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ABSTRACT

The Asia and the Pacific Programme of Educational Innovation for Development (APEID) has a primary goal of contributing to the building of national capacities for undertaking educational innovations linked to the problems of national development, thereby improving the quality of life of the people in the member states. One of the major interests of this group is science and technology education. A workshop was held to discuss the following topics: (1) reviewing problems and issues in the development of scientific and technological talent; (2) developing exemplar instruments for identifying scientific and technological talent; (3) developing nurturing programs for the scientifically and technologically talented; (4) promoting interest among science educators in the development of scientific and technological talent; and (5) exchanging ideas on how to improve the development of the scientifically and technologically talented. Also included in the document are the agenda, list of participants, the development of learning/teaching materials for real-life problem-solving situations, and examples of problem-solving situations. (ZWH)

APEID

# The Development of Exemplar Identification Instruments for a Science and Technology Education Talents Programme

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APEID

Asia and the Pacific Programme of Educational Innovation for Development

# The Development of Exemplar Identification Instruments for a Science and Technology Education Talents Programme

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# CONTENTS

# INTRODUCTION

## Background

The Asia and the Pacific Programme of Educational Innovation for Development (APEID) has as its primary goal to contribute to the building of national capacities for undertaking educational innovations linked to the problems of national development, thereby improving the quality of life of the people in the member states. The Asian Centre for Educational Innovation Development (ACEID), a unit at the UNESCO Principal Regional Office for Asia and the Pacific (UNESCO-PROAP) co-ordinates the activities of APEID. One of the programmes under the fourth cycle (1987-1991) is on science and technology education. Under this programme, the Institute of Science Education, Chonbuk National University proposed the organizing of a regional workshop on *"The Development of Exemplar Identification Instruments for a Science and Technology Education Talent Programme"*.

The workshop was held at Chonbuk National University, Chonju, Republic of Korea from 14 to 25 November 1988. The meeting was attended by participants from seven countries with five resource persons from the host country, the Republic of Korea. The agenda of the meeting is in Annex I, and the list of participants is in Annex II.

## Officers of the Meeting

The meeting elected Dr. Wha-Kuk-Lee as moderator, and Prof. Seung-Tai Park as Chairperson. The rapporteurs are Mr. G. Fish (Australia) and Dr. Adoracion Ambrosio (Philippines).

## Inauguration

The opening address was given by Dr. W.S. Kim, President of Chonbuk National University. Congratulatory addresses were delivered by Mr. T.P. Hong, Superintendent, Board Of Education, Chonbuk Province; Mr. J.J. Yook, Mayor, Chonju City; and Dr. S.O. Cho, Secretary General, Korean National Commission for UNESCO.

**Preparatory Work**

The rise and fall of a nation depends upon its educational power, and the speed of development of a nation also lies in the quality of its education. Nowadays, all nations are doing their best for the development of their country by bringing up available manpower rather than relying solely on their natural resources. Developing countries (e.g. Korea) which are poor in natural resources, have to focus their efforts on the development of scientifically competent and creative manpower.

In 1984 to 1985, at Chonbuk National University, Institute of Education, models of teaching and learning were examined in the context of their effectiveness, to enhance students' creativity at secondary school. The Institute also started research in 1986 on those who are scientifically gifted in secondary school.

Prior to this research, the government of the Republic of Korea felt the need for producing creative and productive scientists through the provision of special programmes for the scientifically gifted students. In 1982, a model for comprehensive gifted education in science was suggested by a group of professionals who were concerned about the education of the scientifically gifted. As a result, a Science High School was established in 1983, and four more were established between 1984 and 1988. In 1986, the Korea Institute of Technology was established for the education of the scientifically gifted at the college level.

In this context, their initiatives will be reviewed and examined through discussion by the participants of the workshop. The outcomes of the workshop could also be valuable to other countries in the region.

Prior to the meeting, the participants were requested to prepare country reports which represented the situation concerning science and technology education in general and the provision for talented students in particular.

**Purpose of the Meeting**

The objectives of the workshop were to:

1. Review problems and issues in the development of scientific and technological talent.
2. Develop exemplar instruments for identifying scientific and technological talent.

3. Develop nurturing programmes for the scientifically and technologically talented.
4. Promote interest among science educators in the development of scientific and technological talent.
5. Exchange ideas on how to improve the development of scientific and technological talent.

**Organization of the Workshop**

The Institute of Science Education, Chonbuk National University, in consultation with ACEID assumed the technical responsibility for the organization of the regional workshop, and collaborated on the preparation of technical documents as required. The workshop was conducted in small discussion groups. Opportunities were also provided for participants to visit schools and institutions which promote programmes for the scientifically talented.

Chapter One

# THE PROVISION OF SCIENCE AND TECHNOLOGY EDUCATION IN THE COUNTRIES OF ASIA AND THE PACIFIC

## Structure of the School System

Chart 1 shows the structure of the school systems in the participating countries. There is a great degree of similarity between the systems, except that in the Philippines, secondary educations lasts for only four years. In all cases participation in primary or elementary school is compulsory and free. There is a trend towards an increased retention of students into lower and upper secondary school. In particular, the percentage of students in Japan and the Republic of Korea who continue their education to the upper secondary level is already very high.

## Nature of Science

At the primary level, all countries provide for education in science in one form or another, either as general science or as a science related area integrated with other subjects such as mathematics, social studies and language education. Three elements appear in most statements of objectives for science education:

- the acquisition of scientific knowledge;
- the acquisition of skills of inquiry; and
- the acquisition of positive attitudes to science and the environment.

At the lower secondary level, there is some variation in the participating countries in the degree of integration of the science programme. In Australia, Indonesia, Thailand, Malaysia, and the Republic of Korea, the subject takes the form of general or integrated science. In the Philippines, stress is placed on a separate treatment of the disciplines of biology, chemistry, and physics. In Japan, there are two areas, one covering physics and chemistry, the other the biological and earth sciences.

At the upper secondary level, there are some differences in the nature of the science offered. In the Republic of Korea, science is taught through six compulsory courses - physics, chemistry, biology, earth science, industrial

## Chart 1. Structure of School Systems

<table>
<tr><th>Grade</th><th>Australia</th><th>Indonesia</th><th>Japan</th><th>Malaysia</th><th>Philippines</th><th>Rep. of Korea</th><th>Thailand</th></tr>
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<tr><td>13</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>12</td><td rowspan="3">Secondary</td><td rowspan="3">Upper Secondary School</td><td rowspan="3">Upper Secondary School</td><td></td><td rowspan="2"></td><td rowspan="3">High School</td><td rowspan="3">Upper Secondary School</td></tr>
<tr><td>11</td><td rowspan="2">Upper Secondary School</td></tr>
<tr><td>10</td><td rowspan="4">Sec. School</td></tr>
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<tr><td>7</td></tr>
<tr><td>6</td><td rowspan="7">Primary School</td><td rowspan="6">Elem. School</td><td rowspan="6">Elem. School</td><td rowspan="6">Primary School</td><td rowspan="6">Elem. School</td><td rowspan="6">Elem. School</td><td rowspan="6">Elem. School</td></tr>
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</table>

[shaded] Compulsory and free education

[unshaded] Free education

# free in some rural areas

From: Primary Science Education in Asia and the Pacific,
National Institute of Educational Research, Tokyo, Japan (1986).

technology, and engineering, and two optional courses - history of science development and electronics. In Indonesia, Thailand and Malaysia there is some compulsion to study either "*general*" science or the separate disciplines for some streams of students. In Australia and Japan, the study of science at grades 11 and 12 is optional, and is usually in the form of the separate disciplines.

## Nature of Technology Education

Despite the key role technology has played in human development, it has only recently appeared as a major field of knowledge and experience in school education programmes. This is now changing and countries of the region are looking at ways of incorporating technology into the curriculum.

Technology can be defined as the application of knowledge and experience to serve some useful purpose. Under this definition, emphasis is placed on an applied curriculum and on integrating technology into the various areas of learning.

