing Kandel's three bases of the (1) history and traditions, (2) of the forces and attitudes governing their social organization as reflected in the roles and administration of their educational systems and attitudes, and (3) the political and economic conditions[2] of the U.S.A. and Australia, it is evident that there is both an actual and a perceived relevance of American educational developments for the Australian systems of education.

In addition to the similarities of constitutional and governmental aims for education, and of educational structures,

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[1]Henry M. Brickell, Organizing New York State for Educational Change (Albany, New York: State Education Department, 1961), pp. 27-29.

[2]Kandel, Comparative Education, p. xix.

additional validity for the comparability of educational systems of Australia and the U.S.A. is conferred by:

1. the growing internationalism of science and of education in general, and of science education in particular, as a result of improved communications;

2. increasing trend towards the teaching of science from the "process approach," comparable in both U.S.A. and Australia.

3. the absence of a language barrier.

The comparisons of the conditions in Australia and the U.S.A. indicate the relevance of a number of findings from the literature and research of the U.S.A. in the development of a science curriculum model for use in Australia. Several recommendations were listed earlier in this chapter. The following recommendations for implementation by the proposed ASEF also arise from the comparability of the two educational systems:

Recommendations

2.10. Studies such as Brickell's New York State study[1] should be conducted for the purpose of determining those factors which would encourage the invention and adoption of new science education programs Australian states.

2.11. Opportunities for teaching and studying by Australian science teachers in the U.S.A. should be extended, so as to facilitate an earlier and firsthand knowledge of U.S.A. developments in science education.

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[1]Brickell, Pp. 107.

2.12. Experimental schools should be established for the purposes of experimentation with innovations.

2.13. Procedures selected from NSF sponsored curricula should be subjected to Australian trials under varying conditions in these experimental schools.

2.14. Demonstration classrooms should be established in regular schools in which selected new programs should be taught by teachers who have attended programs (e.g., NSF institutes) designed to facilitate the introduction of innovation.

CHAPTER III

THE OBJECTIVES OF SCIENCE EDUCATION

The purpose of this chapter was to examine the professional literature to determine the sources and nature of the objectives of education, science, and science education in Australia and the U.S.A. On the basis of this review, parallels were drawn between the objectives of the two nations, and a series of recommendations that may have relevance for the construction of an Australian science curriculum model was then made.

Importance of Specifying Objectives

The late Director of Education in Victoria, Australia, Mr. M. P. Hansen, indicated the importance of specifying objectives in terms of their role in the determination of curriculum revision. Hansen wrote:

> The process of curriculum revision means simply the better adaptation of the work of the school to bring it into harmony with the accepted major objectives of the school.[1]

In these terms, a consideration of objectives is basic to the task of developing a curriculum model. Bloom's

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[1] M. P. Hansen, "Foreword," The Case for Curriculum Revision: Being a Report Submitted to the Directors of Education, Victoria, as a result of Observation in Great Britain and America, author G. S. Browne (Melbourne: Melbourne University Press, 1932), p. 9.

statement in developing a taxonomy of cognitive objectives confirmed this view:

> Objectives are not only the goals toward which the curriculum is shaped and toward which instruction is guided, but they are also the goals which provide the detailed specification for the construction and the use of evaluative techniques.[1]

Downing, as early as 1932, writing in the Thirty-First Yearbook of the NSSE said as follows:

> The success of a given unit can be assured when the ends to be achieved by its use are clear to the teacher, when the achievement is tested, and when the pupils are conscious of their accomplishment.[2]

Heil[3] and Reiner[4] also stressed the importance of specifying objectives.

Experts in educational evaluation have emphasized the importance of expressing such objectives in terms of the behavioral changes sought in students. For example, Tyler stressed the importance of deciding course aims as a prerequisite for constructing curricula:

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[1] B. S. Bloom (ed.), Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook 1: Cognitive Domain (New York: David McKay Company, Inc., 1961), p.27.

[2] Elliot R. Downing, "The Course of Study in Biology," A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I(Chicago: The National Society for the Study of Education, 1932) p. 238.

[3] Louis M. Heil et al., "The Measurement of Understanding in Science," Chapter 6 in The Measurement of Understanding, Forty-Fifth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1940), p. 136.

[4] William B. Reiner, "Needed Research in Evaluation in Science Teaching," Science Education, XXXVII (February, 1953), 61-69.

> Unless instruction is to be merely a haphazard or intuitively guided process, it requires rational planning and execution in terms of the plans. Viewed in this way, instruction involves several steps. The first of these is to decide what ends to seek, that is, what objectives to aim at or, stated more precisely, what changes in students' behavior to try to bring about.[1]

The behavioral objectives should reflect the more general educational objectives of the system in which they operate and also of the discipline of which they are a part. Consequently, it is necessary to consider the general educational objectives of Australia and the U.S.A., and also the objectives of science, as prerequisites for determining the objectives of science education and developing a curriculum model.

Determination of Educational Objectives

The relative contributions of the professional educator and the lay public in determining the objectives and curricula of the school has supporters for the whole spectrum of positions. At one end of the spectrum, Lieberman considered that the public had exceeded its rightful position. He stated:

> At the present time, the public expects to decide many things which could be decided by educators. . . . The present attitude of the public, which takes lay interference with the educators professional autonomy for granted, is a logical reaction to the uncritical notions of democracy and professionalism

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[1]Ralph W. Tyler, "The Functions of Measurement in Improving Instruction," Educational Measurement, ed. E. F. Lindquist (Washington, D. C.: American Council on Education, 1961), p. 48.

> which prevails among educators. A much different attitude on the part of laymen can be expected only if and when educators themselves understand the need for professional autonomy and are alert to every opportunity to strengthen it.[1]

On the other hand, the viewpoint has been expressed that, at least in determination of educational objectives, the school should reflect the democratic society which it serves by entrusting to the lay public the "tasks of organizing and operating a school system. . ."

> Board members and the superintendent should concern themselves with the philosophy and purposes underlying the curriculum, methods of teaching being used in the classroom, and results obtained. The interest shown by the parents should be recognized by board and superintendent by inviting parents to serve as members of curriculum committees, to visit the schools, and to contribute to the policies of the school.[2]

Although both Australia and the U.S.A. are democratic nations, the differences in their types of educational administration has led to differences in the degree of lay participation in education. In the U.S.A., the Educational Policies Commission of the National Educational Association (NEA) has accepted the function of identifying and publicizing objectives, and more recently, the NEA Project on Instruction has done likewise. This latter group was constituted as follows:

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[1]Myron Lieberman, "Authority and Control in Education," <u>School and Society: Readings in the Social and Philosophical Foundations of Education</u> Eds. Carl H. Gross, Stanley P. Wronski and John W. Hanson, (Boston: D.C. Heath and Company 1962), p. 370.

[2]Association of School Administrators, "Why We Have School Boards," quoted in Gross, Wronski and Hanson, p. 355.

A fourteen-member National Committee and a headquarters staff were appointed to carry on the work of the Project. The National Committee was composed of classroom teachers, public school administrators, and university professors. From time to time, distinguished citizens and scholars in the academic disciplines served in special advisory capacities.[1]

This NEA Project on Instruction was set up to consider

some basic problems relating to the instructional program of the schools. There is no shortage of ideas about what these problems are and how they should be solved. There is, in fact, a constant babble of voices as millions of people with many and often conflicting ideas speak out about education.

. . . .

All of these voices have a right to be heard. One voice that should speak out clearly indeed is the voice of the teaching profession itself. With this firm belief, the National Education Association established in 1959 the Project on the Instructional Program of the Public Schools (Project on Instruction).[2]

Referring to educational objectives in one of their recommendations, the National Committee of the NEA Project on Instruction stated:

The public, through the local school board, is responsible for determining the broad aims of education. The professional staff is responsible for translating the broad aims into specific objectives that indicate priorities and define clearly the behaviors intended for the learners. The local Board of Education has responsibility for

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[1]National Education Association, Project on Instruction, Schools for the Sixties: A Report of the NEA Project on Instruction (New York: McGraw-Hill Book Company, Inc., 1963), p. vii.

[2]Ibid., p. 34.

> seeing that an acceptable statement of objectives and priorities is prepared and for endorsing such a statement.[1]

The Australian viewpoint typically has been that a centralized committee within each state can determine statewide objectives. For example, the State Committee on Education in Victoria reported that the Council of Public Education had produced the most useful set of objectives available.[2] This Council is "an advisory body set up by the Act of 1910. . .[through which] the Department keeps in touch with general opinion in the community on matters affecting education. The Council includes representatives of the University, the registered schools, industrial, and general educational interests."[3] The State Committee on Education added:

> The schools of the State system have been established by legislative enactments of the State Parliament. They are therefore schools of the Victorian community in general, and can be assumed to be established to serve the community in ways which the majority of the community accept as proper. The legislative enactments, however, give us little guide to what general or specific objectives the system has.[4]

From further investigations as to the source of objectives, the Committee found that the community

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[1]National Education Association, Project on Instruction, Schools for the Sixties. . ., p. vi.

[2]Victoria, Department of Education, Report of the Committee. . ., p. 35.

[3]Ibid., p. 23.

[4]Ibid., p. 34.

expression of objectives had been made through its parliamentary representatives and/or committees of enquiry. These had been couched in general, and not in specific terms.[1] The Committee then defined its position concerning the relative roles of the community and educators as follows:

> We believe that it is the proper function of the professional educator to translate the broad and general goals, required of the schools by the community, into more specific objectives and to determine those courses which will be most effective in helping the child reach these objectives. . . . But even broad objectives may change, if not in detail then in emphasis. It is important therefore that they should be under periodic review by the community in the light of its own perception of changing needs. It is equally important, we believe, that the professional educator be involved in such a review so that he may both know how acceptable his past efforts have been, and put forward his own experience--his experience for example of the realistic or unrealistic nature of the stated objectives, the need for greater clarity, greater detail, or perhaps even greater generality in their expression, or the need for greater guidance so far as priorities are concerned.[2]

The year 1963 witnessed increasing community concern for and participation in education. At a national Congress on Education, 4000 delegates representing all walks of life, and thirty-two national and state organizations from all Australian states met in Melbourne to discuss the theme

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[1]Victoria, Department of Education, Report of the Committee. . ., p. 36.

[2]Ibid.

"Education, Australia's Greatest Responsibility."[1] However, in the absence of local levels of school boards and other groups concerned with educational policy, there has been little evidence of community participation in Australia in the determination of educational objectives.

Recommendations:

3.01. The specification of educational objectives in Australia should take into account the following principles:

   a. The specification of educational objectives requires the expression of the educational preferences of a community, i.e., of value judgments.

   b. The objectives should be derived from a consideration of philosophical (to reflect the value system), sociological (to reflect cultural determinants) and psychological (to reflect the conception of individuals) factors.

   c. The reliability of the objectives may be increased by increasing the degree of involvement of the community in specifying the broad objectives.

3.02. Educational organizations cognizant of the above principles such as the Commonwealth Office of Education, Australian College of Education, Australian Council of Educational Research, Australian Teachers' Federation and the state Education Departments should assume responsibility for convening periodically meetings of delegates from as wide a range of appropriate organizations as practicable for the purpose of identifying sets of broad educational objectives for Australia.

3.03. The above educational organizations should also assume responsibility for translating the broad

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[1]"4000 Press Congress Resolutions," The Teachers' Journal, XLVI (June, 1963), 153-59.

> educational goals into specific objectives which will assist those responsible for the development of curricula.

Determination of Objectives of Science Education

Although the involvement of the lay public in the specification of the broad educational objectives has frequently been advocated in the U.S.A., no such advocacy appears to have been seriously advanced for determining the science education objectives. Traditionally, until the mid-fifties, these objectives had been determined in the main by groups of educators. However, this policy resulted in the development of a strong dispute in the U.S.A. Fraser wrote:

> One of the basic issues in today's debate about the public schools is the proper relation between the academic disciplines, or the organized fields of scholarly knowledge, and the curriculum of the elementary and secondary schools. Two generations ago this question was little debated. . . . It was assumed that society's needs would be met by transmitting as much as possible of the organized, available knowledge.[1]

An outcome of such a policy was the expression of dissatisfaction with science education objectives and curricula. Scientists issued statements such as:

> Curricula and courses in mathematics and science in elementary and secondary schools. . . have failed to evolve at a pace commensurate with the rapid growth of scientific and technological knowledge characteristic of the twentieth century. The lag is due in part to the volume and impact of new knowledge and the accelerating pace of discovery. To some extent it is also attributable to the gulf which has developed

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[1]Dorothy M. Fraser, Current Curriculum Studies in Academic Subjects (Washington, D.C.: National Education Association, 1962), p. 1.

> between research scientists primarily concerned with the acquisition of new knowledge and teachers, writers, school administrators, and others primarily concerned with the diffusion of knowledge.[1]

The establishment of the National Science Foundation (NSF) in 1950 as an independent agency of the U.S. Government has exerted a direct influence on the objectives and teaching of school science. One of the basic principles of the NSF's programs for science education was:

> The attack on the problems of education in the sciences requires the mutual understanding and sympathetic cooperation between those eminent in teaching and those eminent in science--including those outstanding scholars who have demonstrated excellence in both domains. The Foundation will actively solicit and encourage such cooperation. Further, the Foundation's science education activities must be developed with the fullest cooperation and advice of the scientific-educational community.[2]

Consequently, scientists became involved to an unprecedented degree in the determination of science teaching objectives. The extent of this involvement is indicated partly by the following report:

> . . .ten Nobel Laureates are now actively involved in various projects to improve school science education in the United States, whereas during the twenty-five years preceding the 1950's, not one distinguished person was so engaged.[3]

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[1]National Science Foundation, National Science Foundation Programs for Education in the Sciences (Washington, D.C.: U.S. Government Printing Office, March, 1961), p. 28.

[2]*Ibid.*, p. III.

[3]Claude W. Gatewood and Ellsworth S. Obourn, "Improving Science Education in the United States," A Joint Paper

The involvement is also indicated by the following statement of one of a set of guiding principles that applies to the support of course content projects at all educational levels and in all scientific fields:

> A course-content improvement project originates when scientists of high professional stature and teachers of recognized competence and experience present evidence that an urgent need for improved subject matter exists in a particular field. Projects are directed by college-level scientists, and grants are made to institutions of higher learning and professional scientific societies. Emphasis is placed on subject matter rather than pedagogy. However, the involvement of teachers at the appropriate level is essential to help insure that the materials developed will be pedagogically sound. Teachers take part in the initial writing and in classroom trials of the preliminary versions of new courses.[1]

It would appear that the policy of involving scientists is based upon certain assumptions:

1. The involvement of scientists in curriculum making will upgrade science curricula.
2. By virtue of their scientific training, scientists are qualified to formulate curricula for science education at elementary and secondary school level.
3. The competence of these scientists extends to the development, i.e., beyond their knowledge of up-to-date knowledge of their particular fields of specialization.

Presented at the Request of the Commonwealth Education Liaison Committee by the United States Office of Education and the National Science Foundation at the Commonwealth Conference of the Teaching of Science in Schools (Ceylon: The Conference, December 9-21, 1963), p. 1.

[1]Staff, Division of Scientific Personnel and Education, National Science Foundation, "The Role of the National Science Foundation in Course Content Improvement in Secondary Schools," The School Review, LXX (Spring, 1962), 12-13.

4. National groups such as the AAAS are best qualified to identify scientists who should be involved.

Teams including scientists, educators and psychologists are currently collaborating in the development of school science curricula. At the recent Commonwealth Conference on science teaching held in Ceylon, Gatewood and Obourn indicated their support of this teamwork approach:

> Leadership and work of scientists of stature are essential but all elements of the educational community must contribute-- teachers, administrators, psychologists, and other people with special talents bearing on the educational enterprise.[1]

Hilgard supported this viewpoint.[2]

The rationale for the use of such a team is presented in part by Marshall. He wrote that

> . . .all of the new science curriculum projects have included these features:
>
> 1. They have sprung from the minds mostly of professional scientists--whose who are in the best position to know what science our children most need to study.
>
> 2. They have involved, along with the scientist, professional educators--those in the best position to know how the science should be taught.[3]

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[1]Gatewood and Obourn, "Improving Science Education in the United States," p. 9.

[2]Ernest R. Hilgard, "A Perspective on the Relationship Between Theory and Educational Practices," in Theories of Learning and Instruction: 1964, Sixty-Third Yearbook of the National Society for the Study of Education, Part I (Chicago: The National Society for the Study of Education, 1964), pp. 412-13.

[3]J. Stanley Marshall (ed.), "The Improvement of Science Education and the Administrator," in The New School Science--

The assistance of psychologists is premised on their knowledge of child development and readiness for learning.[1] Barnes wrote of the urgency of assistance from scientists from the fields of behavior and psychology. He considered this would result in an incorporation of the research findings on the nature of learning into science curricula.[2]

Gagné provided additional rationale for the involvement of psychologists. He stated that:

> What is to be accomplished by means of such science curricula is a change in behavior of human individuals, and this is the technical content of the discipline of psychology.[3]

Based upon the above rationale, the following recommendation is presented:

Recommendation

3.04 The validity of a set of objectives for the teaching of science in Australia should be increased by having these objectives specified by a team comprising scientists, educators, and psychologists, collaborating so as to maximize their appropriate roles. These roles are:

A Report to School Administrators on Regional Orientation Conferences in Science (Washington, D.C.: American Association for the Advancement of Science, 1963), p. 5.

[1]Fraser, p. 3.

[2]Cyrus W. Barnes, "A Definition of Science Education: Curriculum Research," Science Education, XLV (December, 1961), 396.

[3]Robert M. Gagné, "A Psychologist's Counsel on Curriculum Design," Journal of Research in Science Teaching, I, Issue 1 (1963), 27.

1. scientists to identify content and its structural form, and processes;

2. educators to determine teachability, practicability and methodology for teaching; and to relate science education objectives to the broader educational objectives;

3. psychologists, to screen processes, contents and methods selected by above, and to determine the appropriateness of age and grade placement.

Educational Objectives

Educational objectives in Australia

For many years, there was a philosophical vacuum in Australia as far as the expression of objectives was concerned. In 1932, Browne wrote:

> If the plan of Curriculum Revision outlined should be put into operation, one of the first tasks would be to formulate a set of objectives for State education. . . . If this were done with the co-operation of district committees, there would emerge a State-wide educational aim, and teachers would know exactly what their efforts were intended to achieve.
>
> There have been countless statements of educational aims in the past, some of them very inspiring, but most of them too general to serve as the foundation upon which to build a curriculum for present-day schools.[1]

With Cramer, in 1956 Browne again drew attention to the need for a set of objectives expressing Australia's unique situation. They wrote:

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[1]Browne, The Case for Curriculum Revision, p. 70.

> Australia has need for the formation or evolution of an educational philosophy of its own which will embody the characteristics of its own mode of life, its cultural ideas and national aims. . . . A body similar to the Educational Policies Commission in the United States would have an interesting and significant piece of work to carry out in Australia, and signs are not wanting that the Australian community would be willing to assist in this task and could make valuable suggestions.[1]

A statement on "The Aims of Australian Education" representing the consensus obtained from committees of teachers and administrators in each Australian state was adopted at the 1964 national conference of the Australian Teachers' Federation. The statement of aims read in part as follows:

> General
>
> The aim of education is to develop the individual to his maximum capacity.
>
> In so far as education is a part of the process of living and should be viewed as continuing throughout a person's life, it should provide opportunities for the fullest possible development of the intellectual, physical, social, emotional, aesthetic, moral and spiritual qualities, the effective use of his leisure time, and the employment of his several capacities in those fields where he can best make his contributions to society.
>
> Whilst it is agreed that there are educating influences such as the home, the Church, and the community, all of which are inter-related, the State education systems have a special contribution to make in the following fields:--
>
> ·Fundamental Skills and Knowledge. . .
> ·Vocational Preparation. . .
> ·Worthy Citizenship. . .

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[1]Cramer and Browne, Contemporary Education. . ., p. 350.

- Intellectual Development. . .
- Ethical Character. . .
- Aesthetic Appreciation. . .
- Health. . .
- The Worthwhile Use of Leisure.[1]

The Victorian and New South Wales Commissions on education have also developed statements of objectives. The Report of the Committee on State Education in Victorian stated that the purposes of Victoria schools are all

> . . .directed by one overriding principle: that within the resources of schools and teachers available there should be opportunity for every child in the State to receive an education suitable for his age, ability and aptitudes, and that no child should be debarred by mental or physical handicap, or distance from school, from receiving an appropriate education. So far as it is within the power of the State system to do so, its broad goal is equal opportunity for all to make the most of their native endowment.[2]

The Report indicated that particular objectives were necessary to enable programs to be developed, and that the most useful single statement of objectives was that contained in the Report on Educational Reform and Development in Victoria put out by the Council of Public Education in Victoria in 1945.[3] The aims suggested by this Council were closely similar to those of the 1964 Australian Teachers' Federation Conference quoted above.

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[1]"The Aims of Australian Education," The Teachers' Journal, XLVII (April, 1964), 78.

[2]Victoria, Department of Education, Report of the Committee. . ., p. 34.

[3]Ibid., p. 36.

According to the Committee, the tasks of developing objectives in specific terms and of determining courses of study belong to the professional educators, with their knowledge of students, school organization and optimal student behaviors. The Committee devised a list of general objectives which incorporated the following:

1. Development of knowledge useful at present or in post-school life;

2. Memorization of knowledge and development of skills to prepare children for a useful lifetime occupation, sound citizenship, marriage and its responsibilities, and happy and fruitful use of leisure time:

3. Development of self-expression.[1]

In New South Wales, the Report of the Committee Appointed to Survey Secondary Education, basing its selection of objectives on acceptance by a significant proportion of the community in which the school will function, listed the following:

1. Health
2. Mental skills and thought
3. Capacity for critical thought
4. Readiness for group membership
5. The arts of communication
6. Vocation
7. Leisure
8. Spiritual values.[2]

One can perceive here a degree of correlation between this statement and that of the 1918 U.S.A. Commission on the

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[1]Victoria, Department of Education, Report of the Committee . . ., p. 34.

[2]New South Wales, Department of Education, Report of the Committee. . ., pp. 57-62.

Reorganization of Secondary Education[1] which is outlined in the following section.

Educational objectives in the U.S.A.

From time to time in the U.S.A., continuing educator groups such as the National Society for the Study of Education (NSSE) and the Educational Policies Commission of the National Education Association (NEA) have formulated statements of purposes of education. One influential statement of purposes was that of the Commission on the Reorganization of Secondary Education, produced in 1918, and known as the Cardinal Principles of Education. This report listed the major objectives of education as:

1. Health
2. Command of fundamental processes
3. Worthy home-membership
4. Vocation
5. Citizenship
6. Worthy use of leisure
7. Ethical character.[2]

In 1938 the Educational Policies Commission of the NEA in defining The Purposes of Education in American Deomocracy, listed four purposes, namely:

1. Self-realization
2. Human relationship

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[1]U.S., Bureau of Education, Commission on the Reorganization of Secondary Education, Cardinal Principles of Sec ondary Education, A Report of the Commission of the Reorgan ization of Secondary Education, appointed by the National Education Association (Washington, D. C.: U.S. Government Printing Office, 1918), pp. 10-11.

[2]Ibid.

3. Economic efficiency
4. Civic responsibility.[1]

In 1956, a group of psychologists under the leadership of Bloom published a classification system purporting to represent the complete spectrum of educational objectives. This classification consists of three main areas or "domains," namely the cognitive, affective and psychomotor domains. This Taxonomy described the cognitive objectives precisely.[2] In 1964, a taxonomy for the affective domain was completed and published in draft form.[3] The psychomotor domain remains to be developed. The importance of these documents lies partly in the detailed manner in which behavioral objectives have been specified and also in the way that objectives are readily translated into classroom practices.

The 1958 "Rockefeller Report," concerned with the pursuit of educational excellence, regarded the individual as central to the educational process. It was stated in this Report:

> If we are really serious about equality of opportunity, we shall be serious about individual differences, because what constitutes opportunity for one man is a stone wall

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[1]National Education Association, Educational Policies Commission, The Purposes of Education in American Democracy (Washington, D.C.: National Education Association, 1938).

[2]Bloom (ed.), Taxonomy of Educational Objectives. . . Cognitive Domain, pp. 1-207.

[3]D.R. Krathwohl, B. S. Bloom and B. B. Mazia, "Taxonomy of Educational Objectives: The Classification of Educational Goals: Handbook: Affective Domain." Draft copy, Michigan State University, East Lansing, 1964. (Mimeographed).

> for the next. If we are to do justice to the individual we must seek for him the level and kind of education which will open _his_ eyes, stimulate _his_ mind and unlock _his_ potentialities. We should seek to develop many educational patterns--each geared to the particular capacities of the particular student for whom it is designed.
>
> But though the educational patterns may differ, the goals remain much the same for all: enabling each young person to go as far as his aptitude will permit in fundamental knowledge and skills, and motivating him to continue his own self-development to the full along similar lines.[1]

The President's Science Advisory Committee in 1959 also centered their statement of educational ends on the learner. They stated:

> The end is clear: to introduce the growing child, the youth, and the adult to the best and most essential elements of the intellectual and cultural experience of previous generations; to do this in such a way that we stimulate curiosity and encourage each individual to look forward, not backward, to develop his own talents to their maximum, and to continue this development throughout his life.[2]

In 1961, the Educational Policies Commission stated what they considered to be the central purpose of education. They wrote:

> The purpose which runs through and strengthens all other educational purposes--the common thread of education--is the development of the ability to think. This is the central purpose to which the school must

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[1] _The Pursuit of Excellence: Education and the Future of America_, Panel Report V of the Special Studies Project _America at Mid-Century Series_, chairman Nelson H. Rockefeller (Garden City, New York: Doubleday & Company, Inc., 1958), p. 32.

[2] U.S., President's Science Advisory Committee, _Education for the Age of Science, The White House, Washington, D.C. May 14, 1959_ (Washington, D.C.: U.S. Government Printing Office, 1959), p. 1.

> be oriented if it is to accomplish either its traditional tasks or those newly accentuated by recent changes in the world. . . . It must be a pervasive concern in the work of the school.[1]

The most recent statement emanating from the National Education Association resulted from their Project on Instruction. This statement expressed the need to state educational purposes in terms of behavioral changes.

> The essential objectives of education, therefore, must be premised on a recognition that education is a process of changing behavior and that a changing society requires the capacity for self-teaching and self-adaptation. Priorities in educational objectives should be placed upon such ends as:
>
> - learning how to learn, how to attack new problems, how to acquire new knowledge
> - using rational processes
> - building competence in basic skills
> - developing intellectual and vocational competence
> - exploring values in new experience
> - understanding concepts and generalizations
>
> Above all, the school must develop in the pupil the ability to learn under his own initiative and an abiding interest in doing so.[2]

Common to several of the above sets of educational objectives are some important elements which constitute broad educational objectives. These include:

> The development of individuals to their maximum capacity through:

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[1]National Education Association, Educational Policies Commission, The Central Purpose of American Education (Washington, D.C.: National Education Association, 1961) p. 12.

[2]National Education Association, Project on Instructions, Schools for the Sixties. . ., p. 9.

1. the development of certain knowledges, skills and attitudes which will provide preparation for citizenship, vocation, and use of leisure.

2. the development of the ability to think.

Science education should contribute towards these broad educational objectives by providing experiences which:

1. maximize the possibility of individualization of instruction;

2. develop those knowledges, skills and attitudes identified as the most necessary and desirable for future citizenship, vocation and the use of leisure.

3. stimulate thinking.

Recommendations

3.05. The science curriculum should outline experiences which recognize the wide range of individual differences that exists in groups of children. These differences may be with respect to intelligence level, rate of working, interests, attitudes, skills, etc. In order to cater for these differences and yet remain within the limits of practicability in the classroom, a variety of content, activities and methodology is recommended. The use of a common core of experiences in conjunction with open-ended branches from those experiences may provide for some individual differences. The use of the science laboratory is ideally suited for such procedures.

3.06. Science curricula should promote student thinking. The use of open-ended laboratory lessons appears ideally suited for promoting thinking.

3.07. More precise specifications of the behaviors which constitute good citizenship, ideal vocation and profitable use of leisure are needed before the role of science education in their accomplishment can be achieved.

Nature of Science

Since science education should reflect the nature of science and the activities performed by scientists, a clear understanding of science as provided by a definition is important in defining the area of science education. There has been a proliferation of definitions of what science constitutes.[1] Common to many of these definitions is the incorporation of experimentation involving observation, and the subsequent organization of interrelated concepts into an ordered theoretical structure. Simpson considered observation as a critical component. He stated:

> Definitions of science may differ in other respects, but to have any validity they must include this point: the basis of science is observation.[2]

Conant extended this in his definition of science as "an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation and are fruitful of further experimentation and observation."[3] Zim interpreted "experiment as being a technical aid to observation."[4]

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[1] c. f., "Bibliography of Science Definitions," Michigan State University, Science and Mathematics Teaching Center, Pp. 47, (Mimeographed).

[2] George Gaylard Simpson, "Biology and the Nature of Science," Science, CXXXIX (January, 1963), 82.

[3] James B. Conant, Modern Science and Modern Man (New York: Columbia University Press, 1957), p. 54.

[4] Herbert S. Zim, "Science and Education Viewed as a Process," A paper presented at the twelfth annual convention of the National Science Teachers Association, Chicago, Illinois, March 20-24, 1964, p. 5.

Prior to their development of a service document for science curriculum planners, supervisors and teachers,[1] the NSTA Curriculum Committee issued a position statement describing their philosophy of science curriculum developments.[2] In their statement, the NSTA gave what they, as representatives of science education, considered to be the nature of science. The statement read:

> If NSTA is to further the development of sound science curricula, the Association must clarify the sense in which the term "science" will be used.
>
> Science is the activity through which best explanations are sought for the observed facts of nature. These explanations are expressed as theories or statements which conform to the general standards of reliability imposed upon them by the scientific community and which are characterized by economy of thought and expression. In this sense the great conceptual schemes such as the conservation of energy, the kinetic energy of heat, the atomic theory of matter, and the biochemical theory of heredity should be at the focal point of any science curriculum, rather than the individual concepts or the facts about our environment.[3]

The statement then named three aspects of the scientific enterprise, and indicated why each of these three aspects should be part of the science curriculum:

1. Descriptive science or natural history, because it provides the basis for scientific inquiry and plays so prominent a role in a child's conventional experience;

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[1]Robert H. Carleton, "Editorial," The Science Teacher, XXXI (February, 1964), 12.

[2]National Science Teachers Association, "The NSTA Position on Curriculum Development in Science," The Science Teacher, XXXIX (December, 1962), 32-37.

[3]Ibid., pp. 32-33.

2. Science proper, because of its intellectual challenge, which should be a primary goal of scientific education; and

3. Technology, because it served so well to illustrate the practical application of scientific principles and because of its impact on modern society.[1]

In discussing guidelines for curriculum research in science education, Novak provided this meaning of science for curriculum researchers:

> One point needs repeated emphasis; science classes should teach science; not isolated facts, not the history of technology, but an understanding of the major ideas of science and the process by which these ideas are advanced.[2]

As a result of the consideration of the nature of science, the following recommendations relevant to the development of a science curriculum model are presented:

Recommendations

3.08. To reflect the nature of science, science education curricula should place emphasis on experimentation, observation and creative thinking.

3.09. Attempts should be made to specify more closely the work which scientists perform through such techniques as job analyses. Appropriate skills from the scientists' tasks should be incorporated as part of school science curricula.

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[1]National Science Teachers Association, The Science Teacher, XXIX, p. 33.

[2]Joseph D. Novak, "A Preliminary Statement on Research in Science Education," Journal of Research in Science Teaching, I, Issue 1 (1963), 6.

The Objectives of Science Education in U.S.A.

Historically, there has been a shift of emphasis in the U.S.A. both in the sources of objectives of science education and in the emphasis of these objectives. These trends are evidenced in a number of influential documents and statements, as summarized in Table 5:

TABLE 5

HISTORICAL SUMMARY OF SELECTED STATEMENTS OF THE OBJECTIVES OF SCIENCE EDUCATION

Year	Source	Major Emphases
Pre-1850	Surveys of literature	1. Informational 2. Religious 3. Utilitarian[a,b]
1850-1910	Surveys of literature	1. Informational 2. Disciplinary (Religious aim faded)[c]
1920	Commission on the Reorganization of Secondary Education Science Committee[d]	Contributions of science education to the Cardinal Principles of Education--health, command of fundamental processes, home membership, vocation, citizen ship, use of leisure and ethical character[e]
1920-1930	Research	Surveys of the status quo as reflected in

TABLE 5.--(Continued)

Year	Source	Major Emphasis
		existing textbooks, courses of study, and opinions of science teachers.[f]
1927	AAAS Committee	Scientific method as a major objective.[g]
1931	NSSE Thirty-First Yearbook Committee	Major generalizations and scientific attitude[h]
1937	Progressive Education--Commission on Secondary School Curricula, Committee on the Function of Science	Contributions to personal-social needs, democratic society, effective living[i]
1946	American Council of Science Teachers	Similar to 1937 statement of PEA; and safety, consumer education, conservation[j]
1947	NSSE Forty-Sixth Yearbook Committee	Behaviors--functional information, concepts and understandings: instrumental skills, problem solving skills, attitudes, appreciations, interests.[k]

TABLE 5.--(Continued)

Year	Source	Major Emphases
1959	NSTA Conference (NSF supported) on "Planning for Excellence"	Process and product[l]
1960	Woods Hole Conference	Structure[m]
1960	NSSE Fifty-Ninth Yearbook Committee	Learning of concepts generalizations or principles, and scientific methods or attitudes.[n]
1961	National Science Foundation--Division of Scientific Personnel and Education	"Substantive content and nature of contemporary science itself."[o]
1962	National Science Foundation--Science Course Improvement Project	"To go beyond the presentation of what is known and to provide students with experience in the processes by which the facts principles and techniques are developed.[p]
1962	Science education literature	Science as a process of inquiry[q]
1962	AAAS Commission on Science Instruction	Science is a two-dimensional subject: "the dimension of knowledge or content and the dimension of performance or process."[r]

TABLE 5.--(Continued)

Year	Source	Major Emphases
1964	National Science Teachers Association Conference of Scientists	"The nature of science or the process by which new knowledge is obtained." The development of an understanding of the basic ideas of science concomitantly with an appreciation of the methods of science.[s]

[a]Victor Noll, The Teaching of Science in Elementary and Secondary Schools (East Lansing: Michigan State College Press, 1950), pp. 5-6.

[b]Herbert A. Smith, "Educational Research Related to Science Instruction for the Elementary and Junior High School: A Review and Commentary," Journal of Research in Science Teaching, I, Issue 3 (1963), 207.

[c]Noll, The Teaching of Science in Elementary. . ., pp. 5-6.

[d]U.S., Bureau of Education, Commission on Reorganization of Secondary Education, Report of Sub-Committee on the Teaching of Science, Bulletin No. 36 (Washington, D.C.: U.S. Government Printing Office, 1920).

[e]U.S., Bureau of Education, Commission on the Reorganization of Secondary Education, Cardinal Principles of Secondary Education, pp. 10-11.

[f]Francis D. Curtis, A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools (Philadelphia: P. Blakiston's Son & Co., 1926), p. 198.

Francis D. Curtis, A Second Digest of Investigations in the Teaching of Science (Philadelphia: P. Blakiston's Son & Co., Inc., 1931), p. 66.

[g]American Association for the Advancement of Science, "Committee Report on the Place of Science in Education," School Science and Mathematics, XXVIII (June, 1928).

[h]S. Ralph Powers, "The Objectives of Science Teaching in Relation to the Aim of Education," A Program for Teaching Science, pp. 43-44.

[i]Progressive Education Association, Science in General Education: Suggestions for Science Teachers in Secondary Schools and in the Lower Division of Colleges, Report of the Committee on the Function of Science in General Education of the Commission on Secondary School Curriculum (New York: D. Appleton-Century Company Incorporated, 1937), p. 57.

[j]American Council of Science Teachers, National Committee on Science Teaching, Science Teaching for Better Living (Washington: D.C.: National Education Association, 1942).

[k]National Society for the Study of Education, Committee on Science Education, "The Objectives of Science Instruction," Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I (Chicago: The National Society for the Study of Education, 1947), p. 21.

[l]National Science Teachers Association, Planning for Excellence in High School Science (Washington, D.C.: National Science Teachers Association, 1961), Pp. 67.

[m]Jerome S. Bruner (ed.), The Process of Education (Cambridge: Harvard University Press, 1960), p. 76.

[n]Paul Dressel et al., "How the Individual Learns Science," Rethinking Science Education, The Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: The National Society for the Study of Education, 1960), p. 39.

[o]National Science Foundation, National Science Foundation Programs for Education in the Sciences, "Foreword" by Bowen C. Dees, p. iv.

[p]National Science Foundation, Science Course Improvement Projects; I: Courses, Written Materials, Films, Studies Supported by the National Science Foundation, "Foreword" by Bowen C. Dees, October, 1962, NSF Document 62-38, p. 1.

[q]Joseph J. Schwab and Paul F. Brandwein, The Teaching of Science (Cambridge, Massachusetts: Harvard University Press, 1962), pp. 64-65.

[r]AAAS, Committee on Objectives, Wisconsin Conference, "Report of Group I, Objectives," Reports from a Conference on Science Instruction in Elementary and Junior High Schools, Frederic B. Dutton (Chairman) (Washington, D.C.: American Association for the Advancement of Science, 1962), p. 1. (Mimeographed).

[s]NSTA, Conference on Scientists, "The Conceptual Schemes of Science," Randall M. Whaley (Chairman) (Preliminary edition: Washington, D.C.: National Science Teachers Association, May, 1964), unpaged. (Mimeographed).

The following trends in science education objectives are discernible in the historical summary:

1. From information *per se* to information basic to an understanding of the structure of a discipline;

2. From informational to retrieval of information;

3. From specification of broad areas (e.g., utilitarian, informational), towards expression in a form more readily translatable to curriculum development;

4. From specific information embracing many fields, to generalizations, concept-formation and knowledge of structures;

5. From a limited range of lower cognitive objectives, to a broader range embracing lower and higher cognitive objectives and the processes utilized by scientists;

6. From specification of objectives by committees largely representatives of educators, to specification by conferences at which scientists have exerted major influences.

Arising from these trends, there are several implications for the construction of an Australian science curriculum model. In the form of recommendations, these include:

Recommendations

3.10. The broad objectives of education and of science should provide guidelines for determining the objectives of science education.

3.11. Since the objectives of science education change periodically, frequent review of these is important for the development of new science curricula.

3.12. Current consensus indicates that the major objectives of science education are:

(a) Knowledge of the structure of science, as reflected by broad concepts.
(b) Facility with the processes of science, as reflected by an ability to act as scientists act.

3.13. The description of objectives in science education in terms of changes of behavior sought, should facilitate the development of valid curricula and evaluation techniques. The Australian Science Teachers' Association should assume responsibility for this task.

3.14. There exists a definite need for the identification of the major concepts of each of the sciences. This task may be promoted under the proposed Australian Science Education Foundation through the various organizations of scientists.

3.15. There exists a definite need for the accurate specification (e.g., by job analyses) of the range of processes performed by a range of scientists. This task may be promoted under the proposed Australian Science Education Foundation.

3.16. The utilization of a team approach to the construction of curricula should take cognizance of the tasks for which collaborators possess special competencies.

3.17 A change in science education objectives necessitates a number of concomitant changes, as follows:

(a) development of new curricula to reflect the new objectives;

(b) development of valid evaluation instruments both for measuring changes of student behaviors and for determining the effectiveness of the new courses;

(c) changes in pre-existing teacher education procedures;

(d) provision of courses for updating classroom teachers;

(e) provision of a full range of new instructional materials (books, apparatus, audiovisual aids, etc.);

(f) provision for involvement of affected personnel in decisions leading to new curricula;

(g) provision for obtaining feedback of the reactions of teachers, pupils and the community;

(h) provision of public relations action to promote acceptance of the new programs.

Present Science Teaching Objectives in Australia

Objectives from State Curricula

Since curricula in Australia emanate from panels appointed by each of the six state Education Departments, statements of the objectives contained in the state curricula provide a broad picture of the overall Australian situation. All students in Australia now study science in their first year of secondary school. The departmental objectives discussed here are in general taken specifically from those of the first year science curricula.

In New South Wales, the 1962 revisions of the beginning secondary school curricula listed the following Basic Aims of the Science Course:

1. To keep alive the wonder and romance of science;

2. To make students look, observe and explain, and to show that science can lead to satisfying interpretation;

3. To have students seek such interpretations, and to show them the experimental techniques of science;

4. To give students a store of related general principles that they can use to interpret the physical world for themselves;

5. To use material for study which harmonises with the interests and needs of the student;

6. To have students know how the scientists work, what they have done and what they are doing for man;

7. To give students an understanding of the scientific attitude and an appreciation of its cultural value.[1]

To achieve these aims, the Department stated that methods utilized should include experiment and observation, evaluation of evidence, problem-solving practical work, and teaching of awareness of the distinction between fact and interpretation.

In Victoria, there has been a trend, similar to that in the U.S.A., towards the processes as important teaching objectives. Concurrently, there has been a concomitant de-emphasis on factual retention as a goal in itself. Evidence for this trend was provided in the 1962 Technical Schools' Science Curricula of the Education Department of

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[1]New South Wales, Department of Education, Science: Syllabus for Form I in 1962 (New South Wales: Department of Education, 1962), p. 2, (Mimeographed).

Victoria. This document set out in some detail a list of behaviorally-expressed course aims, which it described as being of utmost and critical importance. This statement gave the aims as:

(1) To develop an understanding of a series of basic scientific concepts (as opposed to isolated facts) which will help the students:

(a) to understand their environment better;

(b) to understand better the modern world in which they are living;

(c) to gain enjoyment from mastery of these concepts;

(d) to increase their enthusiasm for science;

(e) to form broad ideas which will be useful to them whether or not they pursue specialised scientific courses later.

(2) To develop the ability to assemble simple apparatus.

(3) To develop the ability to PLAN and CONDUCT experiments or other researches of a simple kind, in order to solve problems.

(4) To develop the ability to make accurate and objective observations.

(5) To develop the ability to make their own records by being made responsible for this task.[1]

The principles developed in association with these curricula have expression to the process approach with a content structure, based on a limited number of major themes

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[1]Victoria, Department of Education, <u>Technical Schools' Science Curricula for Forms One and Two</u>, prepared by the Technical Schools' Advisory Panel (Melbourne: Education Department of Victoria, 1962), p. 2, (Mimeographed).

and integrative topics (e.g., the particle). Behavioral objectives and practical skills to be developed were also clearly indicated. The objectives included are listed above. The practical skills included such abilities as boiling liquids in test-tubes, using a microscope, taking readings on thermometers and testing for hardness of minerals.[1]

In the state of Western Australia, the Education Department has adopted the statement of aims of the NSSE Forty-Sixth Yearbook as the basis of its 1962 science courses. There is some development of the included topics to illustrate "Work To Be Covered," "Understandings To Be Established," and "Skills To Be Developed."[2]

In South Australia, science is taught mainly for two reasons:

(1) For the knowledge and power it gives; and

(2) For the mental habits and attitudes it develops. It should produce in the pupil an understanding interest in his physical environment.[3]

Following an interim report from the 1961 Queensland Committee on Secondary Education (referred to earlier),

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[1]Victoria, Department of Education, Technical Schools' Science. . ., p. 6.

[2]Western Australia, Department of Education, Science "A" and Science "B" for Secondary Schools (Western Australia: Alex B. Davies, Government Printer, 1962), 7-9.

[3]South Australia, Department of Education, Subjects and Courses of Study in High Schools (Adelaide: W.L. Hawes, Government Printer, 1960), p. 27.

small sub-committees of well-known teachers were appointed by the Committee in the various subject areas, and were currently revising the curricula for trial runs in 1964. "The work and outlook of individuals on the sub-committees may have been influenced by current developments overseas."[1]

In Tasmania, the syllabus indicated that science

> . . .is a predominantly practical approach to an understanding of the scientific aspects of the pupil's environment, and it is not intended for those candidates who may take science for a Matriculation subject. The course is intended to illustrate the scientific method of collecting facts before theorizing, and of basing conclusions on observations. The emphasis is, therefore, upon practical work, and an extensive list of suggested simple experiments is arranged to correspond with the syllabus items.[2]

Objectives from educational literature in Australia

The shift in emphasis perceived of educational objectives in the U.S.A. from that of factual memorization, to emphasize other abilities has been observed also in a number of articles in Australian periodicals. For example, a comprehensive study by Morris sought to determine the objectives of secondary school chemistry by

> (a) an examination of the courses of study; (b) classification of the examination questions set to

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[1]R. C. Lang, "Queensland," in Australian Science Teachers' Association, Conasta XII. . ., p. 21.

[2]Tasmania, The Schools Board, Manual for 1963 (Hobart: The Schools Board of Tasmania, 1962), p. 71.

determine the levels of cognitions tested; (c) consideration of the examiner's comments on the set examinations;(d) administration of a suitable questionnaire to members of the various syllabus committees. The results were compared with those derived from a survey of the educational literature.[1]

Finding considerable inconsistencies and conflicts between stated objectives, curricular content and examinations set,[2] Morris suggested four ways "to alleviate thr problem"

> Firstly, reasonable unanimity on the question of desirable objectives is necessary for those controlling educational policy. Secondly, enough basic field research needs to be implemented to show the best methods of achieving these objectives. Thirdly, the courses of study will need to be reframed so that achievement of these objectives becomes possible. Fourthly, the examinations must begin to test these objectives.[3]

Concern for the effects of the nature of evaluation on the behavioral outcomes of science teaching was also reflected in papers by Cohen and by Rowlands. Cohen reported efforts to develop tests in areas other than factual retention. Particular emphasis was placed on the utilization of valid testing techniques for laboratory competencies, through the use of practical science

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[1]G. C. Morris, "Can Suitable Objectives by Obtained for Chemistry Teaching?" The Australian Science Teachers' Journal, IX (August, 1963), 7.

[2]Ibid., pp. 7-16.

[3]Ibid., p. 17.

examinations. The organization, typical test items, and student performances on the items were described.[1]

Rowlands described some techniques for teaching and testing for the skills involved in "scientific method," utilizing "novel content" drawn from the daily experiences of his pupils.[2] In a subsequent article, Rowlands pointed out the dangers of formalized logical approaches to the teaching of subject matter, and used Bloom's Taxonomy of Educational Objectives as a basis for discussing some of the "neglected aims" in science education.[3,4]

Objectives from Australian Scientists

In 1960, the Western Australian branch of the Australian and New Zealand Association for the Advancement of Science (ANZAAS) conducted a Conference at the University of Western Australia entitled "Some Problems of Science Education in W.A." This Conference was significant in that it brought together a group of forty people comprising physical, mathematical and biological science teachers from

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[1]David Cohen, "Multiphasic Assessment in Science," Bulletin of Victorian Institute of Educational Research, IX (May, 1963), 1-12.

[2]Evan Rowlands, "The Aims of Science: A Novel Approach," The Educational Magazine, XX (December, 1963), 514-18.

[3]Evan Rowlands, "Neglected Aims of Science," The Educational Magazine, XXI (February, 1964), 12-14.

[4]Note: It is worthy of note that this Taxonomy has had a profound effect in stimulating Australian educators

the University, state and private schools, in addition to administrators from the Western Australian Education Department. In his report of this one-day conference, Stanley stated:

> In keeping with the Association's policy of bringing 'science' to the school child and to the layman, it was thought that an investigation of the aims and of the methods of scientific education by those actively engaged in this work in W.A. would be useful, especially in view of the first-year failure rate in Australian universities. It was eventually decided that A.N.Z.A.A.S., an affiliation of scientific societies covering all fields of science, would be a suitable organizing body for a conference to consider some of the problems involved in the teaching of science in W.A. It was decided to limit the conference to one day, and because of this to consider in the first instance only the physical and biological sciences.[1]

Evidence of the thinking of this A.N.Z.A.A.S. group about the aims is provided by this statement about evaluation:

> The university entrance examination should be carefully designed to test the qualities considered necessary in a successful university student. The examination paper should be designed to test not only memory, but also the ability to think and the ability to express views clearly. In laboratory subjects a practical examination should be an integral part of the whole.[2]

This 1960 conference was significant as an embryonic venture between Australian teachers and scientists.

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to rethink critically about their objectives, methods and evaluation instruments.

[1]N. F. Stanley, "The Teaching of Science in University and School," The Australian Journal of Science, XXIII (April, 1961), 327.

[2]Ibid., p. 328.

In 1962, this same Western Australian division of A.N.Z.A.A.S. showed further concern for science education, when they invited nuclear physicist Sir Mark Oliphant to deliver the inaugural Ross Lecture, entitled "Education and the Age of Science."[1] Oliphant stated that "revolutionary changes in education are necessary to enable mankind to meet the new and exciting challenges which face him now, and which will be encountered by his children."[2] One of Oliphant's main themes was a de-emphasis on retention, with more stress to be placed on thinking and retrieval of information.[3] As a statement of a scientist at a meeting of scientists, this was quite significant. Speaking of educational objectives needed for the age of science, Oliphant said:

> There was a time, not so long ago, when it was possible for a human being to absorb almost the whole of knowledge and be a master of most human culture.
>
> . . . .
>
> The system of education which we have inherited belongs to the days when an individual could absorb almost all that was known. It did not matter what was taught, once the three R's were mastered, for the boundaries of knowledge were within the grasp of every inquiring mind. Facts and ideas, some alien or useless to the individual, were crammed into him with the idea that the discipline of learning and of thinking about this ingested mess was applicable in every sphere. . .

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[1]R. W. Stanford, "Inaugural A. D. Ross Lecture: Western Australian Division of A.N.Z.A.A.S.," The Australian Journal of Science, XXV (April, 1963), 417.

[2]Sir M. L. Oliphant, "Education and the Age of Science," The Australian Journal of Science, XXV (April, 1963), 423-24.

[3]Ibid.

> We have seen that today we live in a very different world.
>
> . . . .
>
> Access to information is the core of the problem, for no man can carry in his head all information in any field, or keep completely abreast of advancing knowledge. Cramming of information into students must be replaced by their ability to use books, libraries and electronic methods of retrieval of what is known.
>
> . . . .
>
> A central part of the education of the whole man must be to give him some understanding of the world in which he lives; of the constitution of matter, and the glories of the universe, the nature of life and of consciousness, and hence the destiny of man on earth. With this will come appreciation of the great responsibilities on the shoulders of mankind. Men and women cannot all be scientists or technologists, as some would make them. But all should have sufficient understanding of natural philosophy to be able to make intelligent decisions about how the world shall be shaped for the well-being of all.[1]

At the 1962 Australasian A.N.Z.A.A.S. Congress in Brisbane, one of the symposia conducted by the physics section was devoted to the teaching of physics. At that Congress, a report was given by Webster of the 1960 UNESCO conference on "International Collaboration in the Teaching of Physics," in which reference was made to the scarcity of research in physics teaching and to the failure to update teaching methods.[2] Bullen criticized the teaching of physics for the failure to get "elementary fundamentals

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[1]Sir M. L. Oliphant, The Australian Journal of Science, XXV, 423-24.

[2]Bernard Rechter, "A.N.Z.A.A.S. Congress in Brisbane," The Australian Science Teachers' Journal, VIII (May, 1962), 49.

straight."[1] Bullen added that "the time is more than overdue for an overhaul of very much in science teaching, with appropriate emphasis on clear thinking, and not merely on scientific technique, gadgetry and jargon."[2] However, no specific course of action was planned at that Congress.

In January, 1964, the Council meeting of A.N.Z.A.A.S. received a report from the Australian Science Teachers' Association which contained several suggestions for the improvement of Australian science teaching. These included the formation of a foundation, the development of modern science courses and the design of science equipment and labortories.[3] The following motion was then passed:

> This Council is in sympathy with the principles set out in the submissions made by the Australian Science Teachers' Association and submits the matter to the General Committee for urgent consideration.[4]

It has been indicated that the General Committee subsequently gave favorable condition to the motion, and that suitable action was anticipated.[5]

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[1]K. E. Bullen, "Muddledom in the Teaching of Elementary Physical Principles," The Australian Science Teachers' Journal, VIII (May, 1962), 7

[2]Ibid., p. 12.

[3]"Report of the Proceedings of the A.N.Z.A.A.S. Council Meeting," The Australian Science Teachers' Journal, X (May, 1964), 43-45.

[4]Ibid., p. 45.

Summary

The survey of the Australian science education objectives as evidenced by the existing state curricula and a review of some recent literature from science educators and scientists has indicated a high degree of correlation between the existing objectives in Australia and the U.S.A. This is evidenced by the existing situation in parts of Australia which parallels U.S.A. trends cited previously, as follows:

1. Objectives broader than lower cognitive--extending to include higher cognitive (e.g., critical thinking), scientific attitudes, and processes of scientists;

2. Specification of objectives as changes of behavior sought;

3. Expression of broader informational objectives (generalizations, concepts);

4. An awakening interest in science education by scientists, as evidenced by statements at scientist conventions.

These parallels between the objectives of science education in Australia and the U.S.A. provide added validity for the recommendations stated earlier in this section for the development of an Australian science curriculum model based on experiences in the U.S.A.

CHAPTER IV

REVIEW OF RESEARCH AND PROFESSIONAL LITERATURE OF SCIENCE EDUCATION

This chapter presents a review of the research and professional literature of science education in Australia and the U.S.A., together with some of the relevant research from the area of psychology. The implications of this review for the development of an Australian science curriculum model are then stated.

Educational Research in Australia

Research in education in Australia is largely conducted by officers of research branches of the state Departments of Education, by the Australian Council for Educational Research (ACER) and its state institutes, Commonwealth Office of Education, by University and Teachers' College faculty, and by students seeking higher degrees. However, the research activity by officers of research branches of state Education Departments is limited by the wide range of functions for which they are responsible and by the small staffs which they employ. In Victoria, the main functions of the Curriculum and Research Branch, which has approximately six members, include:

1. Assisting with state-appointed curriculum committees;

2. Organizations and preparation of information for Education Week, Empire Youth Week, Unesco, etc.;
3. Preparing educational statistics;
4. Keeping appraised of interstate and overseas educational developments;
5. Conducting required surveys.[1]

Typical activities of this Curriculum and Research Branch include the preparation of grade spelling lists, revision of readers, furniture design for infant rooms, and in-service training of teachers for the Cuisenaire method of teaching elementary arithmetic.[2] None of these areas is related to research in science curriculum.

Educational research in Australia into problems that may have significance in changing the educational mainstream are limited, and published reports of research are minimal. This reflects the general lack of educational research in Australia. Dunn described this situation as "the most serious of all our shortcomings, for who would believe that our problems are so simple that they can be solved without research. It would not take the fingers of one hand to count the number of Victorians at present employed <u>full time</u> on educational research."[3]

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[1] R. M. McDonell, W.C. Radford and P.M. Staurenghi, <u>Review of Education in Australia 1948-1954</u> (Melbourne: Australian Council of Educational Research, 1956), p. 74.

[2] <u>Ibid</u>.

[3] J. Dunn, "Victoria's Report to Congress," <u>The Teachers' Journal</u>, XLVI (June, 1963), 154.

Evidence of minimal research productivity is provided by a listing of educational research reported from the sources named earlier, in which a total of 298 separate studies were reported to have been in progress throughout Australia during 1963.[1]

Research specifically concerned with science education is likewise minimal. Thus, Radford reported in his summary of research for the period 1950 to 1956 that there was "a surprising lack of work in this field [of science]."[2] The only strictly science education study of the three included by Radford was a status study of biology teaching in the state of New South Wales.[3] The subsequent meagerness of controlled research in the field of science education in Australia is reflected by the inability of Radford to locate even one such study in his review of research for the following five-year period (1957-62).[4]

Since 1962, three studies have been reported in which Bloom's and other classifications of educational objectives

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[1]Commonwealth Office of Education, "Educational Research in Australia: 1963" (North Sydney: Commonwealth Office of Education, 1963), pp. 1-36. (Mimeographed).

[2]Ibid., p. 13.

[3]Ibid.

[4]William C. Radford, "Educational Research in Countries other than the United States: Australia," Review of Educational Research, XXXII (June, 1962), 217-24.

have been utilized as the bases for the development of more valid evaluation instruments for measuring the outcomes of science education.[1] In this category are the studies of Fensham,[2] Morris,[3] and Cohen.[4]

Other Australian studies with possible relevance to curriculum construction in science education include:

a survey of teacher attitude towards a new foundation-sponsored science textbook in the state of New South Wales;

factors related to the development of scientific interest among secondary school pupils;

a replication of some Piaget researches to study science concept development;

a study of creativity;

an examination of the predictive validity of grade 12 physics and chemistry as measures university success;

studies of the development of thought, reasoning power, and human thinking with age (especially for the years nine to fourteen);

development of new courses in South Australia for electronics and heat engines; and in the state of Western Australia for first year science;

research review of learning theory and psychological development of children aged six to fiteeen years relevant to curriculum construction;

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[1]Bloom, Pp. ix + 207.

[2]P. J. Fensham, "Educational Objectives in the Examining of Science Subjects," The Australian Journal of Education, VI (June, 1962), 103-12.

[3]G. C. Morris, "Can Suitable Objectives be Obtained for Chemistry Teaching?" The Australian Science Teachers' Journal, IX (August, 1963), 7-20.

[4]Cohen, VIER Bulletin, IX, 1-12.

study of the influence of high-school biology courses on university success;

evaluation of a new Tasmanian elementary school science program;

the development of programmed instruction units in chemistry;

the effectiveness of teaching machine principles applied to physical science teaching.[1]

This review of Australian science education research emphasizes the limited guidance available from research for the development of science curricula. It also indicates the need to extend research activities. Under these circumstances, the research findings in U.S.A. concerning science education gain added importance for Australian science curriculum development.

Recommendations

4.01. The Australian Science Education Foundation should encourage and support significant research studies in the field of science education. Findings from these studies should be made available to those responsible for developing science curricula.

4.02. The Australian Science Resource Centers should obtain and review science education research reports which emanate in the U.S.A.

Science Education Research in the U.S.A.

The rapid growth in the number of research studies reported in the area of science in U.S.A. is reflected by Table 6:

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[1]Commonwealth Office of Education, "Educational Research in Australia: 1963," p. 1-29.

TABLE 6

RESEARCH STUDIES IN SECONDARY SCHOOL SCIENCE MEETING NARST CRITERIA[a]

Year	Total Number of Studies Listed
1956-1957	25[b]
1957-1959	67[c]
1959-1961	195[d]
1961-1963	169[e]

[a]NARST is the National Association for Research in Science Teaching.

[b]U.S., Department of Health, Education, and Welfare, Office of Education, Analysis of Research in the Teaching of Science July 1956-July 1957, prepared by Ellsworth S. Obourn and Charles L. Koelsche (Washington, D.C.: U.S. Government Printing Office, 1959), p. 37.

[c]U.S., Department of Health, Education, and Welfare, Office of Education, Research in the Teaching of Science July 1957-July 1959, prepared by Ellsworth S. Obourn, Paul E. Blackwood and Margaret J. McKibben (Washington D.C.: U.S. Government Printing Office, 1962), p. 39.

[d]"Review of Research Studies in Science Education at the Secondary School Level, 1959-1961," Science and Mathematics Teaching Center, Michigan State University; Chairman: John M. Mason, p. 4, (Dittoed).

[e]"Review of Research Studies in Science Education: Secondary School Level Committee, 1961-1963," Science and Mathematics Teaching Center, Michigan State University; Chairman: Wayne Taylor, p. 6, (Mimeographed).

Although the quantity of research studies has been increasing, concern has been expressed about the nature and quality of many studies. For example, Cooley expressed concern about the lack of a theoretical framework for research. He wrote:

> Another fundamental difficulty arises from the fact that we often attack issues or problems head-on, without sufficient attention to the framework underlying them. We ask specific questions such as whether or not the laboratory experience should precede, accompany, or follow class discussions, rather than ask broad questions about how children learn science concepts. . . . Similarly, our own advances in science education will come not from a direct attack upon the obvious issues and problems, but by a slow testing of basic relationships which will become useful, operating principles.[1]

Criticism of both the quality of research relevant to science education curriculum development was also expressed by David, Novak, Obourn and Koelsche. David lamented what he referred to as "the paucity of well-conceived, well-designed and vigorously analyzed studies in the field of curriculum."[2] Novak was critical of the relationships between research findings and course objectives:

> Curriculum studies can easily be found in the literature where the value of the specific project is not only questionable, but recommendations presented are in direct contradiction to the objectives in the

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[1]William W. Cooley, "Challenge to the Improvement of Science Education," in Research in the Teaching of Science 1957-1959, pp. 4-5.

[2]O. L. David, Jr., "Foreword," Review of Educational Research, XXXIII (June, 1963), 230.

> field. Also, studies frequently dwell on untrue or irrelevant objectives for the science program proposed.[1]

Referring to the lack of research in the 1957-58 period in the science curriculum area, Obourn and Koelsche stated "that surprisingly little curriculum experimentation was attempted throughout the Nation."[2] In 1961, after asserting that "the trends of greatest importance lie in the most recent research efforts in curriculum development," Boeck and Washton expressed the hope that by 1964

> studies relating to measurement of achievement or change beyond the level of factual information. . . will be included as part of the evaluation scheme associated with the new [science] curriculums.[3]

Despite these several reports of paucity and scarcity of research concerning science curricula, there has been an accumulation of research which appears to have relevance for the development of an Australian science curriculum model. This will be described here in categories as follows:

1. Content, its selection and its grade placement;
2. Scientific skills;

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[1]Joseph D. Novak, "A Preliminary Statement on Research in Science Education," Journal of Research in Science Teaching, I, Issue 1 (1963), 8.

[2]U.S., Department of Health, Education, and Welfare, Office of Education, Analysis of Research in the Teaching of Science July 1956-July 1957, p. 38.

[3]Clarence H. Boeck and Nathan S. Washton, "Science in the Secondary School," Review of Educational Research, XXXI (June, 1961), 269.

3. Factors related to the learner;
4. Classroom practice;
5. Factors related to teachers.

Research on Content, Content Selection and Grade Placement

Studies seeking to identify appropriate course content for various grade levels have utilized techniques such as studies of existing textbooks, children's expressions of interests, surveys of school systems and teacher groups to determine their present practices, and opinions of juries of subject specialists. For example, the Curtis Digests contain numerous studies of the pre-1930 period, in which such techniques were utilized. Typical of these were the studies of Webb (1921) and Richards (1923) on textbooks, Finley (1925) and Pollock (1924) on interests, and Hunter (1924) on "curricular tendencies."[1,2] Curtis referred to the use of text-book analyses as a means for determining important scientific principles as being of paramount importance.[3]

As a consequence of these and many more recent studies, lists of principles appropriate for high school science teaching have been identified in several areas of science.

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[1]Francis D. Curtis, A Digest of Investigations in the Teaching of Science (Philadelphia: P. Blakiston's Son & Co., 1926), Pp. xvii + 341.

[2]Francis D. Curtis, A Second Digest of Investigations in the Teaching of Science (Philadelphia: P. Blakiston's Son & Co., Inc., 1931), Pp. xx + 424.

[3]*Ibid.*, p. 20.