At present, most countries in the region do not offer systematic technological education. At the secondary level, subjects such as industrial arts, industrial studies, technical studies, home studies (home economics), and others, are offered to provide opportunities for students to develop skills for work and daily life. At the upper secondary level, specialized study in these areas is sometimes towards a more vocational orientation.

As the scope of technology education is widened, new subjects or new parts of subjects are being identified and included in the school curriculum in some countries. Examples would include electronics, computer science and the applications of computers such as word processing.

In the context of science, technology education provides an applied focus to studies, inorder to meet the needs of the nation. The studies are, for example, related to daily life, work and leisure, industry, agriculture and environment.

## Science and Technology for Talented Students

For the purpose of this workshop, talented students are those who demonstrate excellence in:

- science ability especially problem-solving abilities;
- mathematical reasoning; and
- language proficiency.

They show creative ability, a strong task commitment and a high interest in science.

Provision of special programmes for talented students in different countries varies according to the policies of the governing educational authorities. While some countries view separate provision as a vital way to stimulate economic development and national leadership, others view segregation as socially divisive and a threat to equality of opportunity and egalitarian ideals.

The Republic of Korea provide for the education of the scientifically talented of five science high schools located in five different places in the country. Students are selected using multi-screening procedures and care is taken to ensure that the identification of talent occurs throughout their education programme. A new curriculum for these high schools was introduced in 1989, the purpose of which is to meet the learning characteristics of scientifically talented students. More time is given to experimentation, wide interests provided for thorough more advanced courses, more emphasis given to explorative learning, and course-work accelerated so that students complete three year courses in two years.

In the Philippines, there is one nationally funded science high school, the Philippine Science High School in Quezon City, and three city funded Science High Schools located in other cities in the country. At the Philippine Science High School, the students are selected using a two-stage process of screening tests. In the science programme, stress is placed on the process side of science, on fostering the ability of students to learn on their own and on responding to the individual needs and talents of the students. The science courses are more advanced, and they open up discussions of real problems and social issues. There is a one year course of three hours per week where students conduct a major independent research activity in their own particular field of talent.

The Development and Promotion of Science and Technology Project (DPST) in Thailand, was introduced to entice talented students into science and technology courses. The aim is to produce 420 highly trained science and technology graduates during the first cycle (1984-1990). Six secondary schools located in different geographic regions of Thailand are centres for the secondary students (Grades 9-12) involved in the project. All students are provided with scholarships. After undertaking their studies, the students automatically enter one of the Universities which are associated with the school centres. To select the scientifically talented students, research was carried out to identify the traits of such students. Tests were designed as selection instruments for six traits. For the students specially designed enrichment programmes are performed after regular school hours. A science camp is also organized annually during the summer vacation for the Grade 10-11 DPST students. In addition, Grade 12 students attend extra curricular academic seminars.

In Malaysia, to increase the number of students capable of pursuing science courses in the upper secondary, up to 30 fully residential science schools which can take in about 22,000 students have been established. These students are accommodated in hostels and many are given scholarships. They are selected on their performance especially in mathematics and language in primary schools. The curriculum followed is the same as in regular schools, but these science schools are better equipped.

In Indonesia, to date there are no special schools for talented students. However, in the last year of secondary schooling some enrichment programmes are offerred in mathematics and science subjects for those students who have shown high academic achievement in these subjects.

In most State education systems in Australia, it is felt that the talented students can be extended through the provision of quality general science programmes at least up to the end of year 10. In years 11 and 12, students may specialize and study intensively the separate science disciplines which are offerred as optional subjects. On a small scale, some Australian states select talented students for special programmes. The selection is based on general academic ability, psychological testing, and parent-teacher or peer nomination. These programmes embrace enrichment, cluster groups of schools, special classes in schools, special interest centres, acceleration classes and out-of-school activities.

In Japan, there is no specific provision for the scientifically and technologically talented. But at the upper secondary level, there are specialized mathematical-science courses. There are five of these intensive, academic courses:

- Science in Mathematical Science;
- Physics in Mathematical Science;
- Chemistry in Mathematical Science;
- Biology in Mathematical Science;
- Earth Science in Mathematical Science.

*Exemplar instruments for ST talents*

The students in mathematical science courses are required to study all five of these subjects. The students are selected by the same entrance examination as general course students.

In most countries of the region, opportunities are being provided for science learning outside the classroom. Science talent searches are used to promote science education through the recognition of outstanding work including that based on research investigation. Awards, prizes and fellowships are sometimes provided through sponsorship from companies and corporations for the successful students. Research organizations or museums have established network of "*hands-on*" science centres for students and teachers. These centres offer experiments and interactive demonstrations. Science clubs are often established to promote the interests of talented students.

Chapter Two

# SCIENCE AND TECHNOLOGY EDUCATION FOR TALENTED STUDENTS IN SECONDARY SCHOOLS

## Objectives of Science and Technology Education for Talented Students

The determination of curriculum objectives in science and technology for talented students should be built on those objectives which have been developed for all students. The objectives should be guided by:

- a synthesis of available research findings in science and technology education;
- the current trends in science and technology education;
- the local needs of particular regions;
- the nature of the disciplines of science and technology, and their roles and purposes in work and daily life.

In most countries, their needs and goals are reflected in the socio-economic plans of the country, the national educational policies, and the general goals and aims of science education.

However, the learning characteristics of talented students and the roles they are expected to play in society need to be taken into account. Particular emphasis might, therefore, be placed on the following objectives:

- to promote understanding of scientific knowledge through explorative learning;
- to provide opportunities for students to apply their knowledge and experiences in science for purposes useful to society;
- to encourage learning experiences that promote creativity;
- to enhance confidence in the ability to contribute to the development of science and technology;
- to promote a high sense of responsibility to make a positive contribution to the development of society.

Chapter Three

# THE CURRICULUM OF SCIENCE AND TECHNOLOGY EDUCATION FOR TALENTED STUDENTS

## Characteristics of Talented Students in Science and Technology

The curriculum of talented students should be qualitatively different from that for other students and it should be based upon the known characteristics which are demonstrated by talented students. The following list outlines the characteristics of talented students in science and technology.

### Cognitive Characteristics

The cognitive characteristics of talented students are the following:

- learn easily and readily;
- express themselves clearly, accurately either orally or in writing;
- demonstrate mathematical abilities one or two years ahead of peers;
- exhibit keen powers of observation;
- can perform fine, precise manipulations;
- have superior powers of reasoning, of dealing with abstractions, of generalizing from specific facts, of understanding meanings, of thinking logically and of seeing into relationships.

### Affective Characteristics

A talented student exhibits the following traits:

- have great intellectual curiosity;
- have great interest in the nature of man and the universe;
- persevere and are not easily discouraged by failure of experiments or projects;

- have ability to carry out work independently with a minimum of direction and supervision;
- have a wide range of interests;
- have self-confidence and self-discipline.

## Ways of Grouping Talented Students

In the experience of participating countries in the region, there seems to be two approaches to the science and technology curriculum for talented students. One approach seeks to provide extension activities within the regular school framework. In this approach, Renzulli's[1] model is used as a basis for extension. Enrichment or exploratory activities are provided for all children as part of the normal programme. Problem solving methods are built into these activities. Students work individually or in small group situations applying their skills to problems which require a high level of performance. Those countries which adopt this model seek to provide for outstanding children in special ways in the regular classroom or in special classes in the regular school.

The second approach provides programmes outside the regular school framework. It is believed that the needs of outstanding students are so different from those of other students and the difficulties of providing for them so marked that it is more economically and educationally sound to provide a separate programme for them. Such programmes are often provided in Special Science High Schools.

## Content, and Teaching and Learning Methods for Science and Technology Programmes for Talented Students

There is general agreement that in designing a science and technology curriculum for talented students, it is difficult to separate content from teaching and learning methods.

When the content of the science and technology programme is considered in relation to talented students, it is believed that it should be built on the foundation of the content of the science programme used for the regular students. However, it is proposed that the content should be enriched and place greater emphasis on

1. Renzulli, J.S. (1977). *The enrichment triad model: a guide for developing defensible programmes for the gifted and the talented.* Mansfield Centre, Conn., Creative Learning Press.