Recent trends in curriculum development have led to the identification of content by scientists. For example, the Course Content Improvement Section of the NSF provides support to projects "initiated and led by outstanding scientists. . .in the development of courses and instructional materials that reflect contemporary scientific knowledge and points of view."[1]

Likewise the value of research on grade level placement has been discounted by statements such as those of Bruner, and Buck and Mallinson. Discussing readiness for learning, Bruner indicated that subjects could be taught to any child at any level. Bruner wrote:

> We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development. It is a bold hypothesis and an essential one in thinking about the nature of a curriculum. No evidence exists to contradict it; considerable evidence is being amassed that supports it.[2]

Buck and Mallinson had earlier made a similar statement in their analysis of elementary school science curricula. They stated:

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[1]National Science Foundation, Division of Scientific Personnel and Education, Course Content Improvement Section, Guidelines for the Submission of Proposals for Course Content Improvement Projects (Washington, D.C.: National Science Foundation, 1962), p. 1. (Mimeographed).

[2]Jerome S. Bruner, The Process of Education (New York: Vintage Books, A Division of Random House, 1963), p. 33.

> Nearly any area of science of any activity is suitable for nearly any grade level provided it is dealt with at the proper level of complexity.[1]

Grade placement of content on the basis of interest to children has been the subject of several studies. For example, children's interests have been studied through analyzing questions they ask and by the use of questionnaires. Such studies have been summarized by Blanc,[2] and by Von Qualen and Kambly.[3] However, these will not be discussed here, since considerable doubts have been raised as to the value of such studies as bases for curriculum construction. These doubts have resulted from statements such as those of Fitzgerald, and Wann, Dorn and Liddle. Fitzgerald wrote that children's interests were "unstable, inconsistent, ill-considered, and unreliable."[4] Wann, Dorn and Liddle wrote that children can become interested in most topics, stating:

> Children's spontaneous interests, which at one time were advocated as a basis of selection for an emerging curriculum cannot be relied on to lead the child into all the areas of knowledge he will need to explore in

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[1]Jacqueline V. Buck and George Greisen Mallinson, "Survey of Research in Elementary School Science Education," School Science and Mathematics, LV (December, 1955), 679.

[2]Sam S. Blanc, "Critical Review of Science Interest Studies," Science Education, XLII (March, 1959), 162-68, cited by Smith, Journal of Research in Science Teaching, I, Issue 1, 215.

[3]Cited by Smith, Journal of Research in Science Teaching, I, Issue 1, 216.

[4]Ibid.

> order to interpret today's world. . . . It appears that young children can become interested in most any topic which is brought to them in a meaningful way.[1]

Summary and implications of research on content, content selection and grade placement

1. There is a current lack of agreement concerning the optimal course content and grade placement of the concepts and principles. Research methods utilized to date have used analyses of textbooks, children's interests, and juries of educators. However, if the professional scientist is to make the contribution for which his specialized training makes him most competent, then the identification of the structure of the sciences and the appropriate content would appear to be a task that might be entrusted to him. This task is already being attempted in the U.S.A. by the projects supported by the NSF Course Content Improvement Program. The ready availability in Australia of constantly revised surveys of the major principles from the major branches of science would constitute a contribution of inestimable value to those charged with the task of curriculum construction.

2. Grade placement of content should be based upon psychological considerations rather than solely upon the interests of children.

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[1]Kenneth D. Wann, Miriam Selchen Dorn and Elizabeth Ann Liddle, Fostering Intellectual Development in Young Children (New York: Teachers College, Columbia University, 1962), pp. 99-100.

Recommendation

4.03. The Australian Science Education Foundation should enlist the assistance of professional scientists in identifying the major principles to be taught in Australian school science, and of psychologists in assisting with psychological aspects of grade place ment.

Research on Scientific Skills

There has been considerable research into the teaching of scientific "skills" (i.e., other than knowledge). This research has been concerned with such aspects as scientific method or methods, inquiry and discovery, application of scientific principles, and the interpretation of reading materials.

Treating the terms "scientific method," "scientific methods," "methods of science," "problem solving," "the scientific attitude," and "scientific attitudes" as synonymous,[1] one finds many studies performed in this area over a period of years.

In a study on the teaching of scientific attitudes, Curtis developed a list of these attitudes based on an analysis of the literature and the rankings of these by a jury of teachers. The list included categories associated with cause-effect relations, curiosity and its satisfaction,

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[1]John Murwyn Mason, "An Experimental Study in the Teaching of Scientific Thinking in Biological Science at the College Level" (unpublished Ph.D. dissertation, Dept. of Education, Michigan State College of Agriculture and Applied Science, 1951), p. 20.

habitual delaying of responses, weighing evidence and respect for other evidence.[1] In another study in the same area, Lampkin developed a list of ninety-two scientific attitudes.[2]

Kahn endeavored to develop specific teaching methods for scientific attitudes for seventh and eighth grade boys. Utilizing the current events reported in the daily newspapers as the basis of his technique, Kahn effected improved scientific attitudes.[3] Lednew and Moser surveyed the understanding, by small groups of ninth grade students, of scientific problems.[4] Meredith found conceptually related science subject matter more effective in effecting problem-solving ability than the topical method of teaching subject matter.[5] In the related area of critical thinking, Charen found that the use of open-ended chemistry experiments was ineffective in significantly improving critical thinking,

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[1]Francis D. Curtis, in <u>A Program for Teaching Science</u>, P. 56.

[2]Richard H. Lampkin, Jr., "Scientific Attitudes," <u>Science Education</u>, XXII (December, 1938), 354.

[3]P. Kahn, "Experimental Study to Determine the Effect of a Selected Procedure for Teaching the Scientific Attitudes to Seventh and Eighth Grade Boys through the Use of Current Events in Science," <u>Science Education</u>, XLVI (March, 1962), 45.

[4]George C. Lednew and Gene W. Moser," Scientific Attittudes Possessed by Junior High School Students," <u>Science Education</u>, XLII (October, 1958), 326-27.

[5]Charles E. Meredith, "Development of Problem Solving Skills in High School Physical Science: (Unpublished Ph.D.

although significantly better in parting facts and principles.[1] Mele, using problem solving techniques for an experimental biology group, produced significantly superior critical thinking ability, when compared with a control group.[2]

A more detailed discussion of similar researches is beyond the scope of this review, but Keeslar,[3] Mason[4] and Duncan[5] provide detailed information about numerous other research findings in the general area of scientific methods.

Woodruff reported one of the most significant conclusions reached in problem solving research was that

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dissertation, Stanford University, August, 1961), in "Review of Research Studies in Science Education: Secondary School Level Committee, 1961-63," Chairman: Wayne Taylor, p. 12.

[1]George Charen, "A Study of the Effect of Open-Ended Experiments in Chemistry on the Achievement of Certain Recognized Objectives of Science Teaching" (unpublished Ed.D. dissertation, University of Colorado, August, 1962), in "Review of Research Studies in Science Education: Secondary School Level Committee, 1961-63," p. 13.

[2]Frank M. Mele, "A Controlled Experiment in the Development of Critical Thinking in 86 Students, Tenth Grade Biology, New Milford (N.J.) High School, 1961-1962," Research Abstracts Bulletin, Montclair State College, LV (1963), 61-63, in "Review at Research Studies in Science Education: Secondary School Level Committee, 1961-63," p. 13.

[3]Oreon Keeslar, "A Survey of Research Dealing with the Elements of Scientific Method as Objectives of Instruction in Science," Science Education, XXIX (October, 1945), 212-16.

[4]Mason, "An Experimental Study. . .," pp.26-52.

[5]Carl P. Duncan, "Recent Research on Human Problem Solving," Psychological Bulletin, LVI (November, 1959), 397-429.

by Buswell with Kersh, taken in conjunction with the studies of Restle, Levine, and Pubols.[1]

> Together they present strong evidence that the ability to solve problems depends on the possession of concepts of how to do it, and Buswell says he saw no evidence that the schools are developing such concepts.[2]

The teaching of discovery and inquiry skills has received increasing attention in recent years. Kersh and Wittrock have produced a definition of learning by discovery. The stated:

> The term "discovery" frequently describes a learner's goal-directed behavior when he is forced to complete a learning task without help from the teacher.[3]

Suchman designated

> . . . three significant facts emerging from the research on the process of discovery: (a) exploration, manipulation, and mastery are intrinsically motivating, (b) a reinforcing sense of power and self-confidence comes from successful autonomous discovery, and (c) the strategy of data intake and processing has an important effect on the productivity and depth of discovery. These facts suggest a psychological basis for a program to improve inquiry skills.[4]

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[1]Asahel Woodruff, "With the Researchers: The Use of Concepts in Teaching and Learning," The Journal of Teacher Education, XV (March, 1964), 95.

[2]Ibid.

[3]Bert Y. Kersh and Merl C. Wittrock,"Learning by Discovery: An Interpretation of Recent Research," The Journal of Teacher Education, XIII (December, 1962) 461.

[4]J. Richard Suchman, "Inquiry Training: Building Skills for Autonomous Discovery." Mimeographed report, University of Illinois, Urbana, Illinois, p. 6.

Suchman's "Inquiry Training" research improved the ability of sixth grade children to ask productive questions.[1] He concluded that "the method in its present form has a marked effect upon motivation, autonomy and question-asking fluency of children."[2] In a study concerned with discovery learning in high school physics, Grote found that "directed discovery" was superior to "direct-detail" teaching of selected mechanics principles and transfer at intervals of one and six weeks.[3]

Concerned as we are with the non-election of science subjects by high school and college students, two findings of Kersh concerning discovery appear to have important implications when considering curriculum construction. These are:

> (1) Students who learned by discovery were motivated to continue their efforts. "If a student is highly interested in a subject, he is likely to continue to learn. Under appropriate conditions of practict and reinforcement, the discovery technique will foster favorable attitudes and interests."[4]

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[1]"Review of Research Studies in Elementary Science, 1961-1963."

[2]J. Richard Suchman, "Rebuilding the Science Program: Inquiry Training in the Elementary School," The Science Teacher, XXVII (November, 1960), 42-47.

[3]Charles Nelson Grote, "A Comparison of the Relative Effectiveness of Direct Detailed and Directed Discovery Methods of Teaching Selected Principles of Mechanics in the Area of Physics" (unpublished Ed.D. dissertation, University of Illinois, 1960), Dissertation Abstracts, XXI (April, 1961), 3016-17, in "Review of Research Studies in Science Education: Secondary School Level Committee, 1961-63," p. 15.

[4]B. Y. Kersh, "The Motivating Effect of Learning by Discovery," Journal of Educational Psychology, LIII (1962), 65-71, cited by Kersh and Wittrock, The Journal of Teacher Education, XIII, pp. 464-67.

(2) "Learning by discovery is many faceted. Answers to problems, general rules for solving problems, and even the motivation to continue learning may be acquired separately or in combination. . . . It is probable that more facets may be acquired simultaneously under conditions of discovery (guided or not) than when learning is highly directed."[1]

Two other researches related to developing specific skills were those of Baar and Barrilleaux. Baar found that pupils must be given specific instruction concerning the application of scientific principles if their effectiveness in such application is to be improved.[2] In Barrilleaux's study, multiple references were found to be as effective as basic textbooks in imparting factual information to eighth-grade science students, and significantly better than basic texts in developing the ability to interpret reading materials.[3]

Summary and implications of research on scientific skills

One of the important implications of the research concerning the various skills is that within the limits of

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[1] Kersh and Wittrock, The Journal of Teacher Education, XIII, p. 466.

[2] Lincoln F. Baar, "Critical Selection and Evaluation of Enrichment Methods in Junior High School General Science," Science Education, XXXIII (December, 1949), 333-34.

[3] Louis Barrilleaux, "A Comparison of the Effects on Certain Areas of Student Development When Teaching Eighth Grade Science with a Basic Text and with Multiple Available References." (Cedar Falls, Iowa: State College of Iowa, June, 1962). (Mimeographed) in "Review of Research Studies in Science Education: Secondary School Level Committee, 1961-63," p. 11.

maturation of pupils, particular skills can be imparted best when specific learning situations are designed to develop those skills. This was underscored by Woodburn's analysis of selected research findings in science education since 1900. Woodburn stated that:

> . . . to develop appreciation for an adeptness in the methods and procedures of science calls for overt instruction directed specifically toward achieving this goal.[1]

For example, inquiry training improves the ability of students to inquire; specific teaching of scientific attitudes effects improvements in the pupils with regard to their scientific attitudes; and ability to apply scientific principles requires specific instruction. Yet, despite the implied need for teachers to use methods appropriate for the development of specific skills Travers and Wallen found that the dominant teacher behavior is the imparting of verbal knowledge, with the students as passive receptors.[2]

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[1] John H. Woodburn, "The Content and Pedagogical Spirit of the New Science Courses and the Findings from Science Education Research." A paper presented at the Thirty-Seventh Annual Meeting of the NARST, Chicago, March, 1964. (Unpaged, typewritten copy, in the files of the writer.)

[2] Robert M. W. Travers and Norman Wallen, The Measured Needs of Teachers, U.S. Office of Education Project No. 444, 1963, cited by Woodruff, The Journal of Teacher Education, XV, p. 83.

The development of curricula in which specific teaching methods are described for attaining the behavioral objectives of the curricula, will facilitate the development of specific skills. Increasing emphasis on problem solving and other skills, in conjunction with the teaching of major knowledge principles (and in replacement of the memorization of isolated content segments) demands the attention of curriculum makers in designing teachable techniques.

Recommendations

4.04. Since particular skills can be imparted best when specific learning situations are designed to develop those skills, Australian science curriculum makers should incorporate into the curricula techniques which facilitate the direct teaching and learning of those skills listed in the behavioral objectives of the curriculum.

4.05. Teacher training should attempt to develop teacher behaviors appropriate to curriculum objectives. For example, consideration should be given to providing that training which is most likely to make the teacher more effective in directing the discovery method of pupil learning.

Research on Factors Related to the Learner

The development of curricula should take into account factors concerning the learning process and the learners. The contribution of science education research to the determination of such factors has been criticized by Barnes, who stated:

> One of the crucial weaknesses in science education as seen through curriculum research is the almost complete

> lack of research on the nature of learning as it can affect science teaching. We build curricula and proceed ultimately to specific lesson plans without validated criteria for judging the contributions of specific educational activities as specific objectives. We are not sure they should be called educational.[1]

Availability of tests.--When related to some other research areas, the number of studies concerned with research on learners is minimal. This may result partly from the fact that diagnosis of individual differences presupposes the existence of ready availability of valid tests of these differences. Such is not the case. Many critics have drawn attention to the critical need to develop evaluation procedures that reflect the wider educational outcomes sought in statements of objectives. Most recently, this need has been voiced by Haney,[2] the NSTA Committee on Evaluation,[3] Trump[4] and Watson.[5] The NSTA Committee stated:

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[1]Cyrus W. Barnes, "A Definition of Science Education: Curriculum Research," Science Education, XLV (December, 1961), 396.

[2]Richard E. Haney, "The Development and Analysis of a Non-Verbal Test of Certain Concepts Children Have of Animals," A Paper presented at the Thirty-Fifth Annual Meeting of the NARST, Washington, D.C., February 21-24 1962, p. 1. (Mimeographed).

[3]National Science Teachers Association, Committee on Evaluation, Analysis of Science Tests, (Chairman, Paul L. Dressel) (Washington, D.C.: National Science Teachers Association, 1959), p. 11.

[4]J. Lloyd Trump, "Some Problems Faced in Organizing Science Teaching Differently," The Science Teacher, XXXI (May, 1964), 37-39.

[5]Fletcher G. Watson, "Research on Teaching Science," Handbook of Research on Teaching, N. L. Gage (ed.) (Chicago: Rand McNally & Company, 1963), p. 1054.

> If teachers search for such objectives as understanding of science theories, the structure of science, problem solving, the ability to reason logically, and the ability to apply what is learned to new situations, most of the standardized tests now available tell them little about the extent to which these objectives are being realized.[1]

Watson found that "the almost universal emphasis upon gains in scores on achievement tests of limited scope is alarming. This emphasis implies that the primary function of a teacher is to develop in the pupil only [a] small range of behaviors."[2]

Implications of research on availability of tests

The implication of these statements is that, if research studies in areas related to learners and the learning process are to be promoted, then a need exists for the development of evaluation devices for the full range of student behaviors specified in statements of curriculum objectives. The availability of such devices is basic to curriculum evaluation. Hence, the following recommendation is presented:

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[1]National Science Teachers Association, Committee on Evaluation, Analysis of Science Tests, p. ii.

[2]Watson, "Research on Teaching Science, in Handbook of Research on Teaching, p. 1054.

Recommendation

4.06. Research to develop valid and reliable evaluative techniques for a range of the behavioral objectives specified within science curricula should receive an urgent priority. The Australian Council for Educational Research is well equipped to direct this research. Australian science curriculum makers should incorporate such evaluative techniques at appropriate points within the curricula.

Concept formation.--A number of recent studies of the learning process have been concerned with concept formation. Woodruff stated that "concept learning is being recognized as the dominant element in learning."[1] Woodruff also provided a clear cut definition of the term "concept" appropriate for curriculum studies:

> For purposes of talking about curriculum planning in general, a concept may be defined as some amount of meaning more or less organized in an individual mind as a result of sensory perception of external objects or events and the cognitive interpretation of the perceived data. A concept is important because it is the internal mediating variable that accounts for the direction of a person's response to a situation.[2]

Citing researches by Gagné and Bolles, Frank, and Gagné, Woodruff stated:

> Efficiency in performance where concepts are the mediating variables is acquired through the efficient acquisition of concepts rather than the practice of the end acts.[3]

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[1]Woodruff, The Journal of Teacher Education, XV, 95.

[2]Ibid., p. 84.

[3]Ibid., p. 83.

Science education research on concept development includes studies by Haney,[1] Butts,[2,3] and McNeil and Keislar.[4] Haney developed a non-verbal test of children's concepts of animals as a device for assessing the intellectual growth of young children. Despite intensive development, Haney found "limitations of the test as it exists at the termination of the present study."[5]

Butts confronted each of twenty highly-selected upper elementary school children with four science experiences for each of four physical science concepts. For each experience, the children first were to write their predictions of the outcomes of certain actions by the experimenter to a demonstration. In the second stage, children asked questions of the demonstrator to which "yes-no" answers were possible. Finally, students were permitted to manipulate the demonstration apparatus. Butts "found there was no significant

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[1]Haney, "The Development and Analysis of a Non-Verbal Test. . .," pp. 1-16.

[2]David P. Butts, "The Degree to Which Children Conceptualize from Science Experience," Journal of Research in Science Teaching, I, Issue 1 (1963), 135-43.

[3]David P. Butts, "Does Experience Equal Understanding?" The Science Teacher, XXX (December, 1963), 81-82.

[4]McNeil and Keislar, reported in "Research Studies in Elementary Science, 1961-1963," p. 2; and in Smith, Journal of Research in Science Teaching, I, 218.

[5]Haney, "The Development and Analysis of a Non-Verbal Test. . .," p. 14.

progress in understanding."[1] He hypothesized an "equation" for further research study, thus:

> Experience plus independence in manipulation plus direction upon cognitive maturity equals conceptual understanding.[2]

Goldberg[3] has raised doubts about concept formation in the study by McNeil and Keislar in which they attempted to validate a teaching unit related to molecular theory at the elementary school level. McNeil and Keislar "studied the explanations of selected natural phenomena by typical children in the first and third grades."[4] These explanations formed the bases for designing auto-instructional "materials to teach highly specific relationships at the abstract or theoretical level." Whereas in a pretest 70 children developed "functional rather than animistic and theoretical concepts," they subsequently answered oral questions related to molecular theory "in theoretical terms for which there is no immediate reality."[5] Goldberg

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[1]Butts, <u>The Science Teacher</u>, XXX, 82.

[2]<u>Ibid</u>.

[3]Stanley Goldberg, "A Note Concerning Teaching Scientific Theory to First Grade Pupils by Auto-Instructional Device," Harvard Educational Review, XXXI (Fall, 1961), 451-53, cited by Smith, <u>The Journal of Research in Science Teaching</u>, I, 218.

[4]"Research Studies in Elementary Science 1961-1963," p. 2.

[5]Goldberg, cited by Smith, <u>The Journal of Research in Science Teaching</u>, I, 218.

criticized this study, referring to the outcomes as providing "a slick veneer on a mass of ignorance," rather than an ability to give scientific explanation.[1]

In keeping with Goldberg's criticism, Suchman found from his "Inquiry Training" project at Illinois that the original questioning by children ". . . revealed a verbalism in science that was not supported by conceptual understanding."[2] This also appeared to be borne out to some extent by responses of a fifth-grade which had been studying astronomy concepts for several weeks. The present writer asked the open-ended question: "How far can you see?" Of twenty-four responses, twenty-two gave answers ranging from ten feet to sixty miles. The other two answers given were "270,000 miles" and "93,000,000" (no unit given).[3] It appears that conceptual understanding of astronomical distances had not been developed.

Woodruff also cited evidence which emphasized the "deep and significant difference between verbal knowledge and conceptual knowledge."[4] Russell reported:

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[1]Goldberg, cited by Smith, The Journal of Research in Science Teaching, I, 218.

[2]Suchman, in "Research Studies in Elementary Science, 1961-1963," p. 4.

[3]Responses in files of the writer.

[4]Woodruff, The Journal of Teacher Education, XV, 83.

> Children develop breadth and depth in their concepts only after much firsthand and vicarious experience in the area involved. An everpresent problem of parents and teachers is the confusion of verbalization with true understanding. Concepts are necessarily incomplete until home, school, community and the wider world can provide experiences against which to check the validity of a generalization.[1]

In terms of the above evidence, the warning contained in the 1961-1963 review of elementary science education research studies appears timely. The writers found that the studies reviewed

> . . . seem to indicate that the process of concept development is one for which careful and deliberate planning must be made. Furthermore, the process of concept development is slow at best. If these inferences are valid, then curriculum developers should give more serious attention to the number of concepts which they propose to have developed at each level. They should also be concerned about the teaching processes by which they propose to develop the concepts.[2]

Burlingame listed several proposals concerning the relative difficulty of concept learning.[3] Woodruff evaluated Burlingame's propositions as

> . . . reasonable in the light of presently available evidence, and their use in curriculum planning and related evaluation on a tentative basis has fairly respectable support in psychology.[4]

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[1]David H. Russell, Children's Thinking (Boston: Ginn and Company, 1956), p. 163.

[2]"Research Studies in Elementary Science, 1961-1963," p. 4.

[3]Mildred Burlingame, "Some Determinants of Concept Formation," The College of Education (University of Idaho) Record, II (1963), 14-19, cited by Woodruff, The Journal of Teacher Education, XV, 95-96.

[4]Woodruff, Ibid., p. 95.

The more important of Burlingame's propositions for the purposes of curriculum construction, were the following:

> Subject matter becomes more meaningful and more directly transferable to behavior when it is transformed from verbal form to conceptualized form.
>
> . . . .
>
> Students must have the concepts in subject matter if they are to engage in problem-solving behavior, but they must also be taught concepts of problem-solving behavior. The mere efforts to solve problems without prior learning will be relatively unproductive.
>
> . . . .
>
> Cognitive processes and verbal process are sufficiently different to require careful differentiation in teaching. It is especially important to avoid substituting verbal processes for cognitive processes, limiting verbal processes primarily to the function of guiding attention of students to cognitive materials and activities.
>
> . . . .
>
> Curriculum content reveals three kinds of concepts: processes, structures and qualities. The perceptual materials for each of them should be distinguished so that there can be relevance between learning materials and expected end products.
>
> Concepts sometimes have hierarchical structure in which advanced concepts can be learned only when supporting concepts are already possessed. When this is the case, learning will be greatly facilitated by observing the hierarchy by means of sequencing. Sequencing seems to be irrelevant when there is no real hierarchy.
>
> Concepts become more effective in thinking when they have been verbalized. Students can be helped to verbalize their important concepts, but verbalization should not be pushed more rapidly than the learner can do it meaningfully.
>
> . . . .
>
> New concepts take form faster when students are given cues and information as to what to look for in learning materials.

> Retention and transfer of concepts is facilitated to the extent students either discover for themselves or in some equivalent way obtain a discoverer's intimacy with the conceptual structure.
>
> . . . .
>
> When students are being introduced to new phenomena from which concepts are to be developed, they should be permitted to explore the new phenomena overtly. In later stages of concept learning, covert mental reactions may become more dominant and more profitable for concept development.[1]

Implications of research on concept formation

Conceptual understanding is promoted by discovery learning. It is a prerequisite to the transfer of the learned behavior to other situations.

Recommendations

4.07. To facilitate conceptual understanding, Australian science curricula should emphasize the discovery approach. This will necessitate maximum use of laboratory facilities. In order to compensate for the additional time this approach may utilize, science teaching should be introduced into elementary classes.

4.08. Curricula should incorporate open-ended situations which facilitate transfer of previously learned behavior.

Research on Classroom Practices

Investigators have continued to conduct studies which purport to evaluate the relative effectiveness of Method A and Method B. Method A has been presented as lecture-demonstration with Method B as laboratory exercise;

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[1]Burlingame, cited by Woodruff, Ibid. pp. 95-96.

or Method A has been the use of instructional telecasts or films or programmed instruction, with Method B "traditional" teaching. It seems important to indicate at the outset some weaknesses of such studies:

> tests of relative effectiveness of two methods rarely are equally valid for the two methods;

Strang expressed the opinion that comparable-group experimentation represented a premature attempt to make educational research scientific.[1] Rosenbloom, echoing Strang's criticisms, stated:

> You know, for example, that in education experimentation, no matter what the hypothesis is, the experimental classes do better than the control classes.[2]

Brownell suggested that, instead of using comparable-group research, behavioral changes of students in the classroom be observed, and a carefully-documented record of the teaching-learning process be so obtained.[3]

However, there is an additional problem here, as presented below:

> Valid tests for many possible behavioral outcomes have not been developed. Frequently, the comparisons are limited to gains in "achievement," where this is measured by a verbal (often retention) test.

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[1]Ruth Strang, "Reactions to Research in Reading," The Educational Forum, XXVI (January, 1962), 188.

[2]Paul C. Rosenbloom, "Large-Scale Experimentation with Mathematics Curriculum," cited by Desmond L. Cook, "The Hawthorne Effect in Educational Research," Phi Delta Kappan, XLIV (December, 1962), 119.

[3]W.A. Brownell, "A Critique of Research on Learning and Instruction in the School," in Graduate Study in

Statements by Watson and the NSTA Committee of Evaluation (quoted earlier in this Chapter) reinforce this point.

There have been many studies concerning the use of audiovisual aids in the classroom. With the increasing shortage of science teachers in Australia, the potential of these aids deserves thorough study by those concerned in curriculum construction. In particular, research findings concerning the effectiveness of instructional television and programmed instruction for science teaching have relevance for curriculum construction.

Schramm summarized the results of 425 quantitative studies concerning the effectiveness of televised instruction. Of the 393 studies which compared the relative effectiveness of instructional television (Method A) and face-to-face (traditional or Method B) instruction, 84 were in the field of science.[1] Results and grade distribution of these relative effectiveness studies are reported in Table 7.

Research such as that tabulated has led to the conclusion that television is at least as effective in teaching science, as is traditional teaching. Schramm has said that

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Education, Fiftieth Yearbook of the National Society for the Study of Education Part I (Chicago: National Society for the Study of Education, 1951), p. 61.

[1]Wilbur Schramm, "Learning from Instructional Television," Review of Educational Research, XXXII (April, 1962), 156-67.

TABLE 7

STUDIES OF THE EFFECTIVENESS OF INSTRUCTIONAL TELEVISION FOR THE TEACHING OF SCIENCE[a]

Grade Level	Studies in which science on ITV significantly superior (0.05 level)	Studies in which no significant difference (0.05 level)	Studies in which face-to-face science instruction significantly superior (0.05 level)	Total
3-6	8	14	1	23
7-9	9	8	3	20
10-12	3	7	3	13
College	1	26	1	28
Total	21	55	8	84

[a]After Schramm, Review of Educational Research, XXXII, p. 157.

"about as much learning seems to take place in a TV class as in an ordinary class."[1] Despite criticisms[2] of the quality of much of the research cited by Schramm,

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[1]Schramm, Review of Educational Research, XXXII, p. 157.

[2]David White Stickell, "A Critical Review of the Methodology and Results of Research Comparing Televised and Face-to-Face Instruction" (unpublished doctoral dissertation, Pennsylvania State University, College Park, Pennsylvania, June, 1963).

instructional television appears to have a defined potential in contributing towards some of the science teaching objectives.[1]

As he did with the research on ITV, Schramm collated the experimental results available in 1962 in the field of programmed instruction. On this occasion, Schramm "warned that some of these experiments have been done with very small experimental groups"[2] and that "comparisons with 'conventional' methods of teaching are difficult and sometimes suspect."[3] He further warned that the generalizability of the results may be limited. Schramm concluded that "programmed instruction has been tried, and has accomplished learning , at every level, from preschool to graduate school."[4] The successful utilization of programmed instruction extended from slow to superior students, rote learning to concept formation and practical skills, supplemental to complete course teaching, and in various countries of the world.[5]

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[1]Daniel Tanner and Frank J. Woerdehoff, "Profiles of Instructional Methodology for Selected Television Courses The School Review, LXXII (Summer, 1964), 201-08.

[2]Wilbur F. Schramm, Programmed Instruction: Today and Tomorrow (The Fund for the Advancement of Education, 1962), pp. 43-70.

[3]Ibid., p. 47.

[4]Ibid., p. 45.

[5]Ibid.

More diverse science areas that have now been programmed include glassblowing, diagnosing faults in electronic circuits, reading radar screens, and qualitative chemical analysis. Of the 122 programs listed as available in September 1962, twenty-four were in the area of science.[1] A year later, a total of 352 programs were reported as available, of which sixty-one were in the sciences.[2]

Watson emphasized the tentativeness of present findings concerning programmed instruction. He stated:

> Experimental studies of programed instruction which report data concerning pupil responses to programs and to pretests and posttests are rare in any subject. This underlines that programing is in its early stages.[3]

Replication of many studies with large samples using valid tests, and validation against the broader science teaching objectives, appear necessary to determine the optimal value of programmed instruction.

Other research studies involving comparisons of methods were based upon the use of films and textbooks. Research on the effectiveness of filmed courses has been

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[1] U.S., Department of Health, Education, and Welfare, Teaching Machines and Programmed Learning: A Survey of the Industry, 1962, prepared by James D. Finn and Donald G. Perrin (Washington, D.C.: U.S. Government Printing Office, 1962), Pp. x + 85.

[2] The Center for Programed Instruction, Programs, '63: A Guide to Programed Instructional Materials Available to Educators by September 1963, L. F. Hanson (ed.) (Washington, D.C.: U.S. Government Printing Office, 1963), p. vi.

[3] Watson in Handbook of Research on Teaching, p. 1052.

reported fully by Watson[1] and by Cohen.[2] In summary, groups taught by film and control groups do not differ significantly in the achievement test scores utilized in these studies. Of three studies concerning the use of textbooks, as against lecture and demonstration methods, the only statistically significant difference was found for the low-intelligence, poor reader group. This group gained significantly as a result of assigned reading.[3] Smith summarized the studies of the effectiveness of technological devices by indicating their potentially significant contribution as an adjunct to the instructional process.[4]

Summary and implications of research on classroom practices

Science education research findings involving the comparison of effectiveness of two methods of teaching are subject to question in many cases due to such factors as the questionable validity of evaluation instruments used, Hawthorne Effect, the unavailability of valid instruments for many of the behaviors sought, methods of treating the

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[1]Watson, in Handbook of Research on Teaching, pp. 1044-1052.

[2]David Cohen, "The Significance of Recent Research in Secondary-School Science Education," Science Education, XLVIII (March, 1964), 162-63.

[3]Ibid., p. 161

[4]Smith, Journal of Research in Science Teaching, I, 217.

data and faulty sampling techniques. In view of the need to remedy this situation, the following recommendation is made:

Recommendation

4.09. Curricula need to incorporate built in valid evaluative techniques so that the effectiveness of the curricula and methods can be gauged in terms of the previously determined objectives.