- identifying issues, problems and themes;
- the development of an understanding of the major concepts and generalization of science and technology; and
- increasing efforts to integrate science studies with other subject areas.

The content should be applied so that it bears a closer relation to the interests of the students and to the needs of society. Thus opportunities should be provided for students to seek solutions to real problems, to extend these solutions to generalization, and to project and apply them to situations which may be different, even futuristic or speculative.

It is common for acceleration programmes to be used with talented learners. In these cases, students complete the work required for, say, entrance into higher education, in a shorter time than regular students. In some countries, technologically oriented elective courses such as electronics and computer science are offered to extend to talented students.

Typically, teachers who teach talented students enrich their science and technology programmes by widening and diversifying the learning experiences of the students. A variety of teaching/learning strategies are required to facilitate the attainment of all desired objectives and to meet all the needs of the learners as well as the expectations of their teachers.

In the Republic of Korea, the time devoted to practical experimentation for those in the Science High Schools is increased to 60 per cent of the total time devoted to science education. In these Science High Schools a variety of teaching methods are used to match the learning capabilities of the students. However, individualized education programmes (IEP) are not employed frequently, because most of the teachers are not trained well enough to use this method.

There is evidence to suggest that talented students require a science and technology curriculum which is based on a sound knowledge of content, and which develops problem-solving capabilities in academic situations and in real life situations.

Problem solving is an acquired skill which needs specially designed learning activities for the students.

The logic of problem solving would indicate the following sequence:

- identification by the teacher or the student of an academic or a real life problem situation;
- distinguishing the essential features of the problem situation;
- defining the problem;
- formulating hypothesis or guesses which maybe applicable to finding a solution;
- testing the hypothesis (or successive hypothesis) until a solution (or solutions) is reached.

In order to learn to solve a problem the student should:

- recognize that the new situation is indeed a problem situation;
- recognize that an identifiable problem exists;
- dissect the problem into manageable sequential sub-problems and determine priorities among the sub-problems;
- recall relevant knowledge and skills previously learned;
- compensate for deficiencies in skills and knowledge by devising alternative approaches to the problem, or by making up for the deficiencies or both.

Students develop the skills for solving problems by repeated exposure to problem situations and by devising solutions to them. Students need to have the opportunity to understand the nature of different types of problem and to acquire the appropriate skills for their solution. The students should be active participants with opportunities to exploit their special talents in the selection of the problem on which to work and through deciding how to attack the problem.

Independent action by students in solving problems, provide opportunities to reinforce creative skills and self-learning abilities. Another area that may be reinforced is values; in particular, codes associated with making hypothesis and testing them, interpreting evidence, making approximations and estimations.

In the initial stages of designing learning sequences for problem-solving, a primary task is to translate subject matter into meaningful problem situations with stimulus questions. The questions should appear natural to the students, appropriate to the stage of development of their thinking, and reflect their curiosity. Curriculum developers and teachers find this process difficult. Another possibility is to identify perceptions children have about phenomena around them, and use science and technology learning as a means of testing these ideas. As a result the skills of problem-solving are exercised, and misconceptions about phenomena can be resolved.

Problem-solving related to real life issues provide enhanced possibilities for developing creativity and inventiveness. Apart from nurturing talent by means of problem solving, the curriculum becomes more relevant to the students, creates in them a more sensitive awareness of their own environment together with an understanding of the socio-economic and cultural development programmes being undertaken by governments to increase the quality of life, and how to intervene in their environment using their classroom knowledge. It contributes to the development of talent in a context of practical functionality. This move towards problem solving of real life situations must be done gradually. More must be done about real life content and to avoid contrived or recipe-style learning situations, relevant learning situations need to be prepared, and teachers trained for this purpose. A possible outline for action is provided in Annex III. A few examples of problem solving situations can be used for generating initial learning or for further nurturing of problem-solving competencies are shown in Annex IV.

In discussing the above issues, reference was made on the need to train teachers in problem solving, and in the development of the broad-based programme itself. To a certain extent, this training in problem solving is being implemented in several countries in the region. The adequate training of teachers for problem solving is essential for nurturing problem-solving skills among students.

In this case, a basic issue is whether the "*drilling*" of teachers in the solving of problems that students are to solve in the classroom (i.e. student level problems), does provide the teachers with adequate problem solving skills.

As an initial phase in the introduction of the new curricula, this drilling is essential. However, for the subsequent development of teachers, it may be necessary to provide increased opportunities for problem-solving at the maturity and intellectual level of the teacher; even if for the moment the problems remain somewhat academic. If more radical environment-based social intervention-oriented, relevant, real-life curricula are forthcoming in the future, the problem solving skills and techniques thus acquired would be a useful starting point for teachers to then explore problem solving processes that are more applied and based on real life situations.

Whatever the strategies used, and whether the focus of the action is nurturing talent by means of problem-solving skills in students or teachers, a necessary requirement is the mastery of subject matter or content that is applicable to the various problem solving situations. Without the mastery of the relevant content, solving problems can be a long, inefficient and tiresome process with the built-in inefficiencies of ad-hoc trial and error strategies, or chance and luck.

## Extra-curricular Activities for Talented Students in Science and Technology

In some countries, talented students in science and technology live on the school campus. In these cases, extra-curricular activities can be easily arranged. Where the situation does not exist, special provisions are often made for the talented students, i.e.. school and community facilities are used out of regular school hours. Community resource people such as scientists, engineers, doctors, etc., are often invited to discuss matters of interest to the students. Greater use is made of visits to interactive science learning centres, to research laboratories, to industry and to centres of higher learning. Excursions and camps based around structured activities or student research projects have been found to be valuable. All these activities provide options for the enrichment of the curriculum for students talented in science and technology.

## Monitoring and Evaluation System for Programmes in Science and Technology for Talented Students

To evaluate the effectiveness of science and technology programmes for talented students, the basic evaluation model "*input, process, and output*" may be used. The principal input to the programmes are the students who have been identified as talented according to a generally accepted definition. These students undergo and educational process which is described by a specific curriculum with a set of objectives, content, and teaching/learning methods chosen on the basis of appropriateness. The output of the curriculum are the graduates.

Assuming that the input to the programmes is properly selected, monitoring of the educational processes indicate areas of strengths and weaknesses which may be the focus of improvement. In the final analysis, the effectiveness of the programme would affect the type of the output both in quality and quantity.

In a supportive environment where the resources needed for the curriculum are adequate in terms of quality and quantity of teachers, laboratories, equipment, and facilities, the programme should produce the type of graduates expected.

If the output is less than the expected, the use of school resources for the programme that has been implemented was probably not effective. efficient and economical. This indicates a need for a redirection and improvement. The statement that follows illustrates this point.

> *Literature on the curriculum for talented students strongly point to the need for matching the learning style of the students and the teaching methods. If teaching methods do not match learning styles, then boredom, frustration and underachievement often result. Approaches such as team teaching individualized instruction, and small group activities require teachers who are not only well prepared academically but also highly motivated and creative. These approaches may not be implemented due to a lack of expertise or inadequate teaching resources.*

A continuing review of the curriculum is needed in view of the fast changing fields of specialization in science and technology. In Japan, for example, the revision of the lower secondary curriculum carried out in 1981 was designed to eliminate wasteful repetition of similar teaching content and to reduce content to the basic and fundamental matters.

Other problems and constraints associated with the evaluation of science and technology programmes for talented students identified from the experiences of country participants include: inadequate motivation of students, lack of incentives for teachers, inadequate counselling programmes for underachievers, absence of a continuous curriculum materials development, and lack of provisions for varied extra-curricular activities that will continually challenge the talented.

The programme evaluation in terms of the academic performance of the talented students is reported statistically as drop-out rates. High drop-out rates due to withdrawal from the academic programme or failure to attain set standards of achievement indicates that the educational process is not working effectively. The drop-out rate from a special science high school, however, should be low considering the cost of the programme. For example, the drop-out rate reported by the Philippine Science High School compared to the drop-out rate of a regular public high school in Metro Manila is relatively low.