The experimental design of many of the studies of effectiveness of mass media has been of doubtful soundness. However, there is evidence that the mass media may be utilized effectively for inculcating certain measurable objectives of science education. The effects of existing teacher shortages and other deficiencies may be minimized by optimal utilization of the mass media in science education.

Recommendation

4.10. Careful studies should be made of the optimal contribution of the mass media towards an effective science program (e.g., for introducing problems, conveying information, etc.). Appropriate instructional telecasts and programmed instructional materials should then be developed as a facet of the overall curriculum development. The Australian Broadcasting Commission is in an excellent position to collaborate in these studies.

Research on Factors Related to Teachers

Criticism of research on teachers has been expressed by Watson, who stated that "most of the studies have seemed to treat the teacher in terms of a narrow, stereotyped conception of his role, not as an aspiring human being in a situation rife with tensions."[1]

That teacher variability is important in science teaching is suggested by an investigation by Fish. Fish found that teachers who scored low on the Rokeach Dogmatism Scale (i.e., less "rigidity") were better able to direct children in discovery of scientific relationships. With the increasing acceptance of discovery teaching in science, this research appears to possess significance, despite the small sample (eighteen student teachers) used in the study.[2]

There are other recent studies related to teachers which appear to have relevance for the development of a curriculum model, and more especially for curriculum construction in a centralized educational system. These are the studies of Uffelman and Verduin. Uffelman found that classroom teachers involved in curriculum development and inservice classes were significantly different from teachers not involved, in

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[1]Watson, in Handbook of Research on Teaching, p. 1054.

[2]Alphoretta Fish, "Directing the Discovery of Scientific Generalizations in Elementary School Science Instruction," School Science and Mathematics, LXII (March, 1962), 183-87, reported in "Biennial Review of Research: College Level, 1961-1963." A paper prepared by Joseph D. Novak and Arnold M. Lahti, and read at the Thirty-Seventh Annual Meeting of NARST, Chicago, March 21, 1964, p. 3. (Mimeographed).

that they accepted the general objectives of the resultant curriculum more, used instructional materials more, knew more about the procedures of curriculum development, accepted the science teaching objectives more, and followed more of the science units developed than teachers not involved in curriculum development. From the use of four groups involved to various extents, Uffelman concluded that the degree of involvement correlated highly with the teachers' degree of acceptance of the resultant program. Uffelman cautioned, however, that the results may have been spurious as a result of the method of forming groups.[1]

Verduin conducted a one-year research in Cassopolis, Michigan, in which he involved forty-five teachers and administrators in a curriculum study "to identify, evaluate and foster solutions to problems in the curriculum." Three university curriculum specialists assisted an elected steering committee which led eight small groups, each investigating a particular problem area with a view to initiating change. Verduin found from the administration of questionnaires an increased interest in education and its problems, awareness of inconsistencies in their own curricula, and a more democratic and professional attitude resulted from

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[1]Robert Lannoye Uffelman, "The Centrally-Coordinated Approach: Teacher Acceptance of Science Curriculum Development Program," Dissertation Abstracts, XXIII, No. 6 (1962), 2036.

the cooperative efforts. More concern was developed for students, fellow educators and education in general. Verduin "concluded that this cooperative approach to curricular change fostered valuable change in the participants and worthwhile change in the curriculum."[1]

In Australia, the need for involving teachers in curriculum revision was expressed by Browne in 1932.[2] On the basis of his visit to the U.S.A., Browne outlined a mechanism for involving teachers within the existing administrative framework of Australia's centralized systems. Browne stated:

> No programme of school work will operate effectively which is not evolved to some extent out of the thinking of the teachers who are to apply it.[3]

Browne proposed that local committees of teachers should work continually on curriculum problems. A central executive curriculum committee, comprising a state curriculum director and representatives of the Director of Education, teachers, inspectors, teachers' college faculties and educational research organizations should direct the studies of the

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[1]John Richard Verduin, "An Evaluation of a Cooperative Approach to Curriculum Change," Dissertation Abstracts, XXIII, No. 12, Part I (1962), 4581.

[2]Professor George Stephenson Browne for about twenty years was the Dean of the Faculty of Education at Victoria's (then) only university, the University of Melbourne.

[3]G.S. Browne, The Case for Curriculum Revision: Being a Report Submitted to the Director of Education, Victoria, as a Result of Observation in Great Britain and America (Melbourne: Melbourne University Press, 1932), p. 22.

local groups, arrange for central conferences and coordinate curriculum activities.[1]

The following successive stages were postulated by Browne for the Central Committee: survey of curriculum area and literature from Australia and overseas, extensive discussion, arousal of teachers' interest (through circulars, area discussion groups, gazette articles) and visits to district groups.[2] The Central Committee should submit tentative drafts of new courses to local committees for modification.[3] Other recommendations of Browne included the following:

> Curriculum revision should be continuous, with local committees meeting at the end of each academic year and suggesting curricula changes to the Central Committee.[4]
>
> . . . .
>
> In one vacation period each year, a feedback conference in Melbourne would be arranged by the Central Committee, and all districts would send representatives to express their views.[5]
>
> . . . .
>
> Teacher criticisms would also be solicited at district conferences through the use of blank pages at the back of courses of studies, provided for their comments.
>
> Following the vacation conference, "Subject Committees" composed of teachers from city and country, working on a

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[1] G. S. Browne, The Case for Curriculum Revision. . ., p. 23.

[2] Ibid., pp. 60-61

[3] Ibid., p. 23.

[4] Ibid., p. 23.

[5] Ibid., p. 64.

> freed-time basis for two periods each of several days, would then draft the new courses, and submit these to the Central Committee for coordination with other subject areas. The courses would then be presented for approval to the administration, printed and published, in suggestive rather than prescriptive [form]. . . desirable local variations would be appropriate for farming, mining, industrial and pastoral areas.[1]
>
> . . . .
>
> Curriculum tests should be constructed in accordance with the course aims, and state norms established.[2]
>
> Volunteer Summer Schools for teachers would also be held in extended vacations, to demonstrate the most successful of new teaching techniques.[3]

Summary and implications of research on teachers

Teacher variability is an important factor in determining the classroom outcomes of a science program.

Recommendation

4.11. Teacher education programs should take cognizance of recent science teaching objectives, and prepare teachers to impart the desired behaviors skillfully. In Australia, this implies a high degree of communication between those members of the state Education Departments responsible for science curriculum construction, and University faculties of graduate education courses responsible for training secondary school teachers of science.

Involvement of teachers in curriculum studies results in desirable types of behavior on the part of those involved.

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[1]G. S. Browne, The Case for Curriculum Revision. . ., pp. 64-65.

[2]Ibid., pp. 67.

[3]Ibid., p. 23.

Recommendation

4.12. Even though there is centralized educational administration in Australian states, consideration should be given to methods for maximizing and encouraging contributions of teachers towards the development and modification of these curricula. Provisions for local flexibility and adaptation should be incorporated into the curricula.

Research from Psychology Relevant to Science Curriculum Construction

Research from psychology provides numerous studies concerned with the identification of appropriate processes in which a child is capable of participation at various stages and ages. However, Peel stated:

> There is surprisingly little research on science teaching that is explicitly designed to test educational practice against psychological theory and experimental result.[1]

Peel cited the Curtis list of twenty "milestones" of science education research for the period 1904-1950, in which only about four "appear to refer to psychological standards," and stated that in England, science education research related to psychology was limited to "the problem of scientific abilities, aptitudes, attitudes and interests."[2]

It is of importance in curriculum construction, especially in determining grade placement of some understandings and

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[1]E. A. Peel, "Psychology and the Teaching of Science," The British Journal of Educational Psychology, XXV (November, 1955), 136.

[2]*Ibid.*

skills to be aware of any limitations imposed by the possible lack of pupil readiness. Failure to recognize the absence of readiness may have serious consequences, as Delacato's extensive investigations with respect to reading difficulties have shown. His researches showed that specific and progressive neural development is important to develop a physiologically optimum condition. Failure to develop fully a particular vertical neural level, according to Delacato's theory, will result in "all succeeding higher levels [being] affected both in relation to their height in the central nervous system and in relation to the chronology of their development."[1] Studies in the processes of science corresponding to Delacato's studies in reading have not been reported. However, the possibility of damage resulting from the acceleration in the teaching of processes suggests the need for caution until appropriate research findings are available.

Another warning of the potential maladjustment that could result from overacceleration of children was provided by Griffiths, following her research on imagination in young children. She wrote:

> Let us remember the emotional accompaniment of every new step forward in development in childhood, the

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[1]Carl H. Delacato, The Treatment and Prevention of Reading Problems: The Neuro-Psychological Approach (Springfield, Illinois: Charles C. Thomas, 1961), p. 19.

> ambivalence involved, the fear, the aggression, the temporary retreat into phantasy. The child must gather energy for each new experience. For this he needs time. At every turn do we find this need to have consideration for factors of time. To attempt to hustle a child out of one stage of development into the next may produce some form of malajustment.[1]
>
> . . . .
>
> His unhappiness when experienced is very real, and deeper than that of a more developed stage of life, because it is unmitigated by any realization of the healing effect and the limitation of all experience imposed by time.[2]

Jersild, warning against over ambitious curriculum requirements, advised that "a performance that is time-consuming and disheartening at one age level may be mastered with less time and effort when he is a bit more mature."[3] To illustrate his point Jersild described an experiment by Benezet in which he postponed for a group of children until ninth grade the teaching of formal arithmetic operations. This group subsequently mastered the operations in a short time "which other children had struggled with for several years in the lower grades."[4]

In view of possible deleterious consequences, studies in which the findings of researches in the psychologies of learning and child development bear on the processes of

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[1]Ruth Griffiths, A Study of Imagination in Early Childhood (London: Kegans Paul, Trench, Trubner & Co., Ltd., 1935), p. 328.

[2]Ibid., p. 357.

[3]Arthur Jersild, "Curriculum Maker--Know Your Child," Childhood Education, XIII (May, 1937), 406.

[4]Ibid.

science have importance for science curriculum development. This has been emphasized by Matala:

> There is indication in some of the course content studies that what we know about how children learn has influenced planning. But all too often this is a noticeable gap. We know little about children's learning and thinking. But what we do know should find more application in curriculum work.[1]

With one of the recent trends in curriculum planning in the U.S.A. towards an increased emphasis on science processes, the rationale for this trend bears examination before adoption in Australia. In particular, the research findings on the ability of children to participate effectively in these processes appears relevant. In the absence of science education research, it is from the field of psychology that such studies need to be borrowed.

Flavell has identified some of the relevant research from the area of educational psychology. Writing of the potential applications of Piaget's system to education, Flavell suggested "the planning of curricula in the context of Piaget's developmental findings."[2] Piaget traced the development of the child's concept of matter, space, time and causality.[3] The broad nature of Piaget's experimentation

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[1]Dorothy C. Matala, "Current Activities in Elementary Junior High School Science," Science Education News, (December, 1960), p. 5.

[2]John H. Flavell, The Developmental Psychology Jean Piaget (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1963), p. 365.

[3]Jean Piaget, The Construction of Reality in the Child (New York: Basic Books, Inc., 1955), Pp. xii + 386.

underlying the development of these concepts was described by Coxford thus:

> Piaget, in his experimental work, categorized the concept attainment of children by ages into three stages. The first stage is no understanding, and the third stage is complete understanding. The second stage is transitional, bridging the gap between the first and the third. A primary question for those responsible for the education of children is this: Does instruction change the age at which children attain stage 2 and 3?[1]

One of the significant factors of Piaget's research for current trends in science education was his concern for understanding the process. As Inhelder described Piaget's experiments:

> The experiment does not merely take account of the child's responses but also for the child's explanation of them. And, by modifying the questions and the experimental conditions, the investigator seeks to test the geniuneness and the consistency of the child's responses.[2]

Many years ago in the U.S.A., Dewey made the distinction between "product" and "process" in the educative process,[3] but there was no supportive research as has been the case

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[1]Arthur F. Coxford, Jr., "The Effects of Instruction on the Stage Placement of Children in Piaget's Seriation Experiments," The Arithmetic Teacher, XI (January, 1964), 4-5.

[2]Barbel Inhelder, "Some Aspects of Piaget's Genetic Approach to Cognition," Monographs of the Society for Research in Child Development: Thought in the Young Child: Report of a Conference on Intellectual Development with particular attention to the work of Jean Piaget (eds., William Kessen and Clementine Kuhlman), XXVIII (June, 1962), 21

[3]John Dewey, How We Think: A Restatement of the Relations of Reflective Thinking to the Educative Process (Boston: D.C. Heath and Company, 1933), pp. 71-75.

with Piaget's work. From Piaget's research, a developmental sequence has been postulated. Describing this, Inhelder indicated that there were three broad stages of cognitive development, each with several sub-stages.

Stage I occurs from birth to about eighteen months, and therefore is not important for science curriculum development. The second developmental stage, called the stage of concrete thinking operations, generally extends from eighteen months until the eleventh or twelfth year.[1] "It is characterized by a long process of elaboration of mental operations. This process is completed by about the age of 7 and is then followed by an equally long process of structuration. Doing their elaborations, concrete thought processes are irreversible. We observe how they gradually become reversible. With reversibility, they form a system of concrete operations."[2]

A typical example is given by Inhelder of a Piaget experiment in which deformation of ball or sausage-shaped pieces of plasticine was regarded by children who had not reached the stage of conservation as changing the amount of matter contained in the plasticine. The thought structure was formed at about age seven, but

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[1]Inhelder, Monographs of the Society for Research in Child Development. . ., pp. 24-25.

[2]Ibid.

> it still requires years before those structures are brought to bear on all possible concrete contents. It can be shown, for example, that the principle of invariance (constancy, conservation) is applied to the quantity of matter earlier than to weight, and volume still later on. . . . Thus, the process seems indeed to be one of genetic construction--a gradual process of equilibration within. Equilibrium is attained at about 11 of 12 years of age. This operational structure, in turn, forms the basis of the development of the formal thinking operations.[1]

The third stage, that of formal thinking operations, begin on the average at about eleven or twelve years of age and is characterized by the development of formal, abstract thought operations. In a rich cultural environment, these operations come to form a stable system of thought structures at about fourteen or fifteen years of age. Inhelder added that it is not until the child reaches adolescence that he "is capable of forming hypotheses and of deducing possible consequences from them."[2]

Those responsible for curriculum construction need to be aware of the limitations imposed on curriculum attainment through children not having reached the appropriate stage. For example, Flavell has asked:

> Do Piaget's findings imply, for example, that initial teaching of scientific method and content should be pegged around early adolescence, when the formal

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[1]Inhelder, <u>Monographs of the Society for Research in Child Development. . .</u>, p. 24-25.

[2]<u>Ibid</u>., p. 27.

> operations which make possible genuine scientific thought are said to be developed?[1]

A small number of researches concerning some of the scientific processes will be reviewed here as illustrations of limitations imposed on curriculum development by lack of pupil readiness. A more detailed review is outside the scope of this present study, but appears to be an area open for complete investigation. The processes selected here are those listed as behavioral objectives by the AAAS Commission on Science Education for their curriculum activities. While the AAAS materials are intended for elementary school use in U.S.A., the potential of the process approach as the basis of an introductory course for Australian science[2] warrants a consideration of these processes here. The processes listed by AAAS were as follows:

Observation
Classification
Recognition and use of space/time relations
Recognition and use of numbers and number relations
Measurement
Communication
Inference
Prediction[3]

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[1]Flavell, p. 365.

[2]Since the study of science in Australia typically is commenced at grade seven level.

[3]Commission on Science Education, American Association for the Advancement of Science, "Science--A Process Approach: Teachers Guide," p. 2 (Mimeographed).

Research from psychology which appears relevant for these science teaching objectives follows.

Observation

Russell used the term "percepts" as synonymous for observation. The child's percepts, according to Russell "are what he knows of objects, qualities, or relationships as a result of his sensory experiences." In this way, observations provide what Russell suggested as the "materials for thinking."[1] Accuracy and objectivity of observations therefore are most important if thinking is to be based on accurate premises. However, there is evidence that the child's sensory experiences may not be accurate in terms of the adult's experiences. Gibson and Olum wrote:

> Very little is known about the perceptual world of the child. Unfortunately, we cannot look at the world through the eyes of the child, and we do not really know what the child sees and in what respect it differs from what we see.[2]

Quantitative observations.--The ability of young children to make accurate quantitative observations is limited by what Piaget has termed the "absence of conservation." For example, a typical child of age six observing a fixed volume

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[1]David H. Russell, "The Development of Thinking Processes," Review of Educational Research, XXIII (April, 1953), 137-38.

[2]Eleanor J. Gibson and Vivian Olum, "Experimental Methods of Studying Perception in Children," Handbook of Research Methods in Child Development, Paul H. Mussen (ed.) (New York: John Wiley and Sons, Inc., 1960), p. 322.

of a liquid poured from one container to another of a different shape will report a change of volume, based upon the change of height or width of the liquid. Typically, the volume-constancy of the liquid ("necessary conservation") stage may not be developed in children until age twelve.[1] The seven to nine year old child denies "conservation of weight" when a plasticine mass has its shape changed ("it's longer," or "it's thinner" justifies this viewpoint). Soon after this age, conservation of weight becomes a necessary phenomenon.[2]

Piaget found that Geneva adolescents typically are unable to appreciate fully the concept of density until age thirteen to fifteen years old. This has been attributed to an inability to relate the two factors (mass and volume) simultaneously. This implies that younger children cannot fully understand the rationale of keeping all variables constant except the independent variable in a scientific experiment.[3]

Implications for science curriculum development

Findings such as these suggest that quantitative concepts involving a single dimension may not become

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[1] Flavell, p. 299.

[2] J. Mc. V. Hunt, Intelligence and Experience (New York: The Ronald Press, 1961), p. 288.

[3] Ibid., p. 237.

meaningful to the average Australian child until about third grade; when two dimensions are involved, the concept may not become meaningful to the average Australian child until grade seven.

Qualitative observations.--Of the qualitative type of observation, young children have difficulty with what adults regard as accurate observation of a liquid surface in a tilted container. On the average, children younger than nine years of age fail to "see" that "the water stays still and the jar moves." Experimental evidence proves ineffective in establishing for the child the concept of horizontality of the liquid surface.[1]

The "Montessori Method" of teaching involved provision of special teaching for facilitating the development of observation and providing discrimination practice for young children. It aimed to "educate the senses" by having children observe and place in order materials and objects with graded properties. For example, children learned to order various sized weights, pieces of wood of various thicknesses or heights, different textures of sandpaper, and colored discs. Discriminations of increasing difficulty

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[1] J. Mc. V. Hunt, p. 334

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were gradually introduced. Montessori believed that education of the senses in the formative years was very important.[1]

Accuracy of the child's observations is known to be affected by fantasy[2] and animism.[3] The objectivity of observations by young children has also been found unreliable in that their perceptions are influenced by their need states. For example, Bruner and Goodman showed that poorer children tend to overestimate coin size more than richer children.[4] Sanford showed that food abstinence causes images of food to be more readily evoked.[5]

Implications for science curriculum development

Whereas a wide range of sensory experiences may develop powers of discrimination, observations of young pupils should not be evaluated against adult criteria.

Classification

The second of the processes listed by AAAS was classification. Of the child's ability to classify, Donaldson

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[1]Marie Montessori, Montessori Method, trans. A. S. George (New York: Stokes, 1912), pp. 173-184.

[2]Russell, Children's Thinking, p. 158.

[3]Ibid., pp. 216-19.

[4]J. S. Bruner and C. C. Goodman, "Value and Need as Organizing Factors in Perception," Journal of Abnormal Social Psychology, XLII (1947), pp. 33-44.

[5]R. N. Sanford, "The Effects of Abstinence from Food Upon Imaginal Proccess: A Preliminary Experiment," The Journal of Psychology, II (April, 1936), 129-36.

wrote that "in the absence of inquiry, the child's ability to handle language may grossly mislead us as to his ability to handle classificatory systems."[1] Lovell stated that the ability of a child from four to ten years of age "to classify seems to depend on the capacity to compare two judgments simultaneously."[2] The difficulty of classifying objects by density (in which two quantities must be interrelated for each object) was discussed earlier in connection with the process of observation.

Goldstein and Scheerer developed a sorting test involving both everyday objects and geometrical shapes. The nature of their study was interesting in that it dealt with three aspects of the problem of classification, as follows:

> The first deals with the formation of a class; the experimenter designating a single object, asks, "Which of all the remaining objects belong with it?" The second is concerned with discovering the criterion that determined a class that already exists, "Why do all these belong together?" The third deals with the possibility of shifting from one criterion to another.[3]

Bruner, Goodman and Austin compared the ability of children to classify material based on the criteria of

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[1]M. Donaldson, reported in Flavell, p. 306.

[2]K. Lovell, <u>The Growth of Basic Mathematical and Scientific Concepts in Children</u> (New York: Philosophical Library, 1961), p. 16.

[3]K. Goldstein and M. Scheerer, "Abstract and Concrete Behavior and Experimental Study with Special Tests," <u>Psychological Monographs</u>, LIII (1941), pp. 1-151.

geometrical shape, color and the kind of frame utilized, with the ability to classify thematic materials, in which sex, dress and mood (smiling or frowning) were the categories.[1] Bruner and his co-workers found that the abstract materials were more easily classified.[2,3] However, it may have been that the criterion interval for classifying the abstract materials was grosser, and therefore this factor rather than the abstract or thematic nature of the materials, may have made the classification relatively easier.

Piaget and Inhelder studied the classification behavior of more than 2000 children aged three to eleven years old, giving them tests requiring the classification of objects and pictures.[4]

> In our experiment with children around six years of age, it has often happened that children who already understand that all ducks are birds will yet maintain that you could take all the birds away and still there would be ducks.[5]

Thompson utilized three different tests to study the ability of ten children from each level of grades one through six to classify objects. In each test, the children

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[1]Jerome S. Bruner, Jacqueline J. Goodman and George A. Austin, A Study of Thinking (New York: John Wiley & Sons, Inc., 1957), p. 106.

[2]*Ibid.*, p. 111.

[3]This volume provides a broad consideration of the nature and techniques of, and motives for classifying.

[4]Inhelder, Monographs of the Society for Research in Child Development. . ., pp. 31-32.

[5]*Ibid.*, p. 33.

were first asked to perform the actual classification and then to explain their groupings. In the Weigl Color-Form Test, twelve cardboard figures can be classified on the criteria of color and form. Younger children, (grades 1-3) tended to use only one criterion, usually color, to form their groups, whereas older children (grades 4-6) tended to form both categories. The BRL Test comprises thirty-four objects which vary in size, color, form, use, material, etc. The main techniques available for categorization are by name (e.g., tools, toys), use (e.g., to set table, smoke), association with a concrete situation (e.g., a game to play), and by common attributes (e.g., rubber of ball and eraser). Thompson found that younger children tended to bring together objects associated in a story heard by them. In the third test, the Vigotsky Tests of Concept Formation, twenty-two wooden blocks were provided. The older children tried more hypotheses, and saw more possible ways of sorting them, than did younger children. Younger children were generally unable to shift from one method of classification, due to the difficulty they experienced in attending to two aspects of the situation at the same time.[1]

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[1]J. Thompson, "The Ability of Children of Different Grade Levels to Generalize on Sorting Tests," Journal of Psychology, XI (January, 1941), 119-126.

Implications for science curriculum development

The ability of children to classify increases with age. The degree of sophistication of child-invented classifications should not be evaluated in terms of adult standards. Nor should young children be expected to understand adult devised taxonomies, such as may be needed in formal studies of biology or geology.

Recognition and Use of Space/Time Relations

Gesell and Ilg established that although there are wide individual differences between children, there is also a "relatively uniform age sequence" in developing concepts of time and space.[1] Summaries of researches by Flickinger and Rehage concerning time concepts have indicated that "past versus present" concept is understood at about age eight, "a full understanding of our system of reckoning time at about eleven years, understanding of time lines at about thirteen years, and something approaching maturity of understanding time words and dates at about sixteen years of age."[2]

Friedman reported that children develop concepts of time largely independent of formal school instruction.

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[1] Arnold Gesell and Frances Ilg, The Child From Five to Ten (New York: Harper and Brothers, 1946), reported in Hunt, p. 130.

[2] Hunt, pp. 133-34.

Using tests of time vocabulary (e.g., present, recent, century, eternal, B.C.) and of ability to arrange events in chronological order (e.g., parent's birthdate, times of Lincoln and Columbus, World War I, Bible, pupil's lifetime), Friedman showed understanding increased grade by grade, but that lack of understanding was still evident at grade six level.[1]

Concerning space concepts, Lovell reported:

> It is not until 9 years that horizontal and vertical are well understood and cease to be found by trial and error.
>
> There is not the slightest doubt that Piaget and Inhelder have provided many excellent experiments demonstrating that children arrive slowly at the spatial concepts which appear so matter of fact to educated adults.[2]

Implications for science curriculum development

The level of development of space and time concepts in average elementary school children is such that concepts beyond their environment and the present day may not be meaningful to them. Such concepts may profitably be delayed until secondary school.

Recognition and Use of Numbers and Number Relations

The danger of accepting the ability of elementary school pupils to verbalize as evidence of comprehension

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[1]K. C. Friedman, "Time Concepts of Elementary School Children," Elementary School Journal, XLIV (February, 1944), 337-342.

[2]Lovell, p. 99.

of number concepts has been sounded by Peel:

> . . . a child may learn to count and even to add simple numbers as a skill or habit, the understanding of which implies a stage of thinking not yet reached.[1]

Wohlwill posited three developmental stages for children in acquiring an understanding of number. These stages were:

> First, they respond to it on a perceptual basis so that if the arrangement of the elements is changed the number of elements may change. Second, numbers are responded to conceptually. In passing from the first to the second phase mastery of the correct verbal terms for the groups plays a prominent role. Third, the relationships among individual numbers are conceptualized.[2]

From one of the most detailed studies made on the development of children's number concepts, Brownell described the typical developmental pattern of children in dealing with concrete numbers. He wrote:

> Assume that he had arrived at the point in development which is represented by the habitual use of partial counting. He is likely to stop some time at this level while he develops a satisfactory degree of efficiency in the use of this method. He then begins to experiment with a new, more mature method--grouping. At first he probably becomes confused, makes mistakes, and requires an undue amount of time when he uses this method. He persists and finally becomes sufficiently skilled in its use to substitute it for the less effective, less mature method of partial counting. He spends some time perfecting his ability to use grouping and then begins

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[1]E. A. Peel, The Pupil's Thinking (London: Oldbourne Book Co., Ltd., 1960), p. 64.

[2]J. F. Wohlwill, "A Study of the Developments of the Number Concept by Scalogram Analysis," Journal of Genetic Psychology, XCVII (1960), pp. 345-377, cited by Lovell, p. 53.

> to experiment with the next more mature method. Thus his progress toward mature methods continues--a step forward towards a more mature method, difficulty in the use of the new method, practice with it, attainment of skill in its use, experimentation with a still more mature method, difficulty in using it, and so on.[1]

Brotherton and his co-workers found that the communicative ability of children with respect to number concepts increased in precision until grade seven, but not beyond that point. Children above grade seven had developed a "reasonably good communicative ability."[2] Pressey and Moore found from an investigation of the growth of mathematical vocabulary that there was an "inadequate mastery of fundamental terminology. . . [by] persons of all ages and social strata," and this inadequacy hindered their subsequent understanding of mathematics.[3] Martin has summarized the results of many studies of number concept formations, and has outlined the developmental stages for children up to eight years old,[4] and further treatment here would be redundant.

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[1]William A. Brownell, The Development of Children's Number Ideas in the Primary Grades: Supplementary Educational Monograph (Chicago: The University of Chicago, 1928), pp. 111-12.

[2]D.A. Brotherton et al., "Indeterminate Number Concepts. . .," cited by Russell, Review of Educational Research, XXIII, p. 129.

[3]Luella C. Pressey and W. S. Moore, "The Growth of Mathematical Vocabulary from the Third Grade Through High School," The School Review, XL (June, 1932), 449-54.

[4]Martin, cited by Russell, Children's Thinking, pp. 126-29.

Implications for science curriculum development

The development of number concepts in young children is slow and sequential. The growth of a number vocabulary sets limits on ultimate development. Numerous-concrete number experiences (e.g., such as the Cuisenaire method) may facilitate number mastery at elementary school level.

Measurement

Lovell reported research appropriate to the measurement process. He cited evidence that "calculations involving volume are not understood until about 12 years of age."[1] Lovell quoted the experiments of Lunzer which bore out some of Piaget's proposals of stages in development of the volume concept. For example, Lunzer showed that the child aged eleven to twelve years discovered

> (a) the method of calculating volume as a function of length, breadth, and height;. . .
>
> (b) The conservation of displacement volume; that is, the amount of air or water displaced by an object.[2]

Lovell also pointed to evidence that

> The repeated application of a given fixed length to measure a length (iteration) certainly involves thinking skills which develop with age. Moreover it is easier for a child to measure a length which is shorter than the ruler, than one which is longer.[3]

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[1]Lovell, p. 120.

[2]*Ibid.*, p. 122.

[3]*Ibid.*, p. 112.

Experiments by Inhelder and Piaget showed that even at age eight, only eighty-five per cent of children who were tested maintained with conviction that the dimensions of two equal-length rods did not change in spite of the displacement when one rod is moved so that the rods are out of line. For children up to age seven, the insertion of a third object between two fixed objects appears to change the distance between two fixed objects.[1]

There is experimental evidence that the learning of measurements involving weights and volumes in a meaningful and permanent manner cannot be attained until the child has proceeded well into the elementary school. Smedslund in Norway has experimented extensively on the effects of providing special teaching to accelerate the acquisition of the concepts of conservation of substance and weight.[2] He found that empirical observations and manipulations of the balls of plasticine did not appear to accelerate the attainment of conservation.[3]

Smedslund then used a "cheating procedure" with subjects who had developed the concept of conservation in weight in two laboratory sessions. The experimenter

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[1]Inhelder, Monographs of the Society for Research in Child Development. . ., p. 30.

[2]Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children: I: Introduction," The Scandinavian Journal of Psychology, II, Number 1 (1961) 11-20.

[3] Jan Smedslund, "The Acquisition of Conservation of

inconspicuously removed some plasticine while changing the shape of one of two previously counterposed masses of plasticine. Smedslund found that "none of the subjects who had acquired the principle during the experiment showed any resistance to extinction." This contrasted with subjects in a control group who had developed their principle of conservation prior to the experiment, indicating that the laboratory-trained subjects

> had learned only a relatively arbitrary empirical law. They were not very shocked or surprised when the law was falsified, and rapidly modified their predictions and explanations."

Accurate measurement of time by children appeared dependent upon the type of instrument they used, according to research reported by Meyer and Piaget. They found that when children measured two identical lengths of time with two different instruments (e.g., stopwatch, sandglass), the children perceived the intervals as different. They stated that children think that they can accomplish more during a period measured by a faster moving instrument.[2]

Substance and Weight in Children: II: External Reinforcement. . .," The Scandinavian Journal of Psychology, II, Number 2 (1961), 71-84.

[1]Jan Smedslund, "The Acquisition of Conservation of Substance and Weight in Children: III: Extinction of Conservation. . .," The Scandinavian Journal of Psychology, II, Number 2 (1961), 85-87.

[2]E. Meyer and J. Piaget, "Some of the Child's Conceptions of Time and Speed," Psychological Bulletin, XXXIV (November, 1937), 702-03.

Implications for science curriculum development

Concepts needed by children of lower elementary school age for measurement are largely tentative and uncertain, and not generally accelerated by formal teaching. As with time/space concepts, it may be advisable to delay formal teaching of measurement until secondary level.