Beside monitoring the programme effectiveness in terms of the academic performance of students, an assessment of the impact of the graduates of the programme maybe undertaken. Such an assessment, however, requires long-term monitoring of careers.

The Philippine Science High School has done a partial study of the careers of its graduates. The report showed that almost all the graduates successfully pursued higher academic studies in tertiary level institutions. It was also reported that in every batch of graduates who are in the work force either in industry, government or academe, those who hold leadership positions at the middle management level have shown high promise in science and technology teaching and research.

Chapter Four

# DEVELOPMENT OF IDENTIFICATION INSTRUMENTS

## Review of Current State of Identification

Identification of talented students in science and technology in different countries in the region varies according to the nature of their educational policies. Those countries which provide special education programmes generally utilize multiple criteria through several steps for screening.

In the Republic of Korea, the Science High Schools first obtain nominations from teachers of about 400 students who are at least within the upper 3 per cent of the lower secondary school population based on previous academic achievement especially in science and mathematics, and who has shown high creativity in science research work. Then in the second stage, the nominated students are tested on achievement tests in mathematics, science, Korean, English, social science and physical education. After the second screening, the Science High Schools administer a science aptitude test, a health examination and interview to gather additional information and confirm the results of screening up the second stage. The best 60 students are then selected.

In Thailand, students who obtain high achievement in science and mathematics (i.e. those whose grade point average is not less than 3.0 on a 4-point scale) and also score in the top 5 per cent of their school populations in aggregate academic marks are allowed to apply for entry to the Development and Promotion of Science and Technology Talents (DPST) programme. The initial screening starts with approximately 4000 students per year. The applicants are then required to complete a battery of tests comprising of achievement tests in science and mathematics, scholastic aptitude (with numerical, verbal, reasoning and spatial sub-scale), scientific attitude and creativity. Approximately 120 students whose scores meet the designated criteria are interviewed and tested orally as the final step in the selection process. Students who pass the final process are ranked according to their total marks. The top 5 per cent of students in each Centre are accepted as DPST students.

In the Philippines, the following steps are followed:

- First screening - teachers recommend pupils who are in the 6th or 7th grade of primary schooling, and who are in the top 20 per cent of the class.
- Second screening - pupils are given the Scholastic Ability Test (SAT). The SAT measures three kinds of school related abilities which are important in academic work. These are verbal ability, mathematical ability and non-verbal ability.
- Third screening - 12 per cent of the applicants, or about 1800 pupils who qualified in the first and second screening are allowed to take the Science-Mathematics Aptitude Test (SMAT). The SMAT measures the students' ability to undertake science/mathematics training such as understanding the methodology of science, and the higher level skills and content of mathematics.

In summary, the three countries in the region utilizes multiple criteria and multiple stage screening methods with emphasis on science and mathematics achievement and aptitude. However, these countries feel that more research should be carried out to enhance the reliabilities and validities of identification instruments and to reduce the cost of implementation of tests.

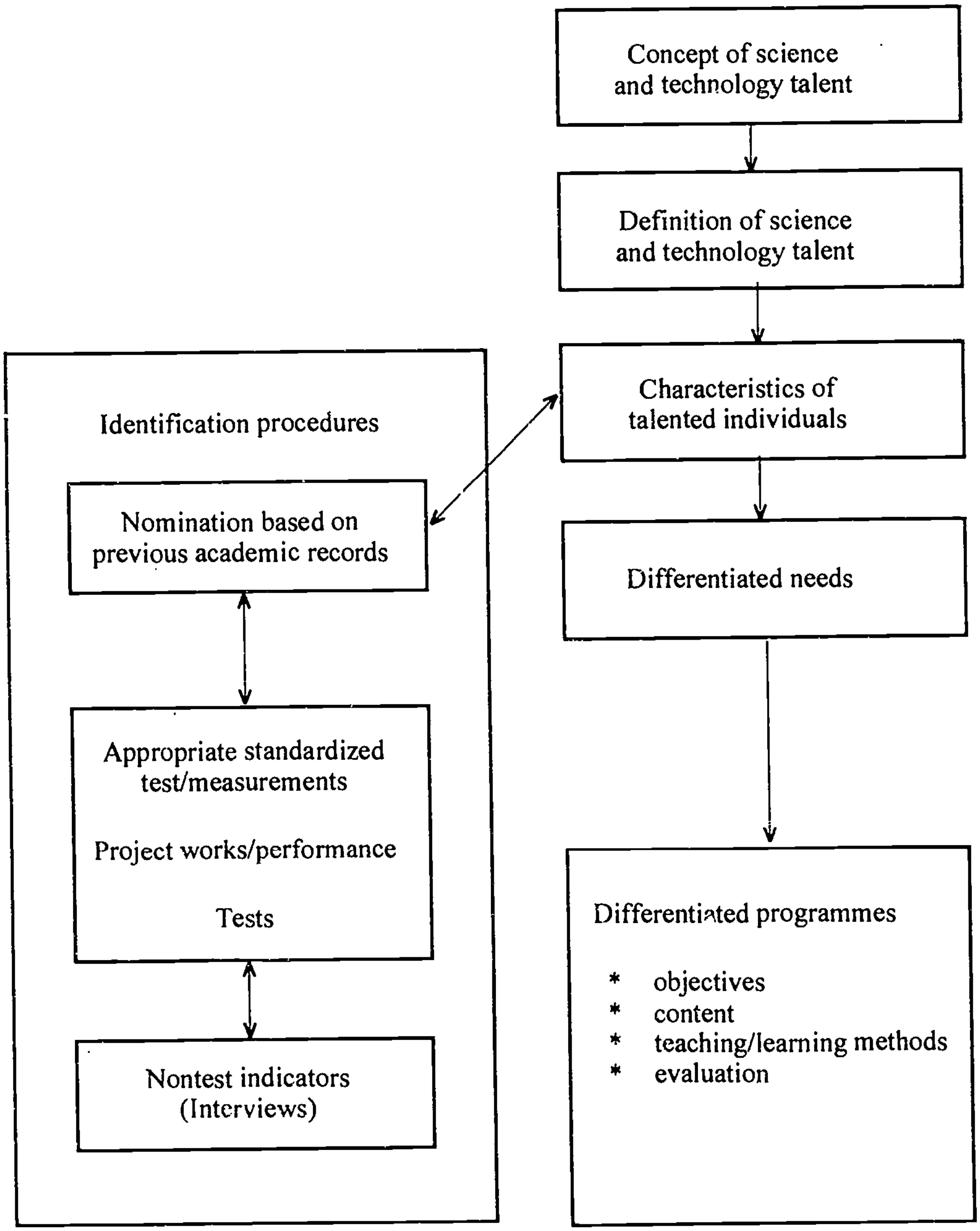
On the other hand, those countries without special educational provisions for talented students in science and technology do not employ a systematic process for screening talented students in science and technology.

**Framework for the Identification of Talented Students**

One of the goals of identification and curriculum planning for the scientifically talented students is to establish and maintain coherence within the programme. When a programme has coherence, the pieces of the programme fit together and interact with one another. Therefore, the identification processes and procedures should be an integral part of the total programme designed for scientifically talented students.

Chart 2 shows how the identification procedures can be integrated into the total programme.

## Chart 2. Framework for Integration



The particular traits of scientifically talented students need to be defined before identification processes can be established. The educational authorities in each country need to affirm what they mean when they use the term "*talented in science and technology*". An agreed definition should then be used consistently as a base on which to build the rationale, identification processes and curriculum for the special programme. Particular care should be taken to ensure that any instrument that are developed are appropriate for the purpose.

In this workshop, it was agreed that talented students in science and technology should include those who have potentials as well as those who already demonstrate excellence. The definition of the talented should, therefore, reflect this consideration. The distinguishing characteristics of talented students should be listed in a way that describes the individuals for whom the identification and nurturing programme is to be developed.

**Identification Procedure**

From country to country, the kinds of tests or methods used in identifying scientifically talented students vary according to the definition of the talented and to their educational policies. Theoretically, multiple criteria should be needed for the identification procedures. The procedure of screening and selection may be preceded by teachers' and/or parents' nomination. For purposes of initial screening, the previous academic record of achievement in science and mathematics (school or nationally-based) of the students should be considered.

The second stage of the procedure consists of a battery of tests which may be used for selecting those who fulfill the criteria. The battery of tests may include:

- Science and Mathematics Achievement Test;
- Scholastic Aptitude Test;
- Science and Mathematics Aptitude Test;
- Scientific Creativity Test.

Countries may use the tests singly or in combination.

After the formal tests, performance tests may be administered to provide supporting evidences. The observation by professional scientists of students carrying out research work is an example of a performance test.

However, performance tests such as Process Exercise Tests and Project Type Tests are time consuming and expensive to implement. On the basis of practicability, these tests are preferably carried out after the second stage in which the number of candidates has been much reduced.

The final stage of the identification procedure is often an interview to gather information about students' personality, attitudes and interests, which will ensure success in the educational programme for scientifically and technologically talented students. A physical examination may also be carried out to identify those with physical and psychological disabilities prior to final decision.

**Exemplar Items of Identification Instruments**

*Science Achievement Test*

| Type of test item | Content | Skills |
|---|---|---|
| Multiple Choice | The test items should cover the content of science curriculum based on the appropriate grade level | Knowledge<br>Comprehension<br>Science<br>Process<br>Skills |

Example:

1. You are asked what would happen to the boiling temperature of water if rubbing alcohol were added to it. What would be the best thing to do?

   a) Check the boiling temperature of rubbing alcohol in a book and draw your conclusions.

   b) Guess that there would be no effect.

   c) Guess that rubbing alcohol would raise the boiling temperature of water and prepare an experiment to prove it.

   d) Set-up an experiment to discover the effect of rubbing alcohol on the boiling temperature of water.

   e) Assume that rubbing alcohol would lower the boiling temperature of water.

2. Unlike poles of magnets attract while like poles repel. Magnetic materials are those that are capable of being attracted by magnets while non-magnetic materials are those that are incapable of being attracted by magnets. The following are three rods:

| | | |
|---|---|---|
| I. | A B | A attracts C |
| II. | C D | E attracts C |
| III. | E F | A repels E |

Which among the rods above may or may not be a magnet?

1. I 2. II 3. III 4. I and II 5. II and III

*Mathematics Achievement Test*

| Type of test item | Content | Skills |
|---|---|---|
| Multiple Choice | The test items should cover the content of maths curriculum based on the appropriate grade level | Computation<br>Comprehension<br>Application<br>Analysis |

Example:

1. A shopkeeper purchases 11 knives with \$10, and later sells 10 knives for \$11. He earns a profit of:

   a) 11 per cent

   b) 15 percent

   c) 20 per cent

   d) 21 per cent

2 The cost of 9 chairs and 3 tables is \$306, while the cost of 8 chairs and 2 tables is \$246.

Then the cost of 6 chairs and 1 table is:

a) $164

b) $165

c) $166

d) $186

*Science Aptitude Test*

| Type of test item | Content | Skills |
|---|---|---|
| Multiple choice | The test items should be content free | Reasoning |

Examples:

1. Mike put two pieces of clay with the same size and shape on a scale as in the picture and the wight is the same.

Clay 1 Clay 2

Scale

Tom changed the shape of clay 2 into a flat one.

Clay 1 Clay 2

Choose the right explanation from the following statements.

a) The clay 2 which is flat is heavier;

b) The two clays weight the same;

c) The clay 1 which is round is heavier.

Why?

a) Because nothing is either added or subtracted.

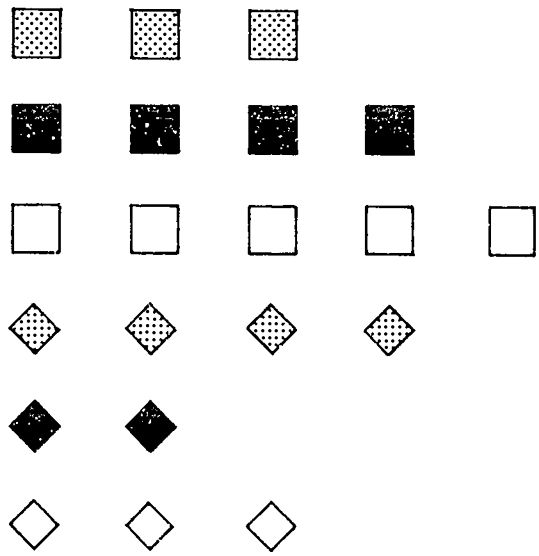
b) Because the flat clay has a larger area.

c) Because anything which becomes flat has less weight.

d) Because there is more clay in the round clay.

2. There are 21 shapes in a sack as follows:

| | | |
|---|---|---|
| dotted square shape | 3 | |
| black shape square | 4 | |
| white square shape | 5 | |
| dotted diamond shape | 4 | |
| black diamond shape | 2 | |
| white diamond shape | 3 | |



All the square shapes are of the same size, the diamond shapes also have the same size. When you pick out one shape, what is the probability that it would be either a square shape or a white colour?

1. 1 out of 3
2. 3 out of 7
3. 1 out of 12
4. 1 out of 21
5. none of the above.

Why?

1. Because out of 21 shapes, there are 9 squares which are either black or white.
2. Because 1/4 of the dotted shapes and 5/12 of the white shapes are squares.

3. Because 12 out of 21 shapes are squares.
4. Because one square should be picked out of 21 shapes.
5. Because there are 12 squares in a sack, and one should be picked out of them.

*Mathematic Aptitude Test*

| Type of test item | Content | Skills |
|---|---|---|
| Multiple choice | The test items should be content free | Computation<br>Comprehension<br>Application<br>Analysis |

Example:

1. The sum of the measures of these three angles of a triangle is 180. If the angles of a triangle are in the ratio 2:3:4 what is the measure of the largest angle?

   a) 20°  
   b) 40°  
   c) 60°  
   d) 80°  
   e) 100°

2. Mr. Mendoza works Mondays through to Saturdays repairing shoes. For this week, he has repaired the following number of shoes: Monday 32; Tuesday 34; Wednesday 26, Thursday 28 and Friday 25. How many shoes must be repaired on Saturday so that his daily average of shoes repaired is 30?

   a) 5  
   b) 20  
   c) 30  
   d) 42  
   e) 35

*Scholastic Aptitude Test*

| Type of test item | Content | Skills |
|---|---|---|
| Multiple choice | This test consists of 4 sub-scales<br>1. Numerical<br>2. Verbal<br>3. Spatial<br>4. Reasoning | Numerical ability<br>Verbal ability<br>Spatial ability<br>Reasoning ability |

Example:

1. Finding the missing number in the sequence:

1, 3, 5 $\boxed{\phantom{00}}$ , 9, 11

a) 4
b) 6
c) 7
d) 8
e) 10.

Verbal instruction: Read the following statement anu tnen answer questions number 0 and 00.

Statement: "Don't be surely like that, my child".

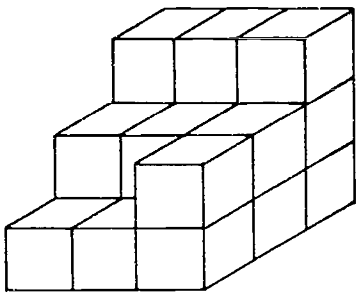
No 0 What is the opposite meaning of "*surely*" in this statement?