Communication

The research literature already reported has suggested that verbalization as one form of communication is not a valid index of comprehension. There are two aspects to this low validity:

1. Ability to verbalize does not necessarily imply comprehension.

Thus Peel wrote:

> Furthermore, language makes this habit-learning easier, since teacher and taught can communicate more easily and hence mere habit of word and number are more easily acquired. We may see relics of this discrepancy between understanding and learning, for example, in what is sometimes called 'verbal fixation.'[1]

2. Inability to verbalize does not necessarily imply absence of comprehension.

Even in the infant, there is evidence that some concepts are well understood before verbalization occurs.[2] Oakes, speaking of elementary school age children, stressed "the

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[1]Peel, p. 64.

[2]Russell, Children's Thinking. pp. 124-25.

importance of recognizing that at times experience and understanding outrun the growth of the child's knowledge of words."[1]

The development of the ability to communicate by means of language has been extensively researched. Many studies have sought to determine the size of the vocabulary of children at various ages and stages. For example, studies of vocabulary development by Smith indicated that the six-year old averaged 2562 words. Mental age was the most significant factor in producing increased vocabulary, with higher social class also having larger vocabularies.[2]

The importance of language as a tool of thinking, as well as a method of communication, has received some attention. Lorimer considered "that the inadequacy of children's thinking is due in large measure to lack of a well-developed system of symbols, especially language."[3]

Implications for science curriculum development

Ability to verbalize may not indicate comprehension, nor may inability to verbalize imply lack of comprehension. It is important that indices of comprehension other than

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[1]Mervin E. Oakes, Children's Explanations of Natural Phenomena (New York: Bureau of Publications, Teachers College, Columbia University, 1947), p. 85.

[2]Madorah Elizabeth Smith, "An Investigation of the Development of the Sentence and Extent of Vocabulary in Young Children," University of Iowa Studies: Studies in Child Welfare, III (May, 1962), 1-92.

[2]F. Lorimer, cited by Oakes, p. 114.

verbalization should be utilized by science teachers. The development of a well-understood science vocabulary may facilitate thinking about scientific topics.

Inference

Dewey defined inference as the

> Process of arriving at an idea of what is absent on the basis of what is at hand. . . .
>
> Every inference, just because it goes beyond ascertained and known facts, which are either by observation or by recollection of prior knowledge, involves a jump from the known into the unknown.[1]

Making an inference, therefore, has problem solving properties. This is indicated by Duncker's definition:

> A problem arises when a living creature has a goal, but does not know how this goal is to be reached[2]

Duncker described problems through which he studied the reaction of subjects to find "how does the solution arise from the problem situation? In what ways is the solution of a problem attained?" Utilizing a think alcud technique, Duncker studied the genesis and development of solutions to several standard problems. In these studies Duncker was concerned by the processes engaged in by the subjects. For example, one problem Duncker posed was this:

> Given a human being with an inoperable tumor, and rays which destroy organic tissue at sufficient intensity,

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[1]Dewey, pp. 95-96.

[2]Karl Duncker, "On Problem-Solving," Psychological Monographs, LVIII, Number 5 (1945), 1.

> by what procedure can one free him of the tumor by these rays and at the same time avoid destroying the healthy tissue which surrounds it?[1]

Similar techniques may have promise in further research for elucidating the inference process in children.

The inability of early secondary school level pupils to make inferences was suggested by researches of Kyle. Reporting Kyle's research, Peel stated that

> In science, the young secondary school pupil describes his results rather than explains them--nor does he find it easy to generalise. This was well shown by Kyle in his study of the extent to which 14-year old pupils could induce Archimedes' Principle in a guided experiment, but none could connect up the results with the idea of up-thrust by the water displaced.[2]

Bedell provided further evidence of the difficulty experienced by children in drawing inferences. He constructed thirty paragraphs each based upon a scientific principle with corresponding test items. He found that the lowest 25 per cent of children with respect to intelligence were unable to perform satifactorily on the inference items. Bedell also concluded that children who can perform satisfactorily on the achievement tests based on recall are not always able to draw inferences since these require different abilities.[3]

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[1]Dunker, Psychological Monographs, LVIII, 1.

[2]Peel, p. 108.

[3]R. C. Bedell, "The Relationship of the Ability to Recall and the Ability to Infer in Special Situations," Science Education, XVIII (October, 1934), 158-62.

One phase of Suchman's "Inquiry Training" project has been concerned with developing the child's ability to infer. Suchman believes that specific training can be used to improve this ability.[1] Griffiths found that in the absence of training, children make use of imagination as a method of problem solving. A special technique was developed in a comparative study of children in London and Brisbane (Australia) by Griffiths. She utilized structured observations of the free behavior of children in order to tap their fantasies and day-dreams. Griffiths concluded that:

> Imagination is, in fact, the child's method of not so much avoiding the problems presented by environment, but of overcoming those difficulties in a piecemeal and indirect fashion, returning again and again in imagination to the problem, and gradually developing a socialized attitude which finally finds expression at the level of overt action and adapted behaviour.[2]

Implications for science curriculum development

The trend towards discovery learning and open-ended laboratory exercises may increasingly require pupils to make inferences. Especially for lower-intelligence elementary school children, this process may prove difficult. Specific training exercises should be devised and incorporated into school curricula to improve the process of making inferences.

1Suchman, "Inquiry Training. . ., (Mimeographed), p. 6.

2Griffiths, p. 353.

Prediction

According to Dewey's definition, there is a degree of overlap between this process and that described in the preceding section (Inference). Evidence from child psychology suggests that children predict outcomes which conform to their own beliefs, even when they are confronted with conflicting evidence. In one such experiment, Smedslund showed inability of forty, five to seven year old children to predict the behavior of other children. Prediction was colored by their own preferences, although they had previously been shown the preference pattern of the other children whose behavior they were to predict.[1] Smedslund concluded:

> When the subjects are faced with a new situation, the earlier ones cease to influence their behavior, and when they think of the earlier situations the present one recedes into the background. These shiftings and successive centerings were clearly reflected in the unstable judgments of our subjects and in their high degree of suggestibility.[2]

Two new instruments for evaluating the ability to predict have recently become available. Suchman developed an instrument for evaluation of the ability of his subjects in the "Inquiry Training" project to predict. Known as the "PCE Test," it is concerned with measuring the behavioral

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[1]Jan Smedslund, "Transitivity of Preference Patterns as Seen by Pre-School Children," The Scandinavian Journal of Psychology, I, Number 2 (1960), 49-54.

[2]*Ibid.*, p. 54.

elements "predict, control, explain."[1] Lesser's instrument was designed for his research with gifted third-grade science pupils.[2] The availability of these instruments will facilitate future studies concerned with the area of prediction.

Implications for science curriculum development

As with other processes discussed earlier, scientific objectivity may be less important to the child than confirmation of previously held beliefs. Evaluation in terms of adult expectation may therefore prove inappropriate.

Summary of Findings from Psychology for Science Curriculum Development

Gagné has stated

> . . . that one of the most important questions for curriculum designers is the question of orderly sequencing of ideas. If the sequence is right, and the learner is informed about the goals of his learning, the motivation will be built in.[3]

Since Hess has stressed that "psychological sequence is an important dimension of curricular planning,"[4] a knowledge of the findings of psychology concerning the

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[1] "Research Studies in Elementary Science, 1961-1963," p. 12.

[2] Ibid.

[3] Robert M. Gagné, "A Psychologist's Counsel on Curriculum Design," Journal of Research in Science Teaching, I, Issue 1 (1963), 27.

[4] Robert D. Hess, "The Latent Resources of the Child's Mind," Journal of Research in Science Teaching, I, Issue 1 (1963), 22.

developmental stages of children becomes very important for science curriculum development. Since psychology is also concerned with a study of behavioral changes, its findings have further significance for curriculum development. In this respect, Gagné defined the purpose of the curriculum thus:

> Fundamentally, the purpose of a curriculum is to organize the educational situation in such a way that students, who are at one stage, or age, incapable of exhibiting certain kinds of behavior relevant to science, become capable of exhibiting certain kinds of behavior.[1]

An important conclusion for the development of a science curriculum model from research on the series of processes discussed is that in almost every case, there is evidence of a developmental sequence leading eventually to the acquisition of the ability concerned. The age of acquisition appears to be determined by maturation level rather than by formal teaching. This indicates that there are limitations placed by the maturation level upon the skills which the child can attain. There are potentially serious implications for over-early introduction of skills into science curricula.

Recommendations

4.13. A thorough cooperative survey of the findings of psychology relevant to science curriculum construction should be sponsored by the proposed ASEF. This would

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[1]Gagné, Journal of Research in Science Teaching, I, p. 27.

facilitate the identification of appropriate science teaching objectives in terms of maturational levels of the pupils.

4.14. Science curricula should be developed for Australian elementary schools utilizing the results of the proposed survey of psychology to assist in developing an appropriate process approach.

CHAPTER V

THE CONTEMPORARY SCENE IN SECONDARY SCHOOL SCIENCE CURRICULA

The purpose of this chapter was to review the current trends in school science curricula in Australia and in the U.S.A. In particular, selected U.S.A. curricula sponsored by the NSF were examined and aspects of these curricula which appear to have relevance for an Australian science curriculum model were identified.

Existing State of Science Curricula in Australia

Curriculum development in Australia is largely the concern of the Department of Education in each of the six states. While there is some variation from state to state, there are also many similarities in the existing curriculum procedures throughout Australia. In the discussion that follows, the procedures utilized in Victoria are described.

Elementary School Science in Australia

Science as observed in the schools of the United States is not part of the elementary school curriculum of Victoria. The subject known as Nature Study is taught in grades K through six. The content of this course was spelled out in an Education Department publication in some detail.[1] However, objectives were not expressed behaviorally. The nature of the course was spelled out in these terms:

> It is rather a spirit, a habit, or an attitude of mind that is caught. As a school subject, it is an opportunity for a teacher to intensify a child's awareness and appreciation of the natural whole of which he is a part.
>
> . . . .
>
> Thus looking, seeing, interpreting, understanding, and appreciation are the stepping-stones in nature-study that is alive. Having the development of these habits as its aims, nature-study calls for a teacher imbued with a spirit that will infect his pupils.[2]

There is evidence that these objectives are not being fulfilled. The following critical statement appeared in the official Departmental teacher's guide:

> In too many schools nature-study is the antithesis of the living study it should be, and various reasons may be suggested for this. Some teachers claim that they have not the necessary background to cope with the subject.
>
> . . . .
>
> Is it any wonder that nature-study is dead, when it is taught as something completely isolated fron nature?
>
> Too many teachers attempt to teach nature-study in the same way as they teach arithmetic, grammar, and other subjects, that is, by formal class lessons. At a set time each week (dictated by the timetable) a lesson is given on a certain topic (dictated by the work program). Little or no preparation is made by the pupils, and the teacher proceeds along the lines of some general teaching method.[3]

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[1] Victoria, Department of Education, Circular of Information O (New Series: Nature Study (Observational Work) (Melbourne: W. M. Houston, Government Printer, 1958) p. 10.

[2] Ibid.

[3] Ibid., p. 9.

A parallel situation in the U.S.A. over thirty years ago was noted by Powers and Craig in the NSSE's Thirty-First Yearbook. They foresaw that the teaching of nature study was doomed. Teachers were ill-prepared for teaching nature study. As Powers wrote on that occasion: "A program which is inconsistent with the abilities of teachers in service to develop is also doomed to failure."[1] Craig commented on the role expected of the nature study teacher:

> The teacher was expected to be an expert naturalist and to identify and make interesting object lessons of what came to hand. . . . The teacher who was unprepared to teach on the incidental basis blocked the possibilities of any incident arising.[2]

Concomitantly with the present day situation in Victoria of inadequately-trained teachers and poor teaching of nature study, there have been indications of support for the introduction of science teaching into elementary schools.[3] AAAS curriculum materials are being tried during 1964 at a private school (Essendon Grammar School) in Victoria.[4] In Tasmania, primary school science is receiving current consideration.[5] Under the circumstances, interest in American

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[1]S. Ralph Powers, in A Program for Teaching Science, p. 44.

[2]Gerald C. Graig, in A Program for Teaching Science, p. 157.

[3]M.V. Cove, The Place of Science in Primary School Curriculum (Melbourne: Victorian Institute of Educational Research, 1958).

[4]Letter from M. L. Turner, April 15, 1964.

[5]Australian Science Teacher's Association, Conasta XII: Science Education in Australia Today, p. I.

science teaching developments at elementary school level are receiving close appraisal by some Australian educators.

Recommendations

5.01. The ASEF should institute a series of experimental science programs for the purpose of determining optimal programs of science education for Australian elementary schools.

5.02. Australian teachers who so desire should be granted permission to replace nature study courses by elementary science courses.

Secondary School Science in Australia

In general, when Australian pupils enter secondary school at an average age of about 12.5 years, they have not previously studied science. On entry to a secondary school, all students study courses in general science which include content drawn from the areas of chemistry, physics, biology, geology and astronomy.[1] These courses are continued throughout the first two years of secondary school.[2]

Since education is compulsory in all Australian states until the age of fifteen years, nearly all Australian children receive at least a two-year introductory general science course which includes content from the above five areas. The vast majority of pupils continue in high school

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[1]Australian Science Teachers' Association, Conasta XII: Science Education in Australia Today, Pp. 24.

[2]Note: The duration of the school year in Australia in governmental schools is approximately forty-two weeks, namely, from February 1 to December 15 each year, with two two-week

beyond the second year,[1] and nearly all of these continue with a third year of general science. The most populous state, New South Wales, in 1963 instituted a four-year, compulsory integrated science course for all students.[2]

In general science curricula are, in general, the products of committees appointed by the administrative officers of the state Departments of Education. In Victoria, appointments to curriculum committees have been made by Science Inspectors. Practicing teachers usually constitute the majority of these committees, and science inspectors, lecturers, teachers' college lecturers and sometimes university lecturers are also represented.[3] That these officers are rarely specially trained for the task of curriculum construction has been one of several matters causing concern to Australian educational leaders. Indicative of this concern, a specially selected committee of the Australian College of Education, charged with the task of

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vacation periods, (c.f., "School and University Term Dates-1963," Education News, VIII (December, 1962), 20.)

[1]In Victoria the holding power for this third year of secondary education rose from 60 per cent in 1953 to 75 per cent in 1958. (Victoria, Department of Education, Report of the Committee. . ., p. 171).

[2]Australian Science Teachers' Association, Conasta XII: Science Education in Australia Today, p. 14.

[3]Ibid., p. 16.

examining selected problems of secondary education, submitted in its report:

> Curriculum construction.
>
> A great deal of discussion occurred indicating dissatisfaction with curricula and syllabuses. Examples of alleged defects were said to result from:-
>
> 1. The influence of strong personalities with "hobbies" on syllabus committees.
>
> 2. The repeated use of books whose success to achieve the aim of the syllabus or curriculum has not been proved.
>
> 3. Lack of enquiry as to the success or failure of a section or sections of a syllabus.
>
> 4. Syllabuses which have apparently no aims other than preparing pupils for a future course of study.
>
> We assume the curriculum to be "all the experiences which are utilized by the school to attain the aims of education." We think that the construction of a curriculum, and of syllabuses connected with it, is a task which needs special training, and that this has not received sufficient attention in Victoria.[1]

With this current reappraisal of the process of curriculum construction in Australia, a study of the stages of curriculum innovation in the U.S.A. and of some of the successful elements of the process may have significance for future developments in Australia.

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[1]Proposed Report to the Victorian Chapter of the Australian College of Education by Sub-Committee D, Appointed to Study "Selected Problems in Secondary Education," Chairman, A. Sutherland, 1961. (Typewritten copy in the files of the writer.)

Stages in Science Curriculum Innovation

Studies in the U.S.A. have shown that educational innovation results from what may be characterized as a seven stage process:

1. emergence of a need;
2. recognition of a need;
3. definition of the need;
4. invention of ways and means of meeting the need;
5. the introduction of the invention into one or more communities;
6. the improvement of the invention in actual practice;
7. the diffusion of the invention throughout the schools of a state.[1]

These stages of innovation are evident in the widespread science curriculum innovation that has occurred in recent years.

Stage 1. Emergence of a need

In Chapter III, the emergence of the need for the improvement of the science education program in U.S.A. was shown to be due at least in part to the non-involvement of the professional scientist in the task of constructing science curricula. By the non-involvement of scientists in construction of Australian science curricula, a similar disparity has developed there.

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[1]Paul R. Mort, Principles of School Administration (New York: McGraw-Hill Book Company, 1946), p. 211.

Specifically, a need for curriculum revision has been said to emerge when the rapid growth and application of scientific knowledge affects living conditions, or when the purposes of education change.[1] In both the U.S.A. and Australia, there has been a changing conception of the nature of the curriculum. Whereas formerly the curriculum was often a listing of "a body of knowledge to be memorized,' an international conference sponsored by UNESCO agreed that curricula now incorporated the totality of "all the activities, experiences, materials, methods of teaching, and other means which are employed by the teacher or taken into account by him, to achieve the aims of education."[2] This changed conception of the curriculum also implies the emergence of a need for new curricula.

Since the history of non-involvement of scientists in curriculum construction and changing conception of curricula is common in Australia and the U.S.A., the need for curriculum innovation in Australia today is just as great as it was in the U.S.A. prior to the recent wave of innovations.

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[1]UNESCO, International Advisory Committee on the School Curriculum, Curriculum Revision and Research (Paris: UNESCO, 1958), p. 5.

[2]Ibid.

Stage 2. Recognition of a need

The need for improvement of school science programs was recognized by the 1950's.[1] In fact, the report of the AAAS Cooperative Committee on Science Teaching in 1946 included suggestions for improving science curricula.[2] However it was not until October 1957 that the urgency of the need to improve science education was fully recognized. It was then underscored by the Russian technological achievements. Fitzpatrick emphasized this by his statement:

> Foreign technological achievements of 1957 and subsequent years jarred the public out of its slumbering complacency. Today we do not hear so much about keeping ahead of our world competitors, but we hear a lot more about catching up with them.[3]

More specifically, the launching of Sputnik I has been variously described, thus:

> Soutnik was the initiating shock for action in secondary schools. . . [which] threatened the self-image of Americans. . . [as not being" the first or best in rocketry;[4]

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[1]c.f., Harry C. Kelly, "The National Science Foundation's Programs in Education in the Sciences," The Educational Record, XXXVIII (April, 1957), 91.

[2]AAAS Cooperative Committee on Science Teaching, "The Preparation of High School Science and Mathematics Teachers," School Science and Mathematics, XLVI (February, 1946), 107-18.

[3]Frederick L. Fitzpatrick, "Editor's Preface," Policies for Science Education (New York: Bureau of Publications, Teachers College, Columbia University, 1960), pp. vii-viii.

[4]Roy Edelfelt, "Innovations in Secondary Education and their Implications for Teacher Education," Paper read before

Sputnik, in a sense, was the catalyst;[1]

> When Sputnik launched the Space Age in 1957, everyone in the United States was ready to do something, even if it was wrong.[2]

> There is no doubt that the spectacular launching of Sputnik gave a tremendous impetus to the stiffening of standards and did much to make it respectable for university professors to concern themselves with the modernization of the curriculum in schools.[3]

> The beginnings of the current curriculum reform movement are commonly identified with the successful launching of the first Russian satellite in the fall of 1957. This spectacular event set off blasts of charges and countercharges regarding the effectiveness of our schools and accelerated curriculum revision, notable in mathematics and the physical sciences.[4]

> Sputnik was merely the enzyme for an organic change which had begun to take place in the secondary school. Just as mutations are increased by radiation pressure, so the rate of educational mutation was suddenly increased by an application of societal pressure.[5]

Perhaps because of its geographic remoteness, Australia displayed less concern about the significance of Sputnik than

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Curriculum Interest Group of the College of Education, Michigan State University, East Lansing, Michigan, May 21, 1964.

[1]Sidney S. Sufrin, Administering the National Defense Education Act (Syracuse, New York: Syracuse University Press, 1963), p. 2.

[2]Gatewood and Obourn, "Improving Science Education in the United States," p. 4.

[3]Frederick H. Jackson, "Key Role of Scientists in Curriculum Change," Science Education News, (December, 1961), p. 24.

[4]John Goodlad, School Curriculum Reform (New York: The Fund for the Advancement of Education, 1964), p. 9.

[5]Paul F. Brandwein, "The Strategy of the New Developments in Science Teaching," Paper delivered at the Fortieth Convention, Canadian Education Association, Quebec City, September 28, 1963, p. 2. (Mimeographed).

did the U.S.A., and the recognition of a need to improve science education curricula appears to have developed directly from concern about shortages of scientific manpower. For example in 1958-59, of the demand reported by the University of Melbourne for 661 engineers and scientists, only 149 graduates were available.[1]

Stage 3. Definition of the need

In providing a definition of the need, the perceived supremacy by Americans of the Russians' space achievement was generalized into terms of insufficient scientists of the high caliber required.[2] In turn, educators and the secondary schools were largely held responsible for their failure to develop updated science programs. The need was defined as increased quantity and quality of scientific training in order to provide the scientific manpower needed for the U.S.A. This was perceived as a task of science education. Evidencing this in their summary of general principles and recommendations, the Science Manpower Project stated:

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[1]University of Melbourne, University Appointments Board, Twenty-Sixth Annual Report: 1959 (Melbourne: University of Melbourne, 1959), pp. 11-14.

[2]The Science Manpower Project, Policies for Science Education, Frederick L. Fitzpatrick (ed.) (New York: Bureau of Publications, Teachers College, Columbia University, 1960), pp. xiii + 219.

> The key factor in the production of science manpower is an effective program of science education.[1]

As indicated in the consideration of the previous stage, the shortage of trained scientific manpower has also been a source of major concern in Australia, and has defined the need for improving school science programs.

<u>Stage 4. Invention of the ways and means of meeting the need</u>

The invention of the ways and means of meeting the need for improved school science programs in the U.S.A. became the task for both educators and scientists throughout the nation. The rapidity with which inventions took place following Sputnik I is exemplified by a survey of educational innovations in New York State. In 1957, immediately preceding Sputnik, there was a total of 228 new programs, of which 81 were new science programs. In 1958, immediately after the launching of Sputnik, the total number of new programs doubled, and the number of new science programs almost trebled (see Table 8).

The invention of the ways of means of meeting the need to improve science education has generally resulted from the initiative of schools, school districts and state education departments, universities, and from professional organizations. Several of these groups have developed curriculum projects,

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[1]The Science Manpower Project, <u>Policies for Science Education</u>, p. 217.

TABLE 8

EDUCATIONAL INNOVATION IN NEW YORK STATE
1953-1960[a]

Year	Total Number of New Programs	Total Number of Programs for "Highly Capable" Students	Number of New Science Programs
1953	79	40	32
1954	88	45	37
1955	116	60	52
1956	170	89	68
1957	228	125	81
LAUNCHING OF SPUTNIK I			
1958	508	319	225
1959	595	355	216
1960	658	393	176

[a]Adapted from: Henry M. Brickell, Commissioner's 1961 Catalog of Educational Change: A Survey of Changing Instructional Approaches and Descriptions of New Programs in the Public and Non-Public Elementary and Secondary Schools in New York State (Albany, New York: State Education Department, 1961), pp. 16-18.

some with the support of the National Science Foundation. The availability of financial support from the National Science Foundation for "first-rate scientists and teachers, working, together"[1] has resulted in the development of superior programs, with a consequent the nationwide impact of the projects invented by university faculty and professional organizations.

In Australia, there is no evidence of a similarly accelerated degree of educational innovation. This may be due in part to the absence of a perceived urgency in Australia for improving science education, but may also be due to the less adequate provision for support of science curriculum projects.

Stage 5. Introduction of the invention into one or more communities

In the U.S.A., the readiness of schools and communities to introduce innovations has been indicated by the degree of adoption of several of the NSF sponsored courses. In Australia, the need to promote an atmosphere favorable to the acceptance of innovation has not been found essential, since the centralized administrative structures can largely impose innovations on schools and communities. However, this has inevitably resulted in a community apathy which does not facilitate educational progress as evidenced by the comparative neglect of education in legislative enachments.

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[1]Staff, Division of Scientific Personnel and Education, National Science Foundation, "The Role of the National Science Foundation in Course Content Improvement in Secondary Schools," The School Review, LXX (Spring, 1962), 2.

Nor does this centralized policy provide the motivation for classroom teachers to innovate.

Implications from American practices which appear to have significance for the development of attitudes more favorable and less passive towards the introduction of innovation include:

Increased involvement of non-educators in determining the course of education through:

1. participation of the lay public in the formulation of broad educational objectives;

2. endeavors made to create a better-informed and more interested public through increased public relations efforts, such as

   (a) appointment of public relations officers;

   (b) use of mass media to publicize curriculum changes.

Motivation for teacher innovations may be facilitated by a change of emphases in the role of the school administrator. Cunningham and Radford suggested this as an optimal role:

> The main task of the administrator. . . is not to insist on, or even to encourage, the introduction of greater uniformity in the classroom. It is rather to ensure the professional development of the teacher so that he will have a clearer grasp of his goals and of the most efficient way of attaining them in relation to the potentialities of his pupils.[1]

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[1]K. S. Cunningham and W. C. Radford, Training the Administrator: A Study with Special Reference to Education (Hawthorn, Victoria: Australian Council for Educational Research, 1963), p. 45.

Stages 6 and 7

Mort's subsequent two stages of innovation (improvement and diffusion) are developed incidentally to later sections of this chapter in considering selected NSF supported curricula.[1]

Support of U.S.A. Science Curriculum Projects

Support for the initiation of new school programs in U.S.A. has been provided from both government agencies and private foundations. It has been estimated that, as of 1964, there is a combined expenditure by the Federal Government and private foundations on curriculum development alone at the pre-college level of about $25 million annually.[2]

Government Agencies

The National Science Foundation

The NSF was established in 1950 by a congressional act as an independent agency of the Federal Government. Its director and the twenty-four members of the National

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[1] c.f., Mort's seven stage process enunciated at the opening of this section.

[2] Jerrold R. Zacharias (Chairman) in "Chairman's Foreword," Innovation and Experiment in Education: A Progress Report of the Panel on Educational Research and Development to the U.S. Commissioner of Education, the Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology (Washington, D.C.: U.S. Government Printing Office, 1964), p. ix.

Science Board are appointed by the President on the advice of the U.S. Senate. Among the functions designated to it were those "to support basic research and education in the sciences."[1,2]

The National Science Foundation has been concerned with encouraging a diversity of innovations which may provide solutions to the problems faced by science education. Consequently, it launched a multi-pronged attack on the existing problems of the number and quality of science teachers and the quality of curricula and equipment. The policy of the NSF was well expressed by the following statement:

> No single method should be relied upon to achieve the desired results. No particular sequence of steps will ensure success. Concurrent action for the improved training of teachers, participation of scientists, selection of equipment, flexibility of programs, and adjustments of syllabi and examinations should provide marked progress in science education.[3]

Within the National Science Foundation, a Division of Scientific Personnel and Education was established to develop

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[1]Organization for Economic Co-operation and Development, Scientific Research, Country Reports on the Organization of Scientific Research: United States, prepared by Mary E. Corning, Office of International Science Activities, U.S. National Science Foundation (France: Directorate for Scientific Affairs, OECD, 1963), p. 16.

[2]National Science Foundation, Programs for Education in the Sciences (Washington, D.C.: U.S. Government Printing Office, 1961), p. 35.

[3]Office of Scientific Personnal, National Academy of Sciences, Guidelines for Development of Programs in Science Instruction: Report of a Study, Making Specific Reference

methods for improving science education. Set up within this Division, the Course Content Improvement Section was charged with providing support for the development of improved science course materials.[1]

The Course Content Improvement Program is to support the efforts of teams in "the development of courses and instructional materials that reflect contemporary scientific knowledge and points of view."[2] The nature of these teams was described thus:

> Initiated and led by outstanding scientists, course content improvement projects enable scholars who are masters of their fields to focus their knowledge, imagination, and time on the creation of new courses and materials. The work is carried out with the cooperation of highly competent teachers, educators, experts in communication arts, and other specialists.[3]

Thus, it was hoped to bridge the gap which had developed between the content of school science and the most recent findings of scientists. Criticism had been expressed in 1959 by the President's Science Advisory Committee with respect to secondary school science courses. The Committee stated:

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to the Teaching Function of the Laboratory in Secondary School Science Programs (Washington, D.C.: National Academy of Sciences, National Research Council, 1963), p. viii.

[1]Staff, Division of Scientific Personnel and Education, National Science Foundation, The School Review, LXX, 2.

[2]National Science Foundation, Division of Scientific Personnel and Education, Course Content Improvement Section, "Guidelines. . .," p. 1.

[3]Ibid.

> The content of secondary-level science courses . . . does not adequately recognize scholarly advances in these fields.[1]
>
> . . . .
>
> It has generally been found that course content has stood still over the last half century or has simply been patched up by adding sections on recent developments as postscripts. During this time, the science itself has advanced at an accelerating pace. . . .
>
> Corresponding criticisms may be made of other science courses. . . . All these courses require a revitalization of their content.[2]

In accepting responsibility for promoting a revitalization of course content, the Course Content Improvement Section outlined several basic principles for program proposals. Three broad categories of studies are supported through the Section. These categories are:

> (1) planning and coordination projects designed to develop basic guidelines for course improvement, to correlate independent developmental projects, and to facilitate wide dissemination of results of such efforts; (2) small-scale projects designed to explore novel approaches to the selection, organization and presentation of subject-matter; (3) comprehensive projects involving large groups of scientists, teachers and other experts in the development of complete model courses or course sequences, including all types of learning and teaching aids.[3]

Institutions from whom proposals are accepted include "colleges, universities, non-profit research institutes,

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[1] U. S., President's Science Advisory Committee, <u>Education for the Age of Science, The White House, Washington, D.C., May 14, 1959</u>, p. 31.

[2] <u>Ibid</u>.

[3] National Science Foundation, "Guidelines. . .," p. 2.

professional scientific organizations, or non-profit educational organizations enlisting the active participation of college and university scientists."[1]

The Course Content Improvement Section has sought to encourage a diversified approach to its objectives of improving course content. This is implicit in its apparently deliberate policy of refraining from spelling out in detail the precise nature of curriculum proposals it will support. Rather, the methods by which proposals are evaluated have been expressed as guidelines.[2]

The mechanism by which the Course Content Improvement Section operates is:

1. The NSF announces that funds are available and invites proposals;
2. Proposals are submitted by interested parties;
3. "Proposals received by the National Science Foundation are reviewed and evaluated by scientists, science teachers and representatives of the Foundation's staff."[3]
4. No official statements are issued in cases of rejection of proposals as to the reasons for rejection.

Of a total of 124 course content improvement proposals submitted for elementary, junior high and high school studies between 1959 and 1963 inclusively, requesting a total amount

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[1]National Science Foundation, "Guidelines. . .," p. 2.

[2]*Ibid.*, p. 5.

[3]*Ibid.*, p. 2.

of more than $51 million, seventy-eight grants were made, amounting to more than $24 million. The extent of adoption of some of the resultant curricula was indicated earlier (Table 2). In addition to the curriculum studies the Course Content Improvement Section administers college and university studies, and programs concerned with the development of supplementary teaching aids, educational films and television, and science teaching equipment.

Implications for Australian curriculum development

The desirability of establishing an Australian Science Education Foundation has already been indicated (see Recommendation 2.01). Likewise the need for enlisting the services of professional scientists to assist in the team development of Australian science curricula has been referred to. The ASEF should have the responsibility for supporting the initiation of curriculum projects in Australia.