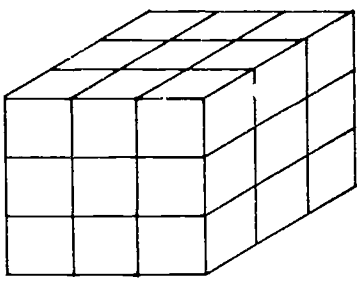
a) likeable
b) pleased
c) glad
d) happy
e) friendly

No 00 What is the emotion of the speaker who made this statement?

a) worried
b) sorry
c) upset
d) sad
e) displeased

2. Spatial No 0 How many block/s must be added in figure A to make the same shape as figure B?





a) 6

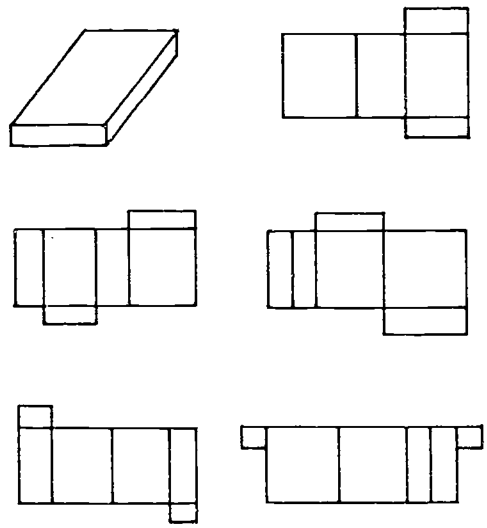
b) 7

c) 8

d) 9

e) 10

Instruction: There are 5 selection choices. Which one can be folded into a box as shown in No 00.



3. Reasoning: Find the pairs with the same relationship as the words given.

Example 1:

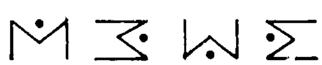
Student: study - ?: ?

a) Doctor: Cure

b) Policeman: Burglar

Instruction: Find the next alternative related to the given figures.

Example 2:



a) 

b) 

c) Farmer: Tractor c) 

d) Movie star: Films d) 

e) Trader: Profit e) 

*Scientific Creativity*

| Type of test item | Content | Skills |
| --- | --- | --- |
| Essay type | Situations related to environment or everyday life | Fluency<br>Flexibility<br>Originality<br>Elaboration |

Example: What would happen if people used hands for walking instead of using feet? Write down as many answers as possible within 7 minutes.

*Scientific Interest Inventory*

| Type of test item | Content | Skills |
| --- | --- | --- |
| Rating scale | Interest in science as an academic subject activities, situations, phenomena | This test is designed to measure students' interest in science. Students may be asked to rate the given statement in each item in terms of opinions, preferences or performances. |

Examples:

Instruction: Please read the following statements and circle the number which best describes your tendency.

| | | | |
|---|---|---|---|
| when | 1 | = | 1 never do |
| | 2 | = | 1 sometimes do |
| | 3 | = | 1 mostly do |

| | | |
|---|---|---|
| 1 | Time runs so fast when I am involved in science experimentation | 1 2 3 |
| 11 | I often wonder how a plant grows | 1 2 3 |

*Scientific Personality Inventory*

| Type of test item | Content | Skills |
|---|---|---|
| Questionnaire with 3-choice selection | Situations given related to environment or every day life which lead to responses of the students | This test is designed to measure students' scientific personality based on the following characteristics<br><br>1. curiosity<br>2. perseverence<br>3. emotional maturity<br>4. responsibility<br>5. independence<br>6. self confidence<br>7. self discipline<br>8. good working habits |

Example:

Instruction: Choose only one answer from the three given responses to the statement.

What do you do to your old toy if you no longer want to play with it?

1. give it to somebody
2. keep it somewhere
3. restore it

*Project Type Test*

| Type of test item | Content | Skills |
|---|---|---|
| Essay | The test items are based on the content of the science curriculum | Manipulation<br>Observation<br>Measurement<br>Data collection<br>Graphing<br>Classifying<br>Interpreting data<br>Making hypotheses<br>Drawing conclusions |

Example:

Using the materials and equipments given on your table please find out which one, water or alcohol, evaporates faster and defend your conclusion using the data you have collected.

*Process Exercises Test*

| Type of test item | Content | Skills |
|---|---|---|
| Essay | The test items are based on the content of the science curriculum | The aim of the Process Exercise test is to test students' abilities and knowledge connected with in science.<br>The tasks are designed to assess the student's ability to use laboratory apparatus, follow instructions for practical work, make observations draw conclusions from observations, develop hypotheses and so on.<br>The tasks usually require manual operations, laboratory skills and scientific knowledge. |

Examples:

Abbreviation of Items:

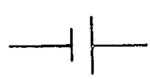
| | |
|---|---|
| 1. Combustion | Observation of the form of combustion of cotton, synthetic fibre and wool. |
| 2. Potato | The form of dissolution of starch and sugar in cross-section of a potato. |
| 3. Flashing bulbs | Understanding of flashing bulbs and making a circuit with them. |
| 4. Black box | Investigating the wiring in a black box used by the tester. |
| 5. Rocks | Comparison of rocks on the basis of a photograph and observation of fossils with a magnifying glass. |
| 6. Identification of a solution | The analysis of a solution using a chemical reagent. |
| 7. Animal specimen | Write differences and similarities of two kinds of animals from pictures. |

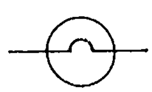
*Item No. 1.* Using the equipment on the desk, answer the following questions.

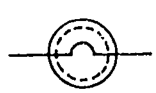
1. Of the three miniature electric bulbs - red, blue and green which is the flashing bulb?
2. Connect up the bulbs in such a way that two flash and one burns steadily. When you have finished, draw a wiring diagram using the symbols given below.

**Symbols**

**Writing diagram**

Dry battery 

Miniature bulb 

Flashing bulb 

*Item No. 2.* Two animal specimens are on display before you. Look at them carefully.

1. List three ways in which they are alike.

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

2. List three ways in which they are different.

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

**Evaluations of Identification Instruments**

It was generally accepted at the Workshop that identification procedures and nurturing programmes for talented science students should be based on the learning characteristics of talented students and the roles that they are expected to play in society.

It was also agreed that the choice of identification procedures and nurturing programmes for the talented are guided by the educational philosophy of each particular country and the resources which are made available by the government.

What direction should then be taken?

For the countries in the region which elect to pursue special programmes for the scientifically talented students, a number of identification instruments have been recommended. A question has been raised regarding the validity of the identification instruments; hence the need for the continuing development of such tests, particularly those which measure the affective domain of interests and attitudes. More research is needed in the area of creativity testing.

Two recommended procedures for identification of science talent, i.e. the science process exercise test and the project type test require additional time and resources for administration.

Research studies in the Philippines has shown that the Philippine Science High School (PSHS) teacher-made Science and Mathematics Achievement Test (SMAT) has predictive validity. The PSHS however, has to develop a creativity test and make better use of its personality traits inventory findings to follow up more effectively student achievement, particularly the underachievers and those who need reinforcement in the school programme.

In Thailand, research studies on the identification of the scientifically talented students have shown that the omission of creativity measures (which is included in the battery of tests in Thailand) would have a fairly marked effect on students' selection. Moreover, it has been found that the workload associated with the administration and scoring of a creativity test is heavy, and sometimes more subjective. The results also show that using fluency in place of these three criteria measures of the creativity test (i.e. fluency, flexibility and originality) was found to have little impact on the selection of the top students. Therefore, the practicality of the scoring methods as well as the validity and reliability of these should be taken into consideration.

In Korea, with short experience in identifying the scientifically and technologically talented students, it was suggested that more research work should be carried out to find better predictors or indicators of students talented in science and technology. More specifically, the science achievement test which is the main instrument and used on the second stage may just measure the knowledge students attained through lower secondary education, instead of potential creativity in science problem solving.

Therefore, a Project Type Test should be developed and utilized to evaluate creativity and task commitment in problem solving of students, and the validity and reliability of the science aptitude test should be improved.

Chapter Five

# SUMMARY AND CONCLUDING STATEMENTS

## Summary

Science and technology education for talented students should be designed to match their particular learning capabilities and characteristics. It has been shown that there are two main ways of grouping talented students in order to meet their specific needs. One approach attempts to give enriched learning opportunities in the regular classroom or in the regular school. The other is to establish separate science high schools which provide special programmes for the selected students.

In each case, these outstanding students require programmes based on different and more focused objectives. They need a curriculum which contains different content from that of the regular students and a variety of teaching learning methods which maximize the potential development of the students.

Care must be taken in selecting and nurturing the individual talents of this significant proportion of the young people of the countries of the region. It will be from this group that the leaders of science and technology of the future will come.

It is considered that the countries of the region will use validated test instruments which suit their particular needs. However, it is likely that multiple screening procedures will be required to provide adequate methods. A framework for such selection procedures and processes has been developed as part of the proceedings of the workshop. Exemplar items are included in this report.

## Concluding Statements

To further increase the capabilities of the countries in the region to meet the economic and social needs of the people, it seems appropriate to base their growth on the development of a highly skilled and adaptable work force and on the exploitation of science and new technologies. Each country should make particular efforts to increase the pool of scientifically and technologically talented students. Different countries may wish to choose a particular option for the identification and nurturing of these talented students according to their specific needs, policies and resources. Curriculum development, the preparation of soundly researched identification instruments and in particular teacher training and retraining will all need to be addressed.

# A N N E X E S

Annex I

## AGENDA

1. Inauguration
2. Election of Office Bearers
3. Confirmation of the Agenda and Schedule of Work
4. Presentation of Country Reports
5. Provision of Science and Technology Education in the Asia and Pacific Region

   Structure of School System

   Nature of Science Education

   Nature of Technology Education

   Science and Technology and the Education of the Talented
6. Science and Technology Education for the Talented in Secondary Schools

   Objectives

   Curriculum

   Monitoring and Evaluation of the Programme
7. The Development of Identification Instruments for the Science and Technology Talents

   Review of Instruments Currently Used

   Framework for the Identification of Instruments

   Exemplar Identification Items

   Identification Procedures

   Validation of Identification Instruments
8. Summary and Conclusions
9. Consideration and Adoption of Draft Final Report
10. Closing Session

Annex II

## LIST OF PARTICIPANTS

| | |
|---|---|
| Australia | Mr. Graham Fish<br>Director of Curriculum Services<br>Tasmanian Education Department<br>71 Letitia Street, North Hobart<br>TAS 7002 |
| Indonesia | Mr. Herman Y. Kanalebe<br>Lecturer<br>Universitas Kristen Satya Wacana<br>Jalan Diponegoro 52-60<br>Salatiga 50711 |
| Japan | Mr. Masao Miyake<br>Head<br>Science Education Section<br>NIER, 5-22 Shimomeguro 6 Chome<br>Meguroku, Tokyo |
| Korea (Rep. of) | Prof. Seung-Tai Park<br>Director<br>Institute of Science Education<br>Chonbuk National University<br>Chonju |
| | Prof. Ki-Jong Lee<br>Professor<br>Physics Department<br>Chonbuk National University<br>Chonju |
| | Prof. Wha-Kuk Lee<br>Professor<br>Chemical Education Department<br>Chongbuk National University<br>Chonju |
| | Dr. Suk-Hee Cho<br>Senior Researcher<br>KEDI<br>Seoul |

| | |
|---|---|
| Korea (Rep. of) *cont'd* | Prof. Kun-Heun Lee<br>Professor of Education<br>Korea Institute of Technology<br>Seoul |
| | Prof. Kuk Haeng Lee<br>Professor<br>Chemical Education Department<br>Chonbuk National University<br>Chonju |
| Malaysia | Mr. Ibrahim M. Noh<br>Malaysia National Commission<br>for UNESCO<br>Bank Pertanian Lubuh<br>Pasar Besar<br>Kuala Lumpur |
| Philippines | Ms. Adoracion D. Ambrosio<br>Director<br>Philippine Science High School<br>Agham Road<br>Diliman<br>Quezon City |
| Thailand | Ms. Suwaporn Semheng<br>Resource Person<br>Research Evaluation Team<br>Institute for the Promotion of Teaching<br>Science and Technology<br>924 Sukhumvit Road<br>Bangkok 10110 |

Annex III

## THE DEVELOPMENT OF LEARNING/TEACHING MATERIALS FOR REAL-LIFE PROBLEM-SOLVING SITUATIONS

In preparation for developing such learning/teaching materials, a systematic perspective programme may have to be considered. The following outline is merely illustrative of one such perspective action sequence.

*Phase 1*: Gathering potentially learnable/teachable content from the (rural) environment, such as (rural) practices regarding the environment already in use; possible improvements to these practices; environmental measures focussed upon and related to the improvement of the quality of life of (rural) people. Especially important are those associated with socio-economic and cultural development programmes of the government. In many of these, the co-operation of research institutions (industrial, agricultural, fishery, medical etc.), tertiary level institutions, institutional networks and the respective national development departments will undoubtedly be needed.

*Phase 2*: Analysis of existing national curricula to seek points of convergence and natural entry points for the content obtained in phase 1.

*Phase 3*: Development of learning/teaching experiences or episodes, which are still within the framework of the national curricula, but with a "*problem orientation*", to incorporate the Phase 1 products into the Phase 2 sequences; and the development of pre-service teacher education materials. Further development of prototype equipment and demonstration packages would also be likely (i.e. solar heaters, small agricultural ecosystems within the management and husbandry practices of small farmers, and within back-garden conditions; animal/insect/fungus-proof storage bins; clay construction samples; short-height water pumps; small man/animal driven machines, etc.). For this purpose also, agencies outside the education system would need to be harnessed.

*Phase 4*: Production of learning/teaching materials and equipment and other components required for field implementation. Again, portions of this phase would involve close association with agencies outside the education system. This will be followed by field in-service education of teachers, and introduction into pre-service educational institutions, at which time too, agencies outside the education system are likely to be needed. The materials produced would best be described as short text materials (rather than textbooks), which may be *"plugged in"* at appropriate times and would support existing curricula and textbooks.

*Phase 5*: Field implementation (on a pilot or national scale depending on the particular implementation strategy utilized).

To retain the pedagogical requirement of problem solving in the materials being developed in Phase 4, the sequences must reflect the processes of problem solving, not *"kitchen recipe"* sequences.

For example, the following illustrates one possible type of initial template framework for developing such sequences:

| Information/comprehension* | Analysis/synthesis/ evaluation/application |
|---|---|
| Husks (maize), hulls(rice), etc. protect the grain from damage during the harvesting and drying and from attack by insects and molds. | Implications for threshing methods used by farmers (whether these damaged grain)<br><br>- leading to improved threshing methods consideration of costs/benefits leading to costs/benefits;<br>- leading to decisions regarding threshing methods of improved variety;<br>- leading to design of improved threshing methods;<br>- leading to using the improved threshing methods. |

* *The information itself, preferably obtained by observation and generalizations made by the learners.*

Phases 1 and 2, to begin with, could become integral components of in-service education programme, and provide excellent vehicles for enhancement of content competence of the teachers, as well as for develor'ng their analytical application and problem-solving skills. The teachers ın the field, as *"homework"* for their in-service sessions, would collect these real life situations (hence extending the arm of the Curriculum Development Centre to all parts of the country). Such collected situations, and others such as those the Centre itself collects, during practice teaching, pre-service trainees too, could be collectors with subsequent analysis done at teacher education institutions, in co-operation with the Curriculum Development Centre. Both collecting methods would, naturally, enhance very quickly, the pool of real-life problem situations of importance in the lives of the learners.

Teacher participation in other phases too could provide not only the lessening of workload of the Curriculum Development Centre, but also provide for on-the-job training for the teachers, and a commitment on their part to the programme, since they would have been involved personally, right from the design stage.

The example as described is a somewhat radical departure in curriculum development with focus on relevance and problem-solving, in its very direct contribution to socio-economic cultural development of the nation, and would provide automatically, a wide range of practical opportunities for developing scientific and technological talent in the learners.

Annex IV

# EXAMPLES OF PROBLEM-SOLVING SITUATIONS

## Type 1: Analysis of a Situation

(No Experimental Investigation Required)

*Example 1*

a) The population of flies in the cattle sheds at an experimental station was so large that the health of the animals was affected. The workers sprayed DDT, and most of the flies were killed. In a few weeks, the population of the flies increased, and again DDT was sprayed, most of the flies were again killed. This sequence was repeated several times as the fly population still increased despite the spraying with DDT. After five sprayings, it became evident that the DDT was becoming less and less effective in killing the flies, until finally, spraying with DDT appeared to be virtually useless.