U.S. Office of Education

A Federal "Department of Education" headed by a Commissioner, was first established by a Congressional bill in 1867. Since 1929, the agency has been referred to as the "Office of Education." The functions of this agency are the collection of statistics and facts to show the status and progress of education, dissemination of information of value in conducting school systems, administration of Federal grants-in-aid to education, cooperative research, special programs, and other functions.[1]

One of the branch units within the Office of Education which has special relevance for school science curriculum construction is the Cooperative Research Branch. Through cooperative contracts with universities and State agencies, new educational knowledge or applications are investigated and disseminated.[2] Projects which have been supported by this Branch include a number relating to learning theory and science instruction. The Branch also disseminates information concerning foundation supported projects.[3]

The science section of the Cooperative Research Branch revised and publicized existing programs and instituted new programs for Fiscal 1964. One of the six program areas for which submission of Proposals was invited was the "Curriculum Improvement Program." Outlining possible projects related to the structure of the science curriculum the Branch suggested the following:

> The development of science program guidelines to facilitate synthesis of science materials, of science

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[1]U.S., Congress, House, Committee on Education and Labor, Federal Educational Policies, Programs and Proposals: A Survey and Handbook, p. 59.

[2]Ibid.

[3]Gatewood and Obourn, "Improving Science Education in the United States," p. 21.

> programs synthesized from materials based on pupils' science learnings and of materials for presently neglected science areas.[1]

The Cooperative Research Program required that the purpose of the project proposal should be to achieve at least one of the following:

1. clarification or redefinition of the nature and aims of science;

2. development of a sequential pattern based upon the factors of human growth and development, and upon the teaching-learning process;

3. development of materials or methods of instruction for achieving the course objectives;

4. evaluation of the effectiveness of materials or methods developed;

5. dissemination of promising materials.[2]

Research on each of these areas may have the effect of improving future curriculum construction in science.

One of the recent additions to the functions of the Office of Education has been that of administering the National Defense Education Act (NDEA) of 1958. The purpose of this Act was to

> correct as rapidly as possible the existing imbalances in our educational programs which have led to an insufficient proportion of our population educated in

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[1]U.S., Department of Health, Education, and Welfare, Office of Education," Cooperative Research Proposals in Science Education," (Washington, D.C.: U.S. Office of Education, March, 1964), p. 4.(Mimeographed).

[2]*Ibid.*, pp. 14-15.

> science, mathematics and modern foreign languages and trained in technology.[1]

Title III of the NDEA included provisions for stimulating a nationwide strengthening of science through State-administered Federal grants to schools needing improved laboratory facilities and equipment and for the development of supervisory or related services. Federal funds must be matched dollar-for-dollar by State and or local funds.[2]

Implications for Australian curriculum development

Provision of extended teacher assistance through the appointment of science supervisors, and of improved laboratory facilities are necessary concomitants for improved science curricula. The recent passing of a Federal Act in Australia providing for science facilities in schools had the purpose of improving school laboratories.[3] The provision of science supervisors with one of their functions to facilitate curriculum innovation should receive the attention of the ASEF. An extension of the research activities of the Commonwealth Office of Education in Australia to initiate educational research activities by other groups may have important science curriculum outcomes.

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[1]Edgar Fuller, "the National Defense Education Act," in Science Materials Centers, Laboratories in the Classroom (New York: Science Materials Center, Inc., 1960), pp. 19-21.

[2]U.S., Department of Health, Education, and Welfare, Office of Education, Report on the National Defense Education Act: Fiscal Year Ending June 30, 1959 (Washington, D.C.: U.S. Government Printing Office, 1960), pp. 6-8.

[3]Gorton, Canberra Press Release Copy.

Other U.S. Government Agencies

Other agencies with minor influence on science curricula in the U.S.A. include the National Aeronautics and Space Administration (NASA) and the Atomic Energy Commission (AEC). In Australia, existing government agencies which include the Australian Atomic Energy Commission and the Commonwealth Scientific and Industrial Research Organization (CSIRO) could well assist in the development of new science curricula.

Private Foundations

A private foundation has been defined as "a non-governmental, nonprofit organization, having a principal fund of its own, managed by its own trustees or directors, and established to maintain educational. . . or other activities serving the common welfare."[1] In U.S.A. in 1964 there were approximately 12,000 private, philanthropic foundations, with assets approaching $12 billion. 272 of these foundations (including Ford, Rockefeller, Carnegie and Sloan) with assets of $9.7 billion expended $437.4 million or 87% of the total support provided in 1960.[2]

One of the largest private foundations is the Ford Foundation. In 1951, the Ford Foundation established The

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[1]Organization for Economic Co-operation and Development, Scientific Research, Country Reports on the Organization of Scientific Research: United States, p. 38.

[2]Ibid.

Fund for the Advancement of Education, and had contributed $64 million towards its operations by 1963. The main activity of the Fund for the Advancement of Education has been to support promising experimental educational programs. Only a small fraction ($141,000) of its total grants for 1964 ($2,594,000) was directed towards curriculum improvement projects, and most of this fraction was earmarked for social studies.[1] In a recent report of the Ford Foundation, no grants were reported which were specifically for the improvement of secondary school science curricula.[2]

Of the thirty new science curricula reported in 1964, only two indicated current support from private foundations.[3] These were the "Science Manpower Project," (with its headquarters at Columbia Teachers College, New York) and the "STAC" (Science Teacher's Adaptable Curriculum) approach project. In a 1960 listing, the Science Manpower Project indicated that twelve foundations contributed towards its support.[4] The STAC approach, designed to facilitate continual science curriculum change through the

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[1]Fund for the Advancement of Education, A Report for 1961-1962 (New York: The Fund, 1963), p. 2.

[2]The Ford Foundation, Annual Report October 1, 1962 to September 30, 1963 (New York: The Ford Foundation, 1964). Pp. 178.

[3]American Association for the Advancement of Science and the Science Teaching Center, University of Maryland, Second Report of the Information Clearinghouse on New Science Curricula, March 1, 1964 (College Park, Maryland, 1964, pp. vii+ 99.

[4]Frederick L. Fitzpatrick (ed.), p. v.

utilization of keysort cards, is being jointly supported by the Ford Foundation and Portland Public Schools.[1]

The PSSC program is now administered by a non-profit organization, Educational Services Incorporated (ESI) which was established and a permanent organization to facilitate revision and expansion.[2] ESI is largely supported by the Federal Government, but eight private foundations and two industrial corporations have also contributed to its work.[3]

The Carnegie Foundation was instrumental in promoting learning studies in science at Princeton University and in developing physical science courses at Harvard University.[4] Of more widespread significance was the six years of financial support the Carnegie Foundation provided for the development of the Science Teaching Improvement Program (STIP) established by the AAAS. Announcing the initial grant of $300,000 in 1955, the Carnegie Corporation indicated that it considered the improvement of secondary school

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[1]AAAS and the Science Teaching Center, University of Maryland, Second Report of the Information Clearing House . . ., pp. 80-81.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," The School Review, LXX (Spring, 1962), 63-64.

[3]ESI Quarterly Report: Winter-Spring 1964 (Watertown, Massachesetts: Educational Services Incorporated, 1964), p. 149.

[4]Gatewood and Obourn, "Improving Science Education in the United States," p. 46.

science teaching a prerequisite to an increased supply of well-trained science students.[1] In addition to four major activities relating to the training and utilization of science teachers, STIP made provision to work with science curriculum studies of the NSF when requested.[2] Through the establishment of the quarterly journal Science Education News, the support provided by the Carnegie Corporation of New York to STIP promoted the dissemination of information to the scientific community and to science educators concerning significant curriculum developments.[3]

Summary and implications for the support of science curriculum projects in Australia

The above discussion illustrates that the major responsibility for the support of large scale science curriculum revision in the U.S.A. has been accepted by agencies of the Federal government. Carnegie Corporation Executive Jackson concurred with this, when he stated:

> Never in our history has so much energy, talent, and money been invested in improving the teaching of basic subjects in the high school curriculum. While a

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[1] "Program to Improve Secondary School Teaching of Science and Mathematics Aided by Corporation," in Announcement of Grants, (New York: Carnegie Corporation, 1955), reprinted in The Australian Science Teachers' Journal, I (November, 1955), 15-19.

[2] "AAAS Science Teaching Improvement Program, 1958-61," Science Education News, (September. 1959), p. 1.

[3] J. R. Mayor, "Science Education News," Science Education News, (June, 1959), p. 2.

limited amount of this activity has been supported by private foundations, the vast majority of the support has come from governmental sources.[1]

In Australia, support for new science curricula has come from the state Education Departments. Support from the government has been limited to the recent act legislated to improve school laboratory facilities. Private agencies have supported publication of a textbook in New South Wales (Nuclear Research Foundation), improvement of science laboratories in non-government schools (Industrial Fund) and science teacher recognition (Australian Industries Development Association). The Industrial Fund for the Advancement of Scientific Education in Schools, operative since 1960, is supported by Australian industrial and commercial companies. The objective of this fund has been to provide extra encouragement for the most talented pupils through the provision of funds for the construction of additional chemistry and physics laboratories.[2] Support has been limited to about sixty selected leading non-government schools. However, there has been no support from other government agencies or private foundations specifically directed to the improvement of school science curricula.

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[1]Jackson, Science Education News, (December, 1961), 24.

[2]A. G. Carver, "The Industrial Fund for the Advancement of Scientific Education in Schools," Education News, IX (February, 1963), 3-7.

Recommendations

5.03. The Australian Science Education Foundation should be provided with a budgetary allocation by the Commonwealth Government for the support of science curriculum projects.

5.04. The Science Teachers' Associations should seek financial support from industry and from private foundations to support specific projects such as the provision of teaching aids, filmstrips and films.

Some Effective Elements of Selected NSF Supported Science Curricula

A number of major curriculum projects in the U.S.A. have received nationwide and international recognition, as reflected by the widespread adoption of their materials. Included in this category are the projects known as:

Physical Science Study Committee (PSSC) physics course;

Chemical Bond Approach (CBA) Project;

Chemical Education Material (CHEM) Study;

Biological Sciences Curriculum Study (BSCS); and the

AAAS "Process Approach."

There have been many reviews of the methods of establishment, philosophy, objectives and courses of the five curriculum projects named above.[1] It is outside the scope of this

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[1]See, for example:

[a]The School Review, LXX (Spring, 1963), for detailed discussions of each of the BSCS, CBA, CHEM Study and PSSC projects:

[b]John Goodlad, School Curriculum Reform (New York: The Fund for the Advancement of Education, 1964). Pp. 96.

present thesis to review in detail any one of the the NSF supported projects. Aspects of the projects will be reviewed concurrently with descriptions of the contemporary Australian situation. Those elements will be examined which appear to have implications for the development of science curricula in Australia. The following aspects will be considered:

1. Process of curriculum development;
2. Philosophy;
3. Objectives;
4. Course content and organization;
5. Teacher training;
6. Evaluation;

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[c]Robert W. Heath (ed.). New Curricula (New York: Harper and Row, 1964), Pp. viii + 96.

[d]Office of Scientific Personnel, National Academy of Sciences--National Research Council, Guidelines for Development of Programs in Science Instruction (Washington, D.C.: National Academy of Sciences--National Research Council, 1963). Pp. vii + 68.

[e]Charles A. Whitmer, "New Approaches in Science Teaching: The National Science Foundation and The PSSC, CBAC, CHEM and BSCS," MSTA Newsletter, IX (January, 1962), 3-18.

[f]American Association for the Advancement of Science, The New School Science: A Report to School Administrators on Regional Orientation Conferences in Science (Washington, D. C.: American Association for the Advancement of Science, 1963). Pp. iv + 92.

[g]David Cohen, "Spotlight on U.S.A. Curriculum Developments in Science," The Australian Science Teachers' Journal, X (May, 1964), 27-38.

7. Curriculum balance;

8. Social significance of science education.

Process of Curriculum Development

There has been little change in Australia in the process of curriculum construction for many years, despite the advocacy for change by educators such as Browne[1] and Cunningham.[2] On his return from a study visit to the U.S.A. in 1932, Browne wrote in his report to the state Director of Education:

> The revision and recasting of the curriculum in the primary and post-primary school bids fair to be the most engrossing and significant education problem of modern times.[3]

Cunningham, returning from the U.S.A. in 1929, commented about Australian curriculum in similar terms. Cunningham said:

> It would seem that in Australia we need not only to revise our curricula, but to revise our attitude toward curricula. The one-man type of curriculum construction has almost vanished, but there is scope for still wider co-operative effort. We need to encourage the view that the curriculum is a means to an end rather than an end in itself.[4]

Plans suggested for involving more teachers at the local level have not been effected, and conformity to the

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[1]Browne, p. 17.

[2]K. S. Cunningham, "Some Aspects of Education in the United States of America," cited by Browne, p. 55.

[3]Browne, p. 17.

[4]Cunningham, cited by Browne, p. 55.

externally prescribed curricula remains the keynote of classroom instruction. Whereas curriculum revisions have been effected, the nature of these revisions and the processes by which such revisions are effected remain areas deserving of careful appraisal. With many curriculum innovations in science in the U.S.A., a study of the processes utilized and of the nature of these innovations may have relevance for Australia's needs.

One important development in the U.S.A. with apparent relevance for Australia has been the collaboration of the professional scientist in identifying and developing the appropriate content of science courses. The participation of the scientist in a well-balanced team comprising also psychologists and educators supported by the NSF has proved itself effective both in producing good quality materials rapidly, and also in subsequently improving those materials. Utilizing a period when the participants are freed from other activities, groups have met together, usually for a period of about six to ten weeks, listened to working papers, formulated an overall plan, and identified the philosophy, objectives and course content after detailed discussion. Courses were then written, often groups being responsible for different chapters. These courses included integrated sets of materials comprising texts, laboratory manuals with renewed emphases on open-ended experiments, teacher guides, equipment and apparatus (often novel) that was in many cases designed specifically for the course, films, filmstrips, collateral reading materials, evaluation instruments, and teaching aids.

With typistes, editors and artists available to produce classroom materials, the courses have often been tried out soon after being written, sometimes in schools nearby to writing session headquarters. In this way, the writers have been able to observe, first-hand, student reactions to the units. With the benefit of this immediate feedback, rapid revision has sometimes been possible.[1] In other cases, feedback has been available after the following school term, when materials had been tried experimentally in several schools containing a diverse range of students. On the basis of these trials and teacher feedback, these materials have been revised (and re-revised after a subsequent second trial period) and given further classroom trials.

The stages of curriculum development are exemplified by development of the AAAS "Process Approach" project, resulting from the activities of the AAAS Commission on Science Instruction. These stages were:

1. The appointment of the Commission on Science Instruction by the Board of Directors of AAAS in

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[1]c.f., Arthur H. Livermore, "Science--A Process Approach," Science and Children, I (May, 1964), 24-25.

the Spring of 1962.[1,2] According to the Executive Secretary of AAAS, Dr. Dael Wolfle, the Commission "is representative of the scientific and educational communities and suggestions for membership were solicited from the various professional societies; but that those on the Commission do not represent particular professional groups; rather they represent broadly various disciplines and professional groups in science and education. In this sense each member of the Commission brings to the body one or more points of view which may be identified with a segment of science education, but which is clearly not identified with particular professional organizations.[3]

2. The first meeting of the Commission was held in May 1962, at which plans were devised for Summer Conferences at Cornell University and the University of Wisconsin.[4]

3. "Two eight-day conferences of representatives of science, education and teachers in the schools were held in the summer of 1962. The purpose of the conference was to explore what is going on in elementary science and to make recommendations to the Commission."[5]

4. Participants invited to the 1962 Summer Conferences by the Commission included "scientists from

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[1]Letter from John R. Mayor, Director of Education, American Association for the Advancement of Science, Washington, D. C., May 14, 1964, to the writer.

[2]AAAS is a non-profit organization comprising 40,000 scientists in twenty sections, and has ninety affiliated societies.

[3]Dael Wolfle, quoted in "A Summary of General Sessions," Report of the AAAS Cornell Conference on Science Instruction in the Elementary and Junior High Schools" (Washington, D. C.: AAAS, July, 1962), p. 2. (Mimeographed).

[4]Letter from John Mayor, May 14, 1964.

[5]*Ibid*.

various disciplines including psychology, leaders in teacher education, school administrators, and teachers."[1]

5. With the benefit of several working papers prepared at the suggestion of the 1962 Conferences, a Summer Writing Session was held at Stanford University in 1963, at which course materials were produced, tried experimentally in elementary classrooms and revised on the basis of these experiences.

6. Materials were then produced for experimental trials in schools during 1963-64.

Implications for Australian science curriculum construction

The utilization of the combined thinking of scientists, educators and science educators in the process of curriculum development in the U.S.A. has produced several influential curricula, and deserves the consideration of Australians responsible for curriculum development. However, despite the ease of implementing centrally devised curricula in Australia's centralized systems, some research evidence suggested this to be unwise. Research on teacher participation in the development of curriculum materials (c.f., Chapter IV) suggested that provisions of flexibility for local adaptations and development of at least part of the course, will promote greater teaching efficiency.

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[1]John R. Mayor, "AAAS Commission on Science Instruction," Science Education News, (December, 1963), p. 2.

Recommendations

5.05. Curriculum development in Australia should be conducted on a full time basis by teams released from other responsibilities.

5.06. Soliciting the active support of top-rank scientists from all fields (e.g., through ANZAAS and CSIRO) to work with Australian science curriculum committees, especially in the identification of course content and in translating the broad purposes of science into specific objectives, is strongly recommended.

5.07. Science curriculum content should be screened through discussions with psychologists with knowledge of the abilities of children, and by teachers with their knowledge of classroom practicability and feasibility.

5.08. The curriculum as published should promote and encourage teachers to adapt the published version to local conditions and needs. Increased provision for involvement of classroom science teachers in curriculum reforms should also be provided in Australia by such mechanisms as the provision of feedback questionnaires and utilization of the responses so obtained.

5.09. Australian curriculum development procedures should include provisions for the preparation of a wide range of materials, including textbooks and/or multiple reference materials, films and single concept loops filmstrips, teaching guides, laboratory manuals, enrichment materials, the designing of special apparatus, and the preparation of valid testing instruments.

Philosophy of Selected NSF Supported Courses

The development of a philosophy of science teaching requires an answer to the question:

> What values should the teaching of science in schools promote most strongly in students?[1]

The statement of the philosophy reflects the fundamental beliefs of those responsible for developing the new curricula. The NSF sponsored courses suggest that the philosophy is that science teaching should promote the value of the processes of inquiry.

Such a statement of the philosophy of the curricula developed with NSF support highlights the value judgment that the various sciences are systems of inquiry rather than static bodies of knowledge. In these terms, school science should therefore facilitate the development in pupils of skills which facilitate the inquiry process.[2] These skills will be valuable both to the future scientist and to the layman in facilitating his understanding of the methods of science.

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[1]c.f., Ole Sand, "Tasks To Be Done in Improving the Social Studies Curriculum," in Improving the Social Studies Curriculum Twenty-Sixth Yearbook of the National Council for the Social Studies, Ruth Ellsworth and Ole Sand (co-editors) (Washington, D.C.: National Council for the Social Studies, 1955), pp. 242-43.

[2]c.f. [a]AAAS Steering Committee, "Science Teaching in Elementary and Junior High Schools," Science, CXXXIII (23 June, 1961), 2020.

[b]John R. Mayor, "Policies for Science Education in the United States," Paper presented to the Association for the Education of Teachers in Science at the Twelth Annual Convention of the National Science Teachers Association, Chicago, Illinois, March 20, 1964, pp. 1-2.(Mimeographed).

Some idea of the guiding philosophy of the NSF sponsored courses can be obtained from the following statement in which Killian suggested that school physics should present the work of the contemporary physicist:

> Much that is a part of physics might be omitted, but what was presented should be given the structure and tasks that reflected the most advanced thinking. It should present physics as the contemporary physicist sees it--as the gradual unfolding of the nature of the universe by a continual process of inquiry, exploration, and discovery, and, as such, one of the most admirable achievements of the human mind and an indispensible part of Western thought and culture. The course should be designed to lead the student to this conception by letting him learn, insofar as possible, by exploring and experimenting as the scientist does.[1]

In keeping with this emphasis on discovery, and on the student acting as a professional scientist acts, there was a shift away from the emphasis on technology. Finlay explained this shift:

> The Physical Science Study Committee judged it wise to shift the emphasis in secondary-school physics away from technology toward a deeper exploration of the basic ideas of physics and the nature of inquiries that can lead to these ideas. This choice was based on the premise that for the future scientist as well as for the non-scientist, an introductory course that provides a grasp of the central ideas of physics and the kind of thought that lies behind them is more useful and rewarding than a course that emphasizes a somewhat more ephemeral technology.[2]

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[1]James R. Killian, "The Return to Learning," in Heath (ed.), p. 255.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," The School Review, LXX (Spring, 1962), 66.

As was suggested for physics, so it was proposed that school chemistry should mirror the work of the professional scientist. Thus, Campbell stated:

> A chemist is a person who makes experimental observations and then interprets them in terms of atoms and molecules and their behavior. The CHEM Study course is planned to allow even first-year students to utilize the same approach and conceptual treatment.[1]

This same philosophy was established by the AAAS Work Group charged with outlining the process goals for the K-9 sequence. The group stated:

> The process goals are truly goals in the sense that the student must be taught to behave in the ways that scientists behave.[2]

If it is considered desirable to teach the child to act as a scientist, it becomes necessary to determine how the scientist does or should act. To determine this may require a scientific study itself.

Brandwein has raised another important philosophical issue. We live in an age in which technology has revolutionized living. To reduce the technology in the science curriculum in such an age is something to be done only after intensive examination of the issues involved. In this connection, Brandwein has stated:

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[1] J. A. Campbell, "CHEM Study--An Approach to Chemistry Based on Experiments," in Heath (ed.), p. 88.

[2] "Preliminary Statement of Behavioral Objectives," <u>Report of [AAAS] Cornell Conference</u>, p. 1.

> If these curriculums (particularly PSCS, CHEMS, CBA) do have a fault, it is this: a curriculum should be responsible to the historical period in which people live and work. Ours is a time of great technological advance. The new curriculums have generally removed technology from their scope, but technology remains in the lives of people.[1]

Summary and implications for Australian science curricula

It is not the purpose here to determine the philosophy of science education for Australia. It is rather to outline the philosophy of selected U.S.A. curricula, and to examine whether it appears to have relevance for Australian science education. The determination of a philosophy for science curricula is essentially an expression of preference, or value judgment, of those responsible for developing the curricula. As Kelly wrote of the BSCS course:

> Any syllabus must be in part a value judgment, whether or not the B.S.C.S. course is up to date and will provide for changing needs of American society must inevitably be merely a matter of conjecture. However, it is quite clear that it meets with the approval of a large number of people in biology education and research.[2]

The more valid and reliable the evidence upon which the statement of the philosophy is based, the sounder is that statement likely to be.

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[1]Brandwein, "The Strategy. . .," p. 10.

[2]Peter Kelly, "The Biological Sciences Curriculum Study," <u>The School Science Review</u>, XLIV (March, 1963), 318-19.

In assessing the relevance of the philosophies of the NSF sponsored curricula for Australian science, an important feature to evaluate is whether school science should attempt to teach children to act as scientists act. One determining factor will be the ability of children to perform the scientific processes at school age. The NEA Project on Instruction questioned whether, because a child is able to perform, that this would justify curriculum inclusion.[1]

Recommendations

5.10. The philosophy of Australian science curricula should reflect the thinking of scientists and educators as to what constitutes the purposes of science education for all Australian children. The Australian Science Education Foundation should arrange a conference of scientists and educators to formulate a philosophy of science education.

5.11. If a detailed consideration of all relevant issues indicates that science education is to teach children to act as scientists act, then some scientific method such as thorough job analyses of practicing Australian scientists should be utilized to determine their practices.

Objectives of Selected NSF Supported Science Curricula

The nature of the authorship exerts an influence in the determination of science teaching objectives. Prior to the construction of the contemporary science curricula, groups of non-scientists had exerted the major influences

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[1]c.f., NEA Project on Instruction, Deciding What To Teach (Washington, D.C.: National Education Association, 1963), p. 45.

on the philosophy and objectives of science education. Educators, including science educators, had produced the Thirty-First, Forty-Sixth and Fifty-Ninth NSSE Yearbooks which had exerted an important influence on the direction of science education. Motivated by the need to increase the quantity and improve the quality of scientific manpower, the NSF and its Course Content Improvement Section promoted curricula devised under the direction of the professional scientist. This support has recently had a profound effect on the current direction of science education.

Broadly speaking, the objectives of the NSF supported curricula have been to update course content, to identify major concepts which underlie the structure of the subject, and to introduce the spirit of inquiry partly through increased student laboratory work.[1] For example, in each of the three BSCS approaches to biology teaching, "the primary emphasis has been on investigation and inquiry as means of acquiring significant knowledge in science."[2] The broad objectives of the BSCS are common to the three version to achieve these ends.[3]

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[1]c.f., J. A. Campbell, "Chemistry--An Experimental Science," The School Review, LXX (Spring, 1962), 54-55.

[2]Bentley Glass and Arnold B. Grobman, "Foreword," Green Version High School Biology (Chicago: Rand McNally and Company, 1963), p. ii.

[3]c.f. Lee J. Cronbach, "Evaluation for Course Improvement," in Heath (ed.), p. 234.

The detailed behavioral components of the inquiry process as objectives of science teaching have not been specified by the NSF supported secondary school curriculum groups. That the objectives of the new courses differ from those of the traditional courses is suggested, at least for the area of physics, by a detailed comparison of both sets of objectives by Trowbridge. Through analyses of all the PSSC materials and of traditional materials, Trowbridge identified seventy-two objectives of physics teaching. Of these, seventeen were unique to PSSC physics. seventeen unique to traditional physics, and the rest were common. However, what Trowbridge stated to be unique PSSC objectives may have better been termed as course characteristics; unified nature of the course, emphasis on basic rather than applied science, reduction in the number of topics, and emphasis on the role of the laboratory.[1]

Of the various NSF sponsored courses to be considered here, only the AAAS "Process Approach" has specified its objectives in behavioral terms (c.f., Chapter IV). In connection with their student evaluation program,

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives of Traditional High School Physics with the Objectives of the Physical Science Study Committee Course, and an Analysis of the Instructional Materials of the Physical Science Study Committee Course: (unpublished Ph.D. dissertation, Ann Arbor: University of Michigan, 1961), p. 273, cited by Richard A. Gibboney <u>et al</u>. "Curriculum Components and Organization," Chapter V of <u>Review of Educational Research</u>, XXXIII (June, 1963), 281-82.

Walbesser wrote:

> It should be quite apparent that the specification of objectives in behavioral terms provides an immediate and direct vehicle by which to communicate the expected goal of any instructional activity.[1]

As this method of stating its objectives by the AAAS Panel appears to have facilitated the subsequent development of course materials, and at the same time has provided a promising inbuilt evaluation mechanism unique among the projects here reviewed, a fuller consideration of its method may contain relevant and important factors for Australian science curricula.

The objectives of the AAAS "Process Approach" curriculum were identified by participants in the AAAS 1963 Summer Writing Program. The published statement of their objectives outlined two dimensions, namely, the dimension of scientific procedure and the dimension of scientific knowledge. The following were identified by the AAAS group as procedures:

1. Recognition and analysis of a problem;
2. use of several sources of reliable information;
3. ability to observe;
4. comparison of phenomena;
5. building systems of classification;
6. use of the instruments of science;
7. use of laboratory technique--especially the experiment;

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[1]Henry H. Walbesser, "Curriculum Evaluation by Means of Behavioral Objectives: Part I: A Design for Curriculum Evaluation." Undated, p. 1. (Mimeographed).

8. evaluation of evidence and drawing of conclusions;
9. invention of a model or theory;
10. need to communicate.[1]

Considering the "Dimensions of Scientific Knowledge," the AAAS panel indicated that "the basic facts and principles of science change more quickly than do basic scientific procedures."[2] It then named the following major areas to provide boundaries and direction to the child's active exploration of his world:

1. the universe;
2. the structure and reactions of matter;
3. the conservation and transformation of energy;
4. the interaction between living things and their environment.[3]

In concluding its "Statement of Purposes and Objective," the AAAS panel stated that:

> In the successful educational encounter, the child will be an active searcher for knowledge and the teacher will form attitudes toward enquiry as well as offer information about the world.[4]

From a grid on which the behavioral objectives ("scientific procedures") were plotted against the content areas ("scientific knowledge"), a set of objectives which were also suggestive of teaching method and evaluation technique, was determined.

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[1]Henry H. Walbesser, "Curriculum Evaluation by Means of Behavioral Objectives: Part I: A Design for Curriculum Evaluation," Undated, p. 1.(Mimeographed).

[2]Commission of Science Education, AAAS, "Science--A Process Approach: Teachers Guide," p. 13.

[3]*Ibid.*

[4]*Ibid.*, p. 14.

At the same time, the objectives as statements of behavioral changes sought, apply to individual students, and the provision of experiences for a class of students with heterogenous abilities, needs, interests and attitudes is therefore essential. Gagné reminded us of this when he stated:

> A curriculum which sets out to change behavior must take some account of the fact that changes occur differently in different individuals.[1]

Attention to individual differences is a task for the classroom teacher. The teacher should modify the experiences of each child according to ability and interest. Success in adaptation will vary according to the ingenuity of the teacher,[2,3] but will depend largely on curriculum suggestions. Among the techniques available for facilitating the individualization of instruction, are:

1. Ability grouping
2. Changes in teaching methodology, such as utilization of open-ended experimentation
3. Programmed instruction to allow for the variation in rates of working

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[1]Gagné, Journal of Research in Science Teaching I, Issue 1, 28.

[2]Fred T. Wilhelms, "The Curriculum and Individual Differences," Individualizing Instruction, The Sixty-First Yearbook of the National Society for the Study of Education, Part I (Chicago: The National Society for the Study of Education, 1962), pp. 62-74.

[3]Association for Supervision and Curriculum Development, Individualizing Instruction, 1964 Yearbook of the Association, Ronald C. Doll (ed.) (Washington, D.C.: Association for Supervision and Curriculum Development, 1964). Pp. ix + 174.

4. Organizational procedures (e.g., ungraded classes, team teaching).[1]

5. Enrichment procedures;

6. Use of specialists to teach talented or disadvantaged students;

7. Differentiated assignments, providing more challenging materials for brighter students (e.g., SRA Learnings in Science Kit)

8. Open-ended laboratory procedures.

A fuller description of these techniques is beyond the scope of this thesis.

Gagné also emphasized that objectives are attainable only insofar as students are motivated. He added:

> In a fundamental and definitional sense, no change in behavior can occur without the presence of motivation. The problem is. . . one of identifying what kinds of motivation will serve to bring about the particular kinds of changes in behavior which may be contemplated by the builders of a curriculum in science.[2]

Recommendations

5.12. Objectives should be stated in behavioral form, in order to facilitate the processes of curriculum and evaluation.

5.13. The objectives of science education should be diversified enough to facilitate individualization of instruction, and should provide for mechanisms of motivation.

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[1]See also: J. Lloyd Trump, "Some Problems Faced in Organizing Science Teaching Differently," Paper presented at the Twelfth Annual Convention of the National Science Teachers Association, Chicago, Illinois, March 23, 1964. Pp.6. (Mimeographed).

[2]Gagné, Journal of Research in Science Teaching, I, Issue 1, 28.

Course Content and Organization

One of the major charges of the NSF supported curricula is reflected in the title of the section to which proposals are submitted, namely, the Course Content Improvement Section. Consequently a major concern of these curriculum projects has been the updating of course content. This has involved the identification by the curriculum project personnel of unifying elements as broad, basic concepts in each of the sciences.[1] These concepts were utilized as integrating themes which at the same time would facilitate the inquiry process and introduce the student to the structure of the content area.[2]

In brief, the concepts selected as integrating units for the various sciences were as follows:

> The two central notions of physics as selected by the PSSC group were the wave particle duality and the modern concepts of the atom.[3]
>
> The BSCS prepared three versions, known as the blue, yellow and green, Revised editions of these emphasize the major themes of the origin of life and its evolution, and the nature of scientific inquiry, with emphasis on the physiological and molecular approach (in the Blue Version); the cellular approach, with

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[1]Goodlad, p. 53.

[2]Bruner, pp. 17-32.

[3]Jerrold R. Zacharias, "The Requirements for Major Curriculum Revision," in Heath (ed.), p. 71.

(Yellow Version); and the ecological and evolutionary approach (Green Version).[1]

The CHEM Study content is organized around three sections:[2] The introductory section with the general framework in which the chemist works--the importance and limitations of the experimental approach and the need for building scientific models such as the kinetic theory and the periodic table. In the development section, using the laboratory approach extensively, introductory concepts are amplified, and new concepts lead to the present atomic model. The principles developed in the first two sections are then applied in the third section, to a study of descriptive chemistry.[3]

The CBA Course theme has usually been stated as the idea of chemical bonds. An alternative statement would be the idea that chemicals possess characteristic structures. To this end, a good deal of attention has been given in the course to the use of geometry in chemical reasoning. In addition, mental models, electrostatics, and energy are threads running through the CBA course.[4]

The AAAS Process Approach does not have an integrating content theme in the same way as the secondary level programs. Rather the materials have been focused primarily on ways to develop basic skills (competence) in observation, classification, making models, and other scientific processes for grades K-3.[5]

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[1]Bentley Glass, "Renascent Biology: A Report on the AIBS Biological Sciences Curriculum Study," The School Review, LXX (Spring, 1962), 22-27.

[2]Richard J. Merrill, "CHEM Study in Action," Journal of Secondary Education, XXXVII (February, 1962), 71.

[3]Richard J. Merrill, "CHEMISTRY: An Experimental Science," The Science Teacher, XXX (April, 1963), 27.

[4]"Central Theme," CBA Newsletter (February, 1961), pp. 1-2.

[5]John R. Mayor, "AAAS Commission on Science Instruction," Science Education News (December, 1962), p. 3.

Summary and implications for Australian science curricula

The identification of integrative themes by practicing scientists for each of the projects has provided a sharp focus for stressing the structure of the disciplines.

Recommendation

5.14. Groups of Australian scientists should be invited by the ASEF to identify integrative concepts for Australian science curricula.

Teacher Training

Brickell, after his study of educational innovation in New York State, concluded that:

> The most successful innovations are those which are accompanied by the most elaborate help to teachers as they begin to provide the new instruction. . . . The key to successful innovation is assistance to teacher.[1]

In these terms, the NSF sponsored in-service teacher institutes are facilitating the introduction of new science curricula. Many of the 35,000 teachers who annually attend these NSF supported institutes are receiving specific assistance for teaching one of the NSF sponsored science curricula.[2] Another type of institute, known as the Academic Year Institute (AYI), provides an emphasis on course content for science and mathematics teachers

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[1]Brickell, Organizing New York State. . ., p. 31.

[2]National Science Foundation, "National Science Foundation," A Brochure (Washington, D. C.: U. S. Government Printing Office, 1962), p. 18.

whose science subject-matter has been limited. AYI courses stress basic principles and their interrelationships. In addition to this subject-matter improvement, encouragements for Institute participants are provided by the opportunity under certain circumstances to earn a master's degree concurrently with the Institute, and by the provision of stipends up to $3000 for the academic year. In 1963-64, the eighth year of AYI programs, there were 1860 participants in attendance at fifty-eight institutions.[1]

With one trend in science teaching objectives of the NSF supported curricula toward discovery learning, the implications of this for teacher education are important. The NEA Project on Instruction indicated the need for a thorough knowledge of content as a basis of learning by discovery:

> Learning through discovery must not be understood to mean that the pupil can investigate, without background, an idea of which he is ignorant. . . . The richer the background of information he can bring to the discovery situation, the more refined and successful his effort is likely to be.[2]

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[1]U.S., National Science Foundation, Academic Year Institutes for Science and Mathematics Teachers, 1963-64, NSF Publication SPE 62-C-9 (Washington, D.C.: U.S. Government Printing Office, 1962). Pp. 20.

[2]NEA Project on Instruction, Deciding What To Teach, p. 39.

In addition, the studies of Suchman[1] and Fish[2] suggested that specific training techniques are necessary to give teachers the necessary skills and attitudes to impart inquiry skills. Likewise, there appears to be a need to develop science teacher training courses to prepare teachers to impart to their pupils the processes of the scientist, and to prepare teachers to promote creativity, initiative and the ability to deal with new problems, as required by the new curricula.[3]

Summary and implications for Australian science curricula

Existing techniques in Australia for updating the training of science teachers are limited to annual science teacher conventions and infrequent seminars arranged by state education departments and universities. Accommodation at these is restricted to an insignificant percentage of science teachers. Consequently, an improvement of science teaching in Australia may be effected by the introduction of inservice training institutes similar to those sponsored by the NSF.

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[1] Suchman, "Inquiry Training: Building Skills for Autonomous Discovery," Mimeographed report, p. 6.

[2] Fish, School Science and Mathematics, LXII, 183-87.

[3] The Association for Supervision and Curriculum Development, "A Learning Theory for Curricular Change," Using Current Curriculum Developments (Washington, D.C.: The Association, 1963) (Mimeographed).

Recommendations

5.15. The ASEF should investigate the possibilities of establishing inservice training to update the knowledge and skills of Australia's science teachers. Both academic year and summer courses should be considered.

5.16. Teacher education (re-education) and attitudes of acceptance and enthusiasm are prerequisites to the success of educational innovation. Special programs in Australia to promote these factors should be arranged by the ASEF.

5.17. The ASEF should sponsor pre-service and inservice courses at the universities for science teachers. These courses should prepare teachers to:

(a) arrange situations in which student problem solving will be required;

(b) conduct open-ended types of lessons, in which instruction is individualized;

(c) be permissive to the extent that student errors may occur, but to know the content so that potential hazards or dangers may be foreseen and prevented;

(d) evaluate in terms of creativity and initiative, rather than in terms of conformity to pre-determined techniques.

5.18. If science education is to reflect the work of the scientist, then there is a need for science teachers to work alongside scientists to understand better the nature of their tasks. Either for part of each year, or for a complete year every several years, the ASEF should provide fellowships which would free science teachers from their classroom teaching to work in the laboratory with scientists. In addition, opportunity for extended contact with scientists should be provided, perhaps through regular meetings or conventions of the science teachers' associations.

Evaluation

Promising techniques for measuring a wide range of student behaviors have been developed by the BSCS Test Construction Sub-Committee and by Walbesser for the AAAS Project. For BSCS, Klinckmann prepared a test grid for developing written items in the areas of recall and reorganization of learned materials, application of knowledge of learned materials, application of knowledge to new concrete situations, the use of skills in understanding scientific problems, and the ability to show relationships between bodies of knowledge.[1] For the AAAS, Walbesser has developed behavioral checklists for evaluating student performance on tests of observations, classification and the other processes listed in its objectives.[2]

The PSSC, CBA and CHEM Study Projects have developed achievement tests whose purpose is to measure attainment with respect to the conventional principles of physics or chemistry, and to measure ability to utilize these principles in situations not previously encountered by the students. These tests of student ability have also been utilized as

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[1]Evelyn Klinckmann, "The Achievement of Goals in the Evaluation of the Biological Sciences Curriculum Study," Paper presented at the One Hundred and Twenty-Ninth Annual Meeting of the American Association for the Advancement of Science, Philadelphia, 26-30 December, 1962. (Mimeographed).

[2]Henry Walbesser, "Notes on the Purpose and Use of the Checklist of Competencies," undated. Pp. 2. (Mimeographed).

criteria of effectiveness of the new curricula. In that these tests have been developed in conjunction with the curriculum materials, they have been said to reflect sound educational practice. Thus Cooley and Klopfer recommended that evaluation instruments must be incorporated as an integral part of educational innovations.[1]

However, more often, courses have been evaluated pragmatically. Once written, the NSF sponsored courses have been submitted to classroom trials. On the basis of teacher feedback, courses have been modified or completely revised. Thus, classroom feasibility is one important criterion of success of the new programs. Hilgard has specified this need for classroom validation. He stated:

> Once a reasonably promising program is developed, it has to be tried out in a classroom, perhaps a laboratory-type classroom, but with real school children taught by a real teacher. Then, before the development is completed, it has to be tried out in a regular classroom, where other obligations also exist.[2]

Atkin concurred with Hilgard's statement, writing:

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[1]William W. Cooley and Leopold E. Klopfer, "The Evaluation of Specific Educational Innovations." Journal of Research in Science Teaching, I, Issue 1 (1963), 73.

[2]Ernest R. Hilgard, "A Perspective on the Relationship Between Theory and Educational Practices," in Theories of Learning and Instruction: 1964, Sixty-Third Yearbook of the National Society for Study of Education, Part I (Chicago: National Society for the Study of Education, 1964), pp. 412-13.

> Feasibility, after all, is a necessary condition for curriculum innovation.[1]

Other criteria of course effectiveness that have been cited in support of NSF financed science curricula has been the interest which they have generated and the enthusiasm of acceptance by teachers and pupils. Some research has endeavored to compare the NSF supported curricula with traditional courses. However, Heath has indicated that this type of research is meaningless:

> It seems most unlikely that any single experiment will provide the answer to the omnibus question "which is better?" This is not because the experiment is poorly designed, but because the question is unanswerable in the general case. The fault in this question is not that it calls for a value judgment and not that it calls for data. Its defect is that it calls for both, at the same time, inextricably mixed.[2]

Cronbach has said that such comparative studies rarely justify their cost.[3]

In terms of long range objectives sought by the NSF, an increased supply of scientists and higher level of scientific literacy among American citizens may constitute another measure of the effectiveness of the NSF supported curricula. The short term effectiveness of the courses

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[1] J. Myron Atkin, "Some Evaluation Problems in a Course Content Improvement Project," Journal of Research in Science Teaching, I, Issue 2 (1963), 129.

[2] Robert W. Heath, "Pitfalls in the Evaluation of New Curricula," Science Education, XLVI (April, 1962), 216.

[3] Cronbach, "Evaluation for Course Improvement," in Heath (ed.), p. 237.

has been the subject of several researches. Some of these have been concerned with determining for which range of student abilities the courses are most suited. Student achievement on written tests evaluating conceptual understanding of PSSC, CBA and CHEM Study suggested that students with higher intelligence and more highly motivated students perform best. For example, the effectiveness of the BSCS materials was evaluated from data received concerning 65,000 taking experimental BSCS courses. Grobman reported that the correlation between achievement on the BSCS Comprehensive final examination and general ability, as measured on appropriate sections of the School and College Ability Test (SCAT), was 0.72.[1] Grobman added that:

> While two separate statistical analyses were made of performance of this low ability group on BSCS tests, teacher and writer feedback indicated that the materials, in part, are unsuitable for this group.[2]

As a consequence of the findings of the difficulties experienced by lower ability students with BSCS materials, a new set of materials has recently been developed by the

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[1]Hulda Grobman, "Some Comments on the Evaluation Program Findings and Their Implications," BSCS Newsletter, No. 19 (September, 1963), p. 27.

[2]*Ibid*.

BSCS staff.[1] These materials were used experimentally in 1963-64 in thirty-six schools, and will be revised in a 1964 BSCS Summer Writing Conference at Boulder.[2]

From the research conducted by Ferris to investigate whether PSSC physics was geared to high achievement level students, Ferris concluded that:

> the evidence obtained from the PSSC testing program during 1958-59 overwhelmingly points to the conclusion that, not only is the course well within the capability of the great majority of U.S. high school physics students, but that experience in it is also highly profitable to a sizeable percentage of relatively low-aptitude students. Further, the evidence refutes the prophecies of skeptics who surmised that the PSSC course would be appropriate only for the exceptionally "bright" student.[3]

More than half of the teachers utilizing CHEM Study materials responded to a questionnaire sent to them in 1963, in which they were required to evaluate subjectively the ability range of CHEM Study students in terms of the goals of the course and in terms of teacher satisfaction (as related to teacher satisfaction with achievement of conventional classes), student interest and enthusiams, and dropout rate. In each of these categories, a substantial

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[1]"BSCS Special Materials for the Slow Learner: Present Status and Plans," BSCS Newsletter, No. 21 (April, 1964), pp. 36-37.

[2]"BSCS Plans for Second Course and SMS (Slow Learner) Materials," BSCS Newsletter, No. 20 (February, 1964) p. 1.

[3]Frederick L. Ferris, Jr., "Physical Science Study Committee--An Achievement Test Report," The Science Teacher, XXV (December, 1959), 579.

majority of respondents answered in a way indicating the superiority of CHEM Study.[1]

The effectiveness of PSSC in producing different modes of thinking or cognitive style, was the subject of another investigation. Trowbridge's study of the differences in objectives of PSSC and non-PSSC physics courses, reported earlier in this chapter, suggested that the students of these two courses should be able to subsequently demonstrate different abilities.[2] It should therefore be possible to construct tests to show this difference. The construction of such a test was attempted by Heath and Wish. They developed a novel device, called "A Test of Cognitive Preference," to determine whether students who had studied the PSSC physics course utilized different modes of thinking from those who had studied conventional physics courses. Multiple choice items were devised for which all four alternative answers were correct. Students were informed that all alternatives were correct, and directed to select the alternative they preferred on the basis of the introductory information given in the item. It was found that their selection reflected a

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[1]"Results of Midyear Questionnaire," Chemical Education Material Study Newsletter, III (May, 1963), 4

[2]Trowbridge, cited by Gibboney et al., Review of Educational Research XXXIII, 281-82.

significant difference between PSSC and conventionally taught students. PSSC students preferred answering in terms of fundamental principles and asking questions in pursuit of basic understanding, whereas the control group students preferred answering from memory of facts and terms, and practical application.[1] The results with the Cognitive Preference Test indicated that instruments could assess curriculum differences in cognitive style. The PSSC was shown to produce observable behavioral differences with respect to their different modes of dealing with the subject matter.[2]

As integral parts of the course materials, tests of student achievement were devised for each of the CBA and CHEM Study chemistry courses. The 1960-61 results showed that students were attaining the respective course objectives as reflected in the tests reasonably well. In an experimental study conducted by Heath and Stickell in 1961-62, students of CBA and CHEM Study (experimental) courses were matched against a group of randomly selected traditional students (control) on the basis of a three-way stratification--geographical, community size and sex

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[1]Robert W. Heath and Myron Wish, "A Test of Cognitive Preference,"(Princeton, N.J.: Educational Testing Serivce, 1963). Pp.15.(Mimeographed).

[2]Robert W. Heath, "Curriculum Cognition, and Education Measurement," Educational Testing Service Research Bulletin 63-6 (March, 1963), p. 18.

of teacher. On an end-of-year test designed to reflect differences in cognitive style, the groups taught by CBA and CHEM Study methods scored significantly higher. As would be expected, groups utilizing CBA and CHEM Study courses scored significantly higher on achievement tests of CBA and CHEM Study course, whereas traditional classes scored higher on a test designed to measure achievement on traditional course.[1] Similar findings to the latter expected findings were found with BSCS materials.[2]

There have been several studies of the ability of students taught by the NSF sponsored curricula to perform well both on tests devised specifically for their courses and on tests devised for the traditional courses. Traditionally taught students are unable to perform with the same degree of achievement on tests developed for the NSF curricula. Heath found this true of CBA[3]

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[1]Rcbert W. Heath and David W. Stickell, "Studies of Curriculum Effects on Achievement in High School Chemistry," Paper presented to The Association for Supervision and Curriculum Development, March 11, 1963, St. Louis, Missouri. Pp.7.(Mimeographed). [Also in "CHEM and CBA Effects on Achievement in Chemistry," <u>The Science Teacher</u>, XXX (September, 1963), 45-46.

[2]Hulda Grobman, "Student Performance in Hew High School Biology Course," <u>Science</u>, CXLIII (17 January, 1964), 265-66.

[3]Robert W. Heath, <u>A Study of Achievement in High School Chemistry: Report to the Chemical Education Material Study</u> (Princeton N. J.: Educational Testing Service 1962). Pp. 12.

and CHEM Study[1] students.

Similar results were found in another novel type of comparison between students of PSSC and traditional physics courses. Suggested by Friedman, the study sought to determine whether the PSSC curriculum fulfilled the objectives of providing the student with a clear understanding of the basic relationships underlying the observations of physical phenomena, PSSC students were supplied with an information sheet of appropriate traditional material and then tested on a traditional test, while non PSSC students supplied with a PSSC information sheet were administered a PSSC test. These crib-sheets were supplied for a period of one week prior to the examinations and also supplied during the examination.[2] "High aptitude PSSC students performed as well as or better than their traditionally-trained counterparts on the traditionally-oriented tests."[3] Low aptitude PSSC students appeared unable to utilize the supplied information. Non-PSSC students did not show any similar ability to score well on the PSSC test. It was concluded that "the PSSC course does

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[1]Robert W. Heath, A Study of Achievement in High School Chemistry: Report to the Chemical Bond Approach Project (Princeton, N.J.: Educational Testing Service, 1962). Pp. 12.

[2]Francis L. Friedman, "Report to the PSSC: A 'Crib Sheet' Study," Educational Testing Serice. Pp. 7 (Mimeographed).

[3]*Ibid*. p. 5.

achieve, at least to some degree, its stated objectives."[1]

De Rose investigated whether the attributes of knowledge, attitude and methods developed by students who had previously learned CBA chemistry or PSSC physics, were subsequently transferred when the other of these two courses was studied. He found no significant difference in performance in the CBA chemistry between those who had previously studied PSSC physics and those who had studied traditional physics, and vice versa. However, there was doubt expressed concerning the sample size, validity of the criterion instruments and other controls.[2] Added interest in this type of study derived from the efforts of two committees in Portland with NSF support to integrate PSSC materials with the CBA materials[3] and also with the CHEM Study materials.[4] The first evaluation of these projects is to be made in Summer, 1964.

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[1]Francis L. Friedman, "Report to the PSSC. . .,"Pp. 5-7.

[2]James V. De Rose, "Relationships Between Achievement in PSSC Physics and the CBAP Chemistry" (unpublished doctoral dissertation, University of Pennsylvania, 1962). Pp. 163, cited by Gibboney et al., Review of Educational Research, XXXIII, 283-84.

[3]Committee on the Integration of CBA and PSSC, Teachers' Guide for Physics-Chemistry: A Resource Book for a Two-Year Course. Prepared under grants from the National Science Foundation and the Portland School District #1, Portland, Oregon. Pp. 92 + appendix.

[4]Committee on the Integration of CHEMS and PSSC, Teachers' Guide for Physics-Chemistry: A Resource Book for a Two-Year Course, Prepared under grants from the National Science Foundation and the Portland School District #1, Portland, Oregon. Pp. 24.

Studies to establish superiority at college of students who had learnt from NSF supported curricula have been made both by Westmeyer[1] and the CHEM Study evaluators.[2] By matching,on the basis of mental ability and high school attended, thirty college students who had studied CBA chemistry at high school with thirty who had studied non-CBA chemistry, Westmeyer concluded that high school CBA students who proceeded to college were superior with respect to college grades, number of students motivated to continue studying science and in laboratory techniques (evaluated by self-rating scale).[3] However, Westmeyer's sample size, statistical procedures and evaluating techniques cast doubts on the validity of his results. In an admissions screening test administered to entering freshman at the University of California, Berkeley, both students who had been taught by the CHEM Study and those who had received traditional courses were administered a test which emphasized fundamentals and physical chemistry. It was concluded that

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[1]Paul Westmeyer, "Follow-up Study of Performance of Thirty CBA Course Graduates and Thirty Matched Non-CBA Course Graduate in College Chemistry," CBA Newsletter, II (January, 1963), 1-2.

[2]Chemical Education Material Study Newsletter, IV (February, 1964), 2-3.

[3]Westmeyer, CBA Newsletter, II, 1-2.

CHEM Study-prepared students enjoyed a distinct advantage on this examination.[1]

Summary and implications for Australian science curricula

In addition to their classroom feasibility trials, and in keeping with recommendations that evaluation should be integrated with curricula, groups responsible for developing the NSF supported curricula have each designed tests specifically to measure student achievement on the particular curriculum concerned. The BSCS and AAAS groups have developed tests which measure a wider range of behavioral changes. Such tests have made it possible to determine the ranges of student ability for which the curricula are most appropriate, and to modify curricula for the other ranges accordingly.

As the NSF supported curricula have objectives which differ from traditional courses, graduates from these courses have developed different abilities. This is reflected by research results. There is some evidence that the cognitive style of students of the new courses differs from students of traditional courses. Insofar as one of the major educational objectives discussed in Chapter III required the development of the ability to think, the NSF supported curricula may be more supportive of broad educational objectives than are the traditional courses.

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[1] Chemical Education Material Study Newsletter, IV, 2-3.

Recommendations

5.19. In developing new science curricula in Australia, techniques for evaluating the behavioral changes listed in the course objectives should be planned and stated clearly, concurrently with publishing the new curricula.

5.20. Before initiating curriculum change in Australia on a statewide basis, classroom feasibility should be tested by trying the new curricula experimentally with a stratified sample of schools throughout the state.

Curriculum Balance

Since NSF supported science projects have had the objective of improving specific content for specific subjects at fairly specific grade levels, the need for overall improvement of science K-12 within a school system has not received their special attention; nor has the relationship with other subjects been a major objective. However, in the child's overall school program, experiences should be

1. horizontally integrated;
2. vertically articulated.

The importance of integration of educational experiences lies largely in the cumulative and reinforcing effects of many learning experiences which may be interrelated. In a discussion of curriculum organization, Tyler indicated that concepts, skills, and values are three kinds of elements in a well-organized curricula which can be utilized to facilitate integration.[1] The possibility of achieving a high degree of integration is dependent upon efforts to promote curriculum coordination.

An obvious interrelationship between the various subject areas will facilitate transfer and concept formation. A soundly articulated K-12 science curriculum should present new subject matter and processes so that they will be developed concurrently with the child's developing abilities, and so that an appreciation of the structure of the subject emerges.

In keeping with its objective to encourage a diversified approach to improving courses content, the NSF sponsored curricula cover a diverse range of topics in several areas of science (e.g., biology, chemistry, earth science, physics). It is the task of the school system to achieve the desired degree of integration and articulation. In seeking integration and articulation, the State Education Departments in Australia have the administrative organization to achieve a high degree of coordination during the process of curriculum development.

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[1]Ralph W. Tyler, "Curriculum Organization," _The Integration of Educational Experiences_, The Fifty-Seventh Yearbook of the National Society for the Study of Education, Part III, Paul L. Dressel (Chairman) (Chicago: The National Society for the Study of Education, 1958), pp. 105-25.

Recommendations

5.21. A curriculum coordinator with a knowledge of the interrelations of the subjects of the school program should be part of any team concerned with curriculum revision in each subject. It shall be the role of this coordinator at science curriculum project meetings to advise on interrelationships of science with other subjects, so as to facilitate horizontal integration of all subjects at a particular grade level.

5.22. A science supervisor with a knowledge of the overall structure of the K-12 science program should be part of any team concerned with science curriculum revision. It shall be the role of the supervisor to advise on the vertical organization of science subjects, so that the structure of these subjects will be presented both most meaningfully to the students and most accurately in terms of the current state of science as an academic discipline.

Social Significance of Science Education

Concern of NSF supported curricula with the improvement of specific course content has precluded attention to some broader concerns of science education. One such concern should be the social and moral significance of science. The applications of scientific advances to the advantage of mankind--on the international level, in particular, to the raising of living standards of the emerging nations--demands of our future citizens a thorough understanding and appreciation of the social significance of the findings of science and technology. As Waterman stated:

> Whether future developments take the form of stupendous power over nature's resources, of influence and control over life or over men's minds, or of traffic with our sister planets, they will in all

> probability raise problems of such concern to the human race that mankind must--repeat must--learn to cooperate in their solutions.[1]

The international and social aspects of science have typically been neglected as concerns of science education curricula, and likewise have not been intensively considered in other subject areas. The reduction of technology in the NSF supported curricula makes more remote the probability of the discussion of the social significance of technological advances. Yet, the need for responsible action as part of the expectations of the scientist's role in today's society is increasing. Eisenhower emphasized this view point. He stated:

> The time has passed when any scientist can maintain that his task is solely the pursuit of pure knowledge without regard for the uses or abuses of that knowledge. . . . Scientists as human beings must accept a responsibility to see that their knowledge and techniques serve the cause of humanity as well as the cause of science. . . . The scientist is playing an increasingly important role in our political and social life. As a society, we are becoming more and more dependent on his advice and his leadership.[2]

Assuming that science education is to reflect what the scientist does, our science curricula should also be responsible for inculcating social and moral values.

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[1]Alan T. Waterman, "Science in the Sixties," American Scientist, XLIX (March, 1961), 8.

[2]Milton S. Eisenhower, "The Third Scientific Revolution," Address delivered at the National Science Fair, Baltimore, Maryland, May 6, 1964, pp. 6-7. (Mimeographed).

Recommendation

5.23. Through specially designed experiences in science, or through arrangement with those responsible for the social studies curriculum, or by other appropriate means, intensive efforts should be made to inculcate

(a) an understanding of the international significance of science and technology;

(b) an understanding of the moral and social responsibilities of the scientist.

Nationally Determined Elements of Science Curricula

The NSF required that courses sponsored by it should have wider than local significance. One outcome of this policy has been the adoption of these courses in several overseas countries. This reflects the fact that science education, like science itself, is based largely upon elements of international significance.

Nevertheless, there are certain unique characteristics of Australia as an isolated underdeveloped continent. These suggest that there may be certain unique contributions that science education can make to the future development of the nation. In 1951, on the occasion of Australia's jubilee year, a seminar entitled Science in Australia was organized at which some potential contributions of science were discussed. After describing the nature of the land, the utilization of science in Australia was described thus:

> Science applied to the primary industries has flourished in Australia, while the more academic aspects have received far less support.[1]

This application of science to problems of primary industry has been reinforced by support from the government and farmers for furthering the activities of the Commonwealth Scientific and Industrial Organization (CSIRO). The CSIRO established itself as the dominant feature of Australian science, and has produced research of outstanding importance to primary industry.[2]

The role of science in Australia has remained closely geared to its developing industries and resources. Sir Frederick White indicated this in describing a policy for Australian science in his ANZAAS presidential address. Potential contributions of science included research in the following areas: in biology and agriculture related to the main producing industries--wool, wheat, cattle and beef, dairy products, tobacco,--making wool and leather superior to artificially-produced competitive substances, diversification and improvement of the markets for dairy products, meat and foods, improved procedures for

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[1]_Science in Australia: Proceedings of A Seminar Organized by the Australian National University on the Occasion of the Jubilee of the Commonwealth of Australia, Canberra, July 24-27, 1951_, eds. M. L. Oliphant and H. G. Oliphant (Melbourne: F.W. Cheshire, 1952), p. vii.

[2]_Ibid._, p. vi.

discovering and recovering mineral resources.[1] By his remarks, White provided a number of suggestions relevant to the development of Australian science curricula. White said:

> Scientific discovery must have a real and living influence on the progress of industry and agriculture. It must, therefore, be part of the thinking and action of industry and of Government.
>
> Australia cannot leave science to develop in the hope that its influence will spread like an infection. A more deliberate approach is imperative.[2]

That these are technological rather than academic foci may reflect an emphasis necessary in Australian school science curricula which NSF sponsored courses have attempted to reduce. This may imply a cultural limitation on one aspect of science education, and certainly this requires consideration in the planning of Australian science curricula.

Recommendation

5.24. In developing Australian science curricula, consideration should be given to those elements of science which are unique to the Australian culture.

Summary

From a consideration of curriculum innovations in U.S.A. and the existing needs of Australian science education,

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[1]Sir Frederick White, "The Strategy of Australian Science," The Australian Journal of Science, XXVI (January, 1964), 191-94.

[2]Ibid., p. 191.

implications for improving Australian curricula and curriculum procedures have been established. As a result, one additional recommendation is presented:

Recommendation

5.25. Procedures utilized by NSF sponsored science curricula should be closely examined by those responsible for developing curricula in Australia with a view to selecting and adapting elements which may have promise for Australian curriculum development.

CHAPTER VI

DEVELOPMENT OF AN AUSTRALIAN SCIENCE CURRICULUM MODEL

This chapter presents a curriculum model for Australian science based upon a synthesis of the recommendations made and upon implications described in previous chapters. The model conforms to a definition of educational models synthesized from several sources of educational theory. Earlier recommendations are also drawn upon to develop a mechanism for the implementation of the model.

Characteristics of Models

The widespread use of the word model in various contexts suggests that in order to avoid ambiguity,[1] it is necessary to define the way in which the word is to be used in relation to curricula. Meadows has indicated the confusion arising from the various connotations given to model, writing:

> This word is a roving beam that spotlights such various things as experimental design, postulate sets, deductive paradigms, theories, concepts, even language itself.[2]

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[1]c.f., May Brodbeck, "Logic and Scientific Method in Research on Teaching," Handbook of Research on Teaching, ed. N. L. Gage (Chicago: Rand McNally & Company, 1963), p. 88.

[2]Paul Meadows, "Models, Systems and Science," American Sociological Review, XXII (February, 1957), 1.

Parsons endeavored to extract the common elements from these several meanings, stating:

> The most general sense of the term model seems to be that of an "ideal type" of structure or process, arrived at by hypothetical reasoning from theoretical premises, which is then used, through comparison with empirical data, to analyze such data. In this meaning, model seems to be almost identical with theoretical scheme.[1]

Griffiths wrote:

> The impression gained from a reading of the literature and from listening to social scientists is that any somewhat systematic presentation of ideas is a model.[2]

Brodbeck said that models may be used as isomorphic theories.[3] She explained:

> When an area about which we already know a good deal is used to suggest laws for an area about which little is known, then the area providing the form of the laws may be called a model for the new area.[4]

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[1]Talcott Parsons, "An Approach to Psychological Theory in Terms of the Theory of Action," Psychology: A Science, ed. Sigmund Koch (New York: McGraw-Hill, 1959), III, p. 695.

[2]David E. Griffiths, "Some Assumptions Underlying the Use of Models in Research," Educational Research: New Perspectives, eds. Jack A. Culbertson and Stephen P. Hencley (Danville, Illinois: The Interstate Printers and Publishers, Inc., 1963), p. 122.

[3]May Brodbeck, "Models, Meanings and Theories," Symposium on Sociological Theory, ed. Llewellyn Gross (Evanston, Illinois: Row, Peterson and Company, 1959), p. 379.

[4]Brodbeck, Handbook of Research on Teaching, p. 88.

Deutsch regarded a model as "sets of symbols and operating rules. . .[having] some structure, i.e., some pattern of distribution of relative discontinuities and some 'laws' of operation."[1] According to Zetterberg, a model prcvides a method of interrelating several propositions.[2]

Meadows distinguished three roles of models, namely: "pictorial or representational (or descriptive), explicative, and verificatory."[3] Of the descriptive role, Toulmin stated:

> The heart of all major discoveries in the physical sciences is the discovery of novel methods of representation, and so of fresh techniques by which inferences can be drawn--and drawn in ways which fit the phenomena under investigation.[4]

The relating of these functions more specifically to educational models and to the curriculum area was provided by statements of Tyler, Beauchamp and Caswell. The structural form of an educational model was suggested by Tyler's statement of the function, nature and usefulness of a model. This statement appears relevant to the development of a curriculum model. Tyler wrote:

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[1]Karl W. Deutsch, "Mechanism, Organism and Society: Some Models in Natural and Social Science," Philosophy of Science, XVIII (July, 1951), 230-31.

[2]Hans L. Zetterberg, On Theory and Verification in Sociology (Totowa, New Jersey: The Badminster Press, 1963), p. 10.

[3]Meadows, American Sociological Review, XXII, 8.

[4]Stephen Toulmin, The Philosophy of Science (London: Hutchinson's University Library, 1953), p. 34.

> What gives it [the classroom] meaning for the investigator of classroom instruction is a "model" which he conceives, a simplified picture of the structure and process of classroom instruction. This model usually includes such elements as a teacher, pupils, objectives of instruction, methods of teaching, materials of instruction, learning outcomes. If he holds such a model in mind, he has a basis for focusing his observations and for arranging and analyzing his data. This development of a formal model provides a way of viewing the complex phenomena in a fashion which permits scientific study. Models serve to simplify a process which appears on the surface to be too varied or complex or haphazard to be understood.[1]

Beauchamp characterized a general curriculum model for the elementary school as being "logically derived and at least partially tested in operation."[2]

Caswell stated:

> The development of sound curriculum theory involves a major task of synthesis and interpretation of basic principles from a variety of fields.[3]

Herrick gave further guidance for the development of a curriculum model, stating:

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[1]Ralph W. Tyler, "The Contribution of the Behavioral Sciences to Educational Research," First Annual Phi Delta Kappa Symposium on Educational Research, ed. Frank W. Banghart (Bloomington, Indiana: Phi Delta Kappa, Inc., 1960), p. 57.

[2]George Beauchamp, Curriculum Theory (Wilmette, Illinois: The Kagg Press, 1961), p. 97.

[3]Hollis L. Caswell, "Sources of Confusion in Curriculum Theory," Paper presented at the Conference on Curriculum Theory Held at the University of Chicago October 16 and 17, 1947, in Toward Improved Curriculum Theory, eds. Virgil E. Herrick and Ralph W. Tyler, Supplementary Educational Monograph, Number 71 (Chicago: The University of Chicago Press, 1950), p. 111.

> A curriculum design becomes more usable in improving educational programs if it has, as its major organizational programs if it has, as its major organizational focus, the problem of selecting, organizing, and teaching the learning experiences of children and youth.[1]

Criteria for a Curriculum Model

Extracting from the statements of characteristics of models described in the previous section those definitional elements which appear appropriate for the development of a curriculum model it is concluded that a curriculum model should:

1. provide a theoretical scheme;[2]
2. contain a systematic presentation of ideas;[3]
3. apply what is known from several known areas to a new area;[4]
4. create a structure containing a set of symbols and operating rules, to provide operational laws and a pattern of distribution for relative discontinuities;[5]
5. provide a method of interrelating several propositions.[6]
6. provide a novel, pictorial representation, suggestive of fresh techniques;[7]

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[1] Virgil E. Herrick, "The Concept of Curriculum Design," Toward Improved Curriculum Theory, p. 44.

[2] Parsons, in Psychology: A Science, III, 695.

[3] Griffiths, in Educational Research: New Perspectives, p. 122.

[4] Brodbeck, in Symposium on Sociological Theory, p. 379.

[5] Deutsch, Philosophy of Science, XVIII, 230-31.

[6] Zetterberg, On Theory and Verification in Sociology, p. 10.

[7] Toulmin, The Philosophy of Science, p. 34.

7. include such elements as the teacher, pupils, instructional objectives, teaching methods, instructional materials and learning outcomes;[1]

8. be logically derived;[2]

9. involve synthesis and interpretation of basic principles from a variety of fields;[3]

10. focus on the problem of selecting, organizing, and teaching the learning processes of children youth.[4]

From this set of criteria, it follows that a science curriculum model may be produced through the logical derivation of a pictorial representation in which the appropriate elements of the several areas considered in the earlier chapters are systematically interrelated. Before establishing the model, it may be helpful to collate the recommendations cited in the earlier chapters.

Summary of Recommendations

2.01. A governmental agency, the Australian Science Education Foundation (ASEF) should be established for the support and encouragement of significant efforts to improve science education.

2.02. The ASEF should comprise representatives selected from such scientist and educator organizations as the Australian Academy of Science, Australia, and New Zealand Association for the Advancement of Science (ANZAAS), the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian Atomic Energy

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[1]Tyler, First Annual Phi Delta Kappa Symposium on Educational Research, p. 57.

[2]Beauchamp, Curriculum Theory, p. 97.

[3]Caswell, Toward Improved Curriculum Theory, p. 111.

[4]Herrick, Toward Improved Curriculum Theory, p. 44.

Commission (AAEC), the Australian National University, the Australian Council for Educational Research (ACER), the Australian Science Teachers' Association (ASTA), the Commonwealth Office of Education, the Australian Teachers' Federation and state Education Departments. In addition, the interest displayed by industry in science education warrants representation of the Australian Industries Development Association (AIDA).

2.03. The Australian Science Education Foundation should generate studies through its component and other appropriate organizations to identify factors such as a philosophy for science education in Australia, the objectives of science education, overseas curriculum practices with implications for Australia, and science elements unique to the Australian culture; and should support research related to such factors as the determination of appropriate content and skills for science curricula, and factors related to the learner, the teacher, and classroom practices.

2.04. Federal funds should be allocated through the ASEF for the development of science curricula of national importance.

2.05. Further allocations of federal funds to schools through the Advisory Committee on Science Facilities for the improvement of science laboratories should be made dependent upon receipt of evidence of sound programs of science education as a major criterion.

2.06. A Science Resource Center should be established in each Australian state for the purpose of obtaining, reviewing, and displaying materials of the NSF supported projects developed in the U.S.A., in addition to other relevant materials from the U.S.A. and other countries.

2.07. Mechanisms should be sponsored by the ASEF in each Australian state for the continual review of developments in other states and of contemporary developments of significance in other countries of the world, particularly the U.S.A. Such mechanisms may include provisions for:

(a) attendance by Australian science educators at NSF sponsored workshops;

(b) regular visits to Australia of directors and other senior officers of U.S.A. science curriculum projects;

(c) study tours in the U.S.A. by science education leaders and officers of the state Education Departments responsible for science education;

(d) appointment of an Australian educational attaché in the U.S.A. to advise Australians on contemporary educational developments in the U.S.A.;

(e) subsidy of systematic trials of curricular innovations under Australian conditions.

2.08. Australian science curricula, including all necessary accompanying materials, should be developed in Australia by procedures similar to those in the U.S.A. which utilize the best manpower and practices known.

2.09. These curricula should be made available for voluntary selection and adaptation by the schools of Australia.

2.10. Studies such as Brickell's New York State study[1] should be conducted for the purpose of determining those factors shich would encourage the invention and adoption of new science education programs in Australian states.

2.11. Opportunities for teaching and studying by Australian science teachers in the U.S.A. should be extended so as to facilitate an earlier and firsthand knowledge of U.S.A. developments in science education.

2.12. Experimental schools should be established for the purposes of experimentation with innovations.

2.13. Procedures selected from NSF sponsored curricula should be subjected to Australian trials under varying conditions in experimental schools.

2.14. Demonstration classrooms should be established in regular schools in which selected new programs should be taught by teachers who have attended programs (e.g., NSF institutes) designed to facilitate the introduction of innovation.

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[1]Brickell, Organizing New York State. . . . Pp. 107.

3.01. The specification of educational objectives in Australia should take into account the following principles:

(a) The specification of educational objectives required the expression of the educational preferences of a community, i.e., of value judgments;

(b) These objectives should be derived from a consideration of philosophical (to reflect the value system), sociological (to reflect cultural determinants) and psychological (to reflect the conception of individuals) factors.

(c) The reliability of the objectives may be increased by increasing the degree of involvement of the community in specifying the broad objectives.

3.02. Educational organizations cognizant of the above principles such as the Commonwealth Office of Education, Australian College of Education, Australian Council for Educational Research, Australian Teachers' Federation and the State Education Departments should assume responsibility for convening periodically meetings of delegates from as wide a range of organizations as practicable for the purpose of identifying sets of broad educational objectives for Australia.

3.03. The above organizations should also assume responsibility for translating the broad educational goals into specific objectives which will assist those responsible for the development of curricula.

3.04. The validity of a set of objectives for the teaching of science in Australia may be increased when such objectives are specified by a team comprising scientists, educators and psychologists, collaborating so as to maximize their appropriate roles. The roles are:

(a) scientists to identify content and its structural form, and processes;

(b) educators to determine teachability, practicability and methodology for teaching; and to relate science education objectives to the broader educational objectives;

(c) psychologists to screen processes, contents and methods selected by above, and to determine the appropriateness of age and grade placement.

3.05. The science curriculum should outline experiences which recognize the wide range of individual differences that exist in groups of children. These diferences may be with respect to intelligence level, rate of working, interests, attitudes, skills, etc. In order to cater for these differences and yet remain within the limits of practicability in the classroom, a variety of content, activities and methodology is recommended. The use of a common core of experiences in conjunction with open-ended branches from those experiences may provide for some individual differences. The use of the science laboratory is ideally suited for such outcomes.

3.06. Science curricula should promote student thinking. The use of open-ended laboratory lessons appears ideally suited for promoting thinking.

3.07. More precise specifications of the behaviors which constitute good citizenship, ideal vocation and profitable use of leisure are needed before the role of science education can facilitate their accomplishment.

3.08. To reflect the nature of science, science education curricula should place emphasis on experimentation, observation and creative thinking.

3.09. Attempts should be made to specify more closely the work which scientists perform, through such techniques as job analyses. Appropriate skills from the scientist's task should be incorporated as part of school science curricula.

3.10. The broad objectives of education and of science should provide guidelines for determining the objectives of science education.

3.11. Since the objectives of science education change periodically, a mechanism for providing frequent review of these is important for the development of new science curricula.

3.12. Current consensus indicates that the major objectives of science education are:

(a) Knowledge of the structure of science, as reflected by broad concepts;

(b) Facility with the processes of science, as reflected by an ability to act as scientists act.

3.13. The spelling out of objectives of science education in terms of changes of behavior sought, has facilitated the development of valid curricula and evaluation techniques. The ASTA should assume responsibility for this task.

3.14. There exists a definite need for the identification of the major concepts which provide the structures of each of the sciences. This task may be promoted under the proposed Australian Science Education Foundation through the various organizations of scientists.

3.15. There exists a definite need for the accurate specification (e.g., by job analyses) of the range of processes performed by a range of scientists. This task may be promoted under the proposed Australian Science Education Foundation.

3.16. The utilization of a team approach to the construction of curricula must take cognizance of the tasks for which collaborators possess special competencies.

3.17. A change in science education objectives necessitates a number of concomitant changes, as follows:

(a) development of new curricula to reflect the new objectives;

(b) development of valid evaluation instruments both for measuring changes of student behaviors and for determining the effectiveness of the new courses;

(c) changes in pre-existing teacher education procedures;

(d) provision of courses for updating classroom teachers;

(e) provision of a full range of new instructional materials (books, apparatus, audiovisual aids, etc.);

(f) provision for involvement of affected personnel in decisions leading to new curricula;

(g) provision for obtaining feedback of the reactions of teachers, pupils and the community;

(h) provision of public relations action to promost acceptance of the new programs.

4.01. The Australian Science Education Foundation should encourage and support significant research studies in the field of science education. Findings from these studies should be made available to those responsible for developing science curricula.

4.02. The Australian Science Resource Centers should obtain and review science education research reports which emanate in the U.S.A.

4.03. The Australian Science Education Foundation should enlist the assistance of professional scientists in identifying the major principles to be taught in Australian school science, and of psychologists in assisting with psychological aspects of grade placement.

4.04. Since particular skills can be imparted best when specific learning situations are designed to develop Those skills, Australian science curriculum makers should incorporate into the curricula techniques which facilitate the direct teaching and learning of those skills listed in the behavioral objectives of the curriculum.

4.05. Teacher training should attempt to develop teacher behaviors appropriate to curriculum objectives. For example, consideration should be given to providing that training which is most likely to make the teacher more effective in directing the discovery method of pupil learning.

4.06. Research to develop valid and reliable evaluative techniques for a range of the behavioral objectives specified within science curricula should receive an urgent priority. The Australian Council for Educational Research is well equipped to direct this research, Australian science curriculum makers should incorporate such evaluative techniques at appropriate points within the curricula.

4.14. Science curricula should be developed for Australian elementary schools utilizing the results of the proposed survey of psychology to assist in developing an appropriate process approach.

5.01. The ASEF should institute a series of experimental science programs for the purpose of determining optimal programs of science education for Australian elementary schools.

5.02. Australian teachers who so desire should be granted permission to replace nature study courses by elementary science courses.

5.03. The ASEF should be provided with a budgetary allocation by the Commonwealth Government for the support of science curriculum projects.

5.04. The Science Teachers' Associations should seek financial support from industry and from private foundations to support specific projects, such as the provision of teaching aids, filmstrips, and films.

5.05. Curriculum development in Australia should be conducted on a full time basis by teams released from other responsibilities.

5.06. Soliciting the active support of top rank scientists from all fields (e.g., through ANZAAS and CSIRO) to work with Australian science curriculum committees, especially in the identification of course content and in translating the broad purposes of science into specific objectives is strongly recommended.

5.07. Science curriculum content should be screened through discussions with psychologists with knowledge of the abilities of children, and by teachers with their knowledge of classroom practicability and feasibility.

5.08. The curriculum as published should promote and encourage teachers to adapt the published versions to local conditions and needs. Increased provision for involvement of classroom science teachers in curriculum reforms should also be provided in Australia by such mechanisms as the provision of feedback questionnaires and utilization of the responses so obtained.

5.09. Australian curriculum development procedures should include provisions for the preparation of a wide range of materials, including textbooks, and/or multiple reference materials, films and single concept loops, filmstrips, teaching guides, laboratory manuals, enrichment materials, the designing of special apparatus, and the preparation of valid testing instruments.

5.10. The philosophy of Australian science curricula should reflect the thinking of scientists and educators as to what constitute the purposes of science education for all Australian children. The ASEF should arrange a conference of scientists and educators to formulate a philosophy of science education.

5.11. If a detailed consideration of all relevant issues indicates that science education is to teach children to act as scientists act, then some scientific method such as thorough job analyses of practicing Australian scientists should be utilized to determine their practices.

5.12. Objectives should be stated in behavioral form, in order to facilitate the processes of curriculum construction and evaluation.

5.13. The objectives of science education should be diversified enough to facilitate individualization of instruction, and should provide for mechanisms of motivation.

5.14. Groups of Australian scientists should be invited by the ASEF to identify integrative concepts for Australian science curricula.

5.15. The ASEF should investigate the possibilities of establishing inservice training to update the knowledge and skills of Australia's science teachers. Both academic year and summer courses should be considered.

5.16. Teacher education (re-education) and attitudes of acceptance and enthusiasm are prerequisites to the success of educational innovation. Special programs in Australia to promote these factors should be arranged by the ASEF.

5.17. The ASEF should sponsor pre-service and inservice courses at the universities for science teachers. These courses should prepare teachers to:

(a) arrange situations in which student problem solving will be required;

(b) conduct open-ended types of lessons, in which instruction is individualized;

(c) be permissive to the extent that student errors may occur, but to know the content so that potential hazards or dangers may be foreseen and prevented;

(d) evaluate in terms of creativity and initiative, rather than in terms of conformity to predetermined techniques.

5.18. If science education is to reflect the work of the scientist, then there is a need for science teachers to work alongside scientists to understand better the nature of their tasks. Either for part of each year, or for a complete year every several years, the ASEF should provide fellowships which would free science teachers from their classroom teaching to work in the laboratory with scientists. In addition, opportunity for extended contact with scientists should be provided, perhaps through regular meetings or conventions of the science teachers' associations.

5.19. In developing new science curricula in Australia, teachniques for evaluating behavioral changes listed in the course objectives should be planned and stated clearly, concurrently with publishing the new curricula.

5.20. Before initiating curriculum change in Australia on a statewide basis, classroom feasibility should be tested by trying the new curricula experimentally with a stratified sample of schools throughout the state.

5.21. A curriculum coordinator with a knowledge of the interralations of the subjects of the school program should be part of any team concerned with curriculum revision in each subject. It shall be the role of this coordinator at science curriculum project meetings to advise on interrelationships of science with other subjects, so as to facilitate horizontal integration of all subjects at a particular grade level.

5.22. A science supervisor with a knowledge of the overall structure of the K-12 science program should be part of any team concerned with science curriculum revision. It shall be the role of the supervisor to advise on the vertical organization of science subjects, so that the structure of these subjects will be presented both most meaningfully to the students and most accurately in terms of the current state of science as an academic discipline.

5.23. Through specially designed experiences in science, or through arrangements with those responsible for the social studies curriculum, or by other appropriate means, intensive efforts should be made to inculcate

(a) an understanding of the international significance of science and technology;

(b) an understanding of the moral and social responsibilities of the scientist.

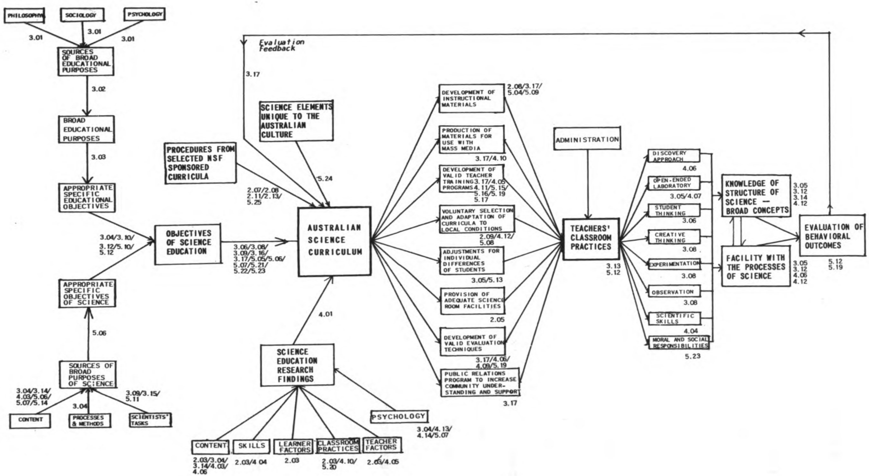
5.24. In developing Australian science curricula, consideration should be given to those elements of science which are unique to the Australian culture.

5.25. Procedures utilized by NSF sponsored science curricula should be closely examined by those responsible for developing curricula in Australia with a view to selecting and adapting elements which may have promise for Australian Curriculum development.

The Model and Its Implementation

Based on the recommendations above, an Australian science curriculum model was developed, and is shown in Figure 1. The model indicates that the objectives of science education are derived from a consideration of the sources of broad educational purposes and the broad purposes of science. The Australian science curriculum is developed by synthesizing factors related to these science

Figure 1.--An Australian Science Curriculum Model (The numbers are keyed to recommendations contained in this thesis.)

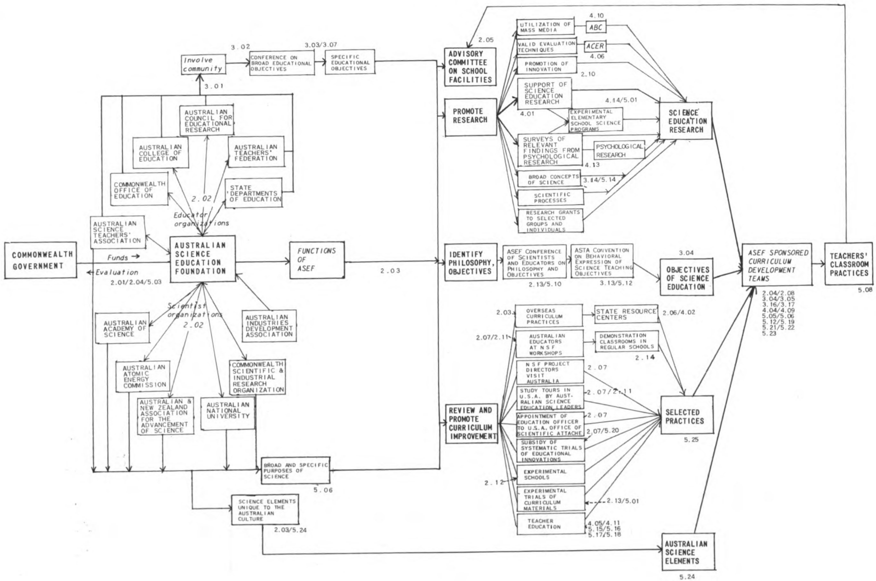


education objectives, with factors related to procedures from selected NSF sponsored curricula, science elements unique to the Australian culture, science education research from several areas, and knowledge of the results obtained from an evaluation of behavioral outcomes of classroom teaching of science (evaluation feedback).

The ramifications of the development of an Australian science curriculum are shown to extend into several areas, necessitating such steps as the development of instructional materials, new teacher training programs, and of evaluation techniques. These several areas jointly influence the teacher's classroom practices. However, the practices will fall within certain guidelines provided by the curriculum model. Resulting from these practices, students should develop a knowledge of the structure of science and a facility with the processes of science. The effectiveness of the curricula will be evaluated, and will influence the development of subsequent curricula.

Figure 2 presents suggested mechanisms for the implementation of this model. The composition of the proposed Australian Science Education Foundation is shown at the left of the figure, and its functions are shown at the right.

Figure 2.--Suggested Mechanisms for the Implementation of an Australian Science Curriculum Model (The numbers are keyed to recommendations contained in this thesis.)



Interpretation of Australian Science Curriculum Model: Figure 1

The development of a science curriculum from the model presented in Figure 1 requires the prior identification of a number of guidelines. These guidelines are shown in Figure 1 to be the objectives of science education (3.13)[1], procedures from selected NSF sponsored curricula (5.25), science elements unique to the Australian culture (5.24) and the findings of science education research (4.01).

As indicated in Figure 1, the objectives of science education (3.10) are derived from the broad purposes of education and of science. The sources of the broad purposes of education (3.01) lie in:

1. philosophy, which determines the value system;
2. sociology, which indicates cultural determinants; and
3. psychology, which provides a conception of the individuals for whom the curriculum is determined.[2]

These broad objectives of education are to be determined periodically by conferences arranged by educational

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[1]Note: As in Figures 1 and 2, the numbers provided in this interpretation are keyed to the appropriate recommendations which are summarized earlier in this Chapter.

[2]Ralph W. Tyler, Basic Principles of Curriculum and Instruction (Chicago, Illinois: University of Chicago Press, 1963), pp. 3-28.

organizations. Delegates from as wide a range of organizations as practicable (3.02) are to be invited, so as to reflect the expression of the community which the curriculum is to serve. The more specific educational objectives of value for curriculum construction are then to be selected from the broad objectives by conferences of the educator organizations (3.03).

The broad purposes of science lie in the identification of

1. the content of science (3.04, 3.14, 5.06, 5.14);
2. the processes and methods of science (3.04); and
3. the tasks performed by the scientist (3.09, 3.15, 5.11).

The content and methods of science are to be identified by representative groups of scientists (5.06), and the scientists' tasks identified by some scientific method such as a thorough job analysis of the work performed by practicing Australian scientists (5.11). Translation of these broad objectives of science into appropriate specific objectives is a task for scientist organizations (5.06). The two sets of appropriate specific objectives (of education and of science) together determine the objectives of science education (3.10, 3.12, 4.07, 5.23). Some of these objectives were described in Chapter III.

Science education research findings of relevance to curriculum construction are derived from six main areas, listed in Figure 1 as content, skills, learner factors, classroom practices and teacher factors (2.03), together with relevant findings from psychology (4.13). Many of these findings were described in Chapter IV. Appropriate procedures from selected NSF sponsored curricula (5.05, 5.06, 5.07, 5.09, 5.14, 5.15, 5.20, 5.25) as described in Chapter V, science elements unique to the Australian culture (5.24) as discussed briefly in Chapter V, and the feedback provided by the evaluation of behavioral outcomes (5.08, 5.12, 5.19) constitute the remaining elements presented in the model as necessary for synthesizing an Australian science curriculum. From the above factors, the curriculum is developed by the mechanism shown in Figure 2.

Once the Australian science curriculum is developed, its utilization by the science teacher in the classroom will be determined by a number of interposed factors. These factors, as shown in Figure 1, include:

development of instructional materials (2.08, 3.17, 5.04, 5.09);

production of materials for use with mass media (3.17, 4.10);

development of valid science teacher training programs (3.17, 4.05, 4.11, 5.15, 5.16, 5.17, 5.18);

voluntary selection and adaptation of curricula to local conditions (2.09, 4.12, 5.08);

adjustments for individual differences of students (3.05, 5.13);

provision of adequate science room facilities (2.05); and the

availability of valid testing techniques (3.17, 4.06, 4.09).

In addition, the model proposes that the community should be appraised of the nature of the science curricula (3.17).

Another factor indicated in the model which has considerable bearing on how the Australian science teacher will utilize the curriculum is the administration. The science inspectors and the school principal exert a major influence on classroom practice. These influences, and those of the other factors above, should influence teaching practices. These practices may also be determined to a large extent by several methodological aspects of the curriculum arising from recommendations from which the model was synthesized. These include the use of the discovery approach (4.06), open-ended laboratory exercises (3.05, 4.07), exercises involving thinking (3.06) particularly of a creative kind (3.08), emphases on experimentation and observation (3.08), upon the development of scientific skills (4.04), and upon understandings of the international significance of science and technology, and of the moral and social responsibilities of the scientist (5.23). The outcome of these methods should be to provide students with a knowledge of the structure of science and its broad concepts (3.05, 3.12, 3.14, 4.12), and with a facility with the processes of science (3.05, 3.12, 4.06, 4.12).

The effectiveness of the curriculum in effecting the behavioral changes sought will be evaluated through measuring student behavioral changes (5.12, 5.19). The nature of these changes may suggest needed modifications in the curriculum (3.17).

Interpretation of the Mechanism for Implementing the Curriculum Model: Figure 2

Figure 2 presents mechanisms for implementing the Australian science curriculum model. The proposed Australian Science Education Foundation (ASEF) (2.01) is shown to be composed of representatives of a number of existing educator and scientist organizations (2.02). The relationship between the ASEF and its component educator and scientist organizations is a reciprocal one. The organizations constitute the ASEF (2.02). In turn, the formation of the ASEF will provide additional activities for these organizations (e.g., 3.02, 3.03, 3.14, 4.06, 4.10, 5.06, 5.14). For example, the educator organizations are shown to be responsible for the involvement of the community in conferences to determine the broad educational objectives (3.02), and subsequently in selecting appropriate specific educational objectives (3.03); the scientist organizations are responsible for selecting appropriate specific objectives of science (5.06) and for identifying those science elements unique to the Australian culture (2.03, 5.24).

Broadly, the functions of the proposed ASEF (2.03) are to select and sponsor groups:

1. to promote and review research which may have relevance for science curriculum construction;
2. to identify the philosophy and objectives of science education;
3. to review and promote curriculum improvement.

In addition, the ASEF would maintain liaison with the existing Advisory Committee on School Facilities. Figure 2 shows more detailed mechanisms for implementing these ASEF functions.

The ASEF will thus operate through a number of existing organizations and will coordinate their contributions to the broad improvement of science education. The outcome of these mechanisms should be to provide the basic information required by the ASEF sponsored curriculum teams (2.04, 2.08, 3.04, 3.16, 5.05, 5.06, 5.21, 5.22) in the development of science curricula for use in Australian schools.

Evaluation of the Curriculum Model

Techniques for evaluating the curriculum model are suggested in statements by Beauchamp, Sand, and Goodlad. Beauchamp's suggested technique for evaluating a curriculum model was

> whether a curriculum can be planned from it, placed into practice, and modified or confirmed by the experience of practice.[1]

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[1]Beauchamp, Curriculum Theory, p. 121.

It has not been the intent in this thesis to develop a curriculum itself, for, as has been indicated, this may be most effectively done by an appropriate team. However, the model and the implementation techniques strongly suggest that Beauchamp's criteria would be satisfied by the use of the techniques shown in Figures 1 and 2.

Sand has described criteria for evaluating the effectiveness of a curriculum. Sand's criteria related to 1. the objectives; 2. the learning experiences; 3. the evaluation program; and 4. the process used for improving the curriculum.[1]

1. The objectives--will have a high validity, according to Tyler, if they reflect child growth and development findings, contemporary society, contemporary thinking of scientists, philosophical values, and the principles of learning.[2] In the curriculum model presented, these factors are basic to the determination of the objectives of science teaching; so that a curriculum based upon the model should have highly valid objectives.

2. The learning experiences--are evaluated by Sand as being effective if they are appropriate to their objectives,

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[1]Sand, Improving the Social Studies Curriculum, pp. 236-254.

[2]c.f., Tyler, Basic Principles. . ., pp. 3-40.

they facilitate the teaching of the behaviors sought, they emphasize various teaching methods, and in terms of their relationship to other grade levels and subjects, emphasis on major content principles and the structure of the sciences, and organization into broad resource units.[1] Learning experiences developed from the model and the recommendations made in this thesis should satisfy each of Sand's criteria of effectiveness.

3. The evaluation program--may be judged according to the statement of purposes of the evaluation, the availability of a range of techniques to evaluate the full range of behaviors, and provision for self-evaluation and continuous evaluation.[2] The model and its recommendations should ensure an effective evaluation program based on these criteria.

4. The processes used in curriculum improvement--may be evaluated according to the identification of the tasks required, the appropriate involvement of participants, the development of leadership, and provision for continued curriculum evaluation.[3] The implementation of the model in the manner suggested in this thesis should ensure that the processes utilized will be effective.

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[1]Sand, Improving the Social Studies Curriculum, p. 248.

[2]Ibid.

[3]Ruth Ellsworth, "Processes Used in Improving the Social Studies Curriculum," Improving the Social Studies Curriculum, pp. 254-264.

A third type of evaluation of the curriculum model presented in this chapter is provided through a set of questions developed by Goodlad. He considered that a sound system for curriculum development should provide answers to the following:

1. What sources are pertinent for determining educational objectives? What is the relative significance of these sources?

2. How should the desirability of specific objectives be determined? How should the feasibility of attaining these objectives be determined?

3. What is the usefulness of a statement of educational objectives in making other curriculum decisions?

4. What components must be considered in organizing the curriculum for effective learning?

5. How much synthesis of these components can and should be effected for the teacher before he begins his teaching?

6. What elements, if any, are common to all major curriculum questions and thus provide theoretical links throughout the entire conceptual system?

7. At what points in the system should consideration of the method and content of organized knowledge predominate?

8. What methods of inquiry are pertinent to each major decision posed by the system?[1]

An examination of the Australian science curriculum model and the suggested mechanisms for its implementation provides answers to each of the questions posed by Goodlad.

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[1] John I. Goodlad, "The School Scene in Review: Toward a Conceptual System for Curriculum Problems," The School Review, LXVI (Winter, 1958), 396.

Consequently, the model appears to have satisfied each of the three sets of criteria presented above.

Suggestions for Future Research

Several areas requiring investigation have been suggested in describing promotion of research as one function of the proposed ASEF. It was suggested that future studies required to contribute to the effectiveness of science curriculum development should include:

1. studies to determine how to accelerate the motivation of introduction of curriculum innovations into Australian schools;
2. studies to develop valid evaluative techniques for a broader range of the objectives of science education;
3. research to ascertain optimal conditions for utilizing the mass media in Australia;
4. the identification of the broad concepts of science appropriate for science teaching in Australia;
5. the determination of the developmental stages of Australian children as they relate to the objectives of science education.

General Conclusions

The purpose of this study was to develop a science curriculum model which may provide a structure appropriate for the development of science curricula in Australia, based largely upon experiences in the U.S.A. The comparative review of the major cultural differences between U.S.A. and Australia indicated that such differences as did exist, were not likely to create major differences with respect to education in general, and science education in particular. It further indicated that conditions in the U.S.A. were such that the rate and quality of educational innovations resulted in a large number of significant developments in science education, many of which could profitably be adapted to the Australian situation.

The implications from American practices which appear to have significance for the development of science curricula in Australia are incorporated into many of the seventy recommendations presented above. The availability of a science curriculum model incorporating these recommendations may supply a sound structure to facilitate improvement in science education. The considerable progress reported in Australian science education and the recent increase in governmental interest in science education suggest the presence of a climate favorable to the implementation of such a model.

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