* *Construct several different hypotheses to account for the facts related to the DDT and the flies in the cattle shed.*

b) One of the workers noted that one large batch of DDT solution had expired but was still used in all the sprayings. It was therefore suggested that the DDT solution could have decomposed with age.

* *Suggest at least two different approaches towards testing this hypothesis.*

c) A fresh batch of DDT was prepared. It was used instead of the old batch on the renewed fly population, at the experimental station. Nevertheless, despite the freshness of the solution, only a few of the flies died. The same batch of DDT was then tried on a fly population at another cattle shed some 50 kilometers away. In this case the results were likely those originally seen the first time DDT was sprayed in the first cattle shed, the experimental station. Most of the flies were killed. Here the results with the same fresh batch of DDT is quite different. The weather conditions at the time of the spraying at the distant cattle shed was similar as when the spray was used without success at the first cattle shed.

* *Resolve the problem situation into its major components. Which components were incorporated in the hypothesis originally made? What components have not been incorporated? (Could anything have happened within the fly population that would account for the decreasing effectiveness of DDT - this is a prompt to be used only if necessary. Other prompts could be - where did the new fly population come from after the first "effective" spraying? Who were the parents? Were the parents among the more susceptible or the more resistant as far as the effects of DDT were concerned? Which individuals would be more likely to survive the second spraying?)*

*Example 2*

Ten flies are in a closed cylindrical transparent glass bottle. It is placed on an accurate weighing scale.

Which of the following is correct?

1. The scale will register the most weight when all the flies are sitting on the bottom of the jar.
2. The scale will register the most weight when the flies are flying around the jar.
3. The weight recorded is the same when all the flies are sitting on the bottom of the jar or are flying.

*Example 3*

A stable, large bubble of air is found under water. A powerful light beam shines through the bubble. Which of the following would the light beam do after passing through the bubble?

- converge
- diverge
- is unaffected

*Example 4*

You have a thick bright coloured blanket A which is a good insulator. You also have a thin coloured blanket B, which is a poor heat insulator.

It is a very cold night and you need both blankets. You will be warmest if you:

- put the blanket A on top to keep the cold out of the bed and put blanket B next to you.
- put the blanket A next to you to keep the heat in and put blanket B on top.
- either way makes no difference.

*Example 5*

Fish compress and expand their swim bladder to change depth. But a fish has no control over its swim bladder. How do they do it?

*Example 6*

Masonry walls which become wet and damp near the ground maybe prevented from becoming so by grounding the wall electrically (running a wire from the wall to a metal stake in the ground). How would shorting the wall prevent moisture in the wall?

*Example 7*

The maximum height of a suction pump can be about 33 feet. So all trees should not be taller than 33 feet because sap cannot rise above this. Is this so? Is the mechanism of sap rising in a tree different from that of a suction pump? How is it different? How is it similar?

*Example 8*

In order to slow down the rusting of steel of large cargo ships, large blocks of a magnesium alloy are often attached to the side of the ship. Does this help at all? How?

**Type II. Analysis of a Situation**

(Experimental Investigation Required)

*Example 1*

Carefully stir a cup of hot coffee until there is a uniform swirl. Then carefully pour a stream of cold milk into the centre. What do you observe? Record your observation. Repeat with hot milk, record your observation. How would you explain your observations?

*Example 2*

It is breakfast time. You want to drink hot coffee. You pour yourself a cup of hot black coffee. You are about to pour cold milk into you coffee when the phone rings. Should you add the milk before you answer the phone, or after you have answered the phone in order to have hot coffee to drink? Test your hypothesis.

*Example 3*

The behaviour of fruit flies (*Drosophila*) lends itself to a number of investigations. Initial investigations for example on mating behaviour could record, interpret and classify such actions as

a) vibration (i.e. wing movement of male, speed with one or two wings, parallel or up and down movement, return to rest position, motion bursts, etc.);

b) waving (slow spread of one wing of male outward from body to 90 degrees held in position and relaxed without vibration);

c) scissors movement (open and close movement of both wings);

d) fluttering (by non-receptive females and males courted by males-wings slightly elevated, separated from contact with each other, moved slightly laterally and vibrated rapidly);

e) circling (male after posturing at the side or rear of a non-receptive female, circles facing the female);

f) stamping (males stamp their forefeet). Special attention may be paid to properties that may be measured quantitatively.

*Example 4*

Fish schooling provides excellent opportunities for observing social organization under diffused (non-specific) external stimuli. (Many other animals also show mass grouping behaviour, but are more difficult to study in a classroom situation).

Species of fish such as Zebra (*Brachydanio rerio*), Harleqauin (*Rasbora heteromorpha*), Scissors-tail (*Rosbora trilinlata*), Rosy tetra (*Hyphessobrycon rosacens*), Tiger barb (*Barbus tetrazona*) are very suitable for the purpose. Observations may be made on single species or mixed species in varying proportions. Among the interesting observations that can be made are: Do they all swim in single species? Are there any signs of aggressive behaviours among the fish in the group? Is there a visible *'pecking'* order in the group? Is there any apparent correlation between density of schooling and *'preferred'* habitat within the aquarium? What effects on grouping behaviour result from vibrations (tapping on the aquarium frame) and from introducing food? Varieties of common canal fish also show very interesting schooling behaviour. Is there a difference in schooling behaviour of fish in polluted canals as compared with fish in relatively clear canals?

*Example 5*

A large magnet placed near a carpenter's bubble level will force the bubble to move. Does the bubble move toward or away from the magnet? How does the magnetic field do that?

*Example 6*

Select a common invertebrate animal (e.g. millipede). Locate a number of colonies. Compare density in each. Relate density to type of habitat. Is there any evidence of a relationship between density and any environmental factors?

How would you determine the extent to which they move from one microhabitat to another? At what time of the day are they active? (Prompt-tagging say with paint spots). What factors determine the distribution of animals? Formulate hypothesis based upon field observations. Investigate these animals in "*choice chambers*" in the laboratory (prompt-conditions such as dark/light, response to other individuals, low/high humidity, variation in responses due to a rhythm of activity within the animal; the psychological condition of the animal in relation to the physical environment; the possible interaction between animals).

If the animals prefer a dark, moist environment and congregate together, how quickly do they lose water? Do they lose water faster if isolated? (Prompt-weighing one animal in a container about every 20 minutes - what sampling? Weighing a number of animals in a container at the same time periods - what sampling?)

*Example 7*

Place a coin in a transparent open cylindrical jar filled with water. Look down through the water surface. At an appropriate angle, the coins's image seems to be on the surface of the water. If you put your hand on the further side of the jar, usually there is no effect on the image. But if your hand is wet, the image disappears. Explain why.

*Example 8*

If you pour honey or treacle or syrup or thick oil from a height, the stream will force itself into a coil. What affects the diameter and height of the coil? The rate at which it forms? Why does the coiling form?

*Example 9*

An old formula from Sri Lanka, for a strong adhesive paste is the following:

*"Four parts glue are soaked for a few hours in 15 parts cold water, and moderately heated till the solution becomes perfectly clear, when 65 parts of boiling water are added, while stirring. In another vessel 30 parts boiled starch are previously stirred together with 20 parts cold water, so that a thin milky liquid without lumps results. The boiling glue solution is poured into this while stirring constantly, and the whole is kept boiling another 10 minutes."*

Is this really a strong paste? How would you alter the setting time of the paste without reducing its strength of adhesiveness?

*Example 10*

Using whatever materials you wish, design and make an instrument that will allow you to see around corners.

*Example 11*

How can you cook an egg using the sun? Prompt: use mirrors, aluminum foil, cardboard and pieces of metal. Design the set-up you wish to use, build it and test it.

*Example 12*

Who can keep an ice cube the longest? You are not allowed to use a refrigerator or a freezer. In many real-life situations in science and technology, students are requir^ed to apply their mathematical skills.

*Example 13*

Associated with Chemistry teaching, (deriving atomic weight proportions from chemical formula say (NH) SO the percentage of any element in a fertilizer may be calculated, if the chemical formula and per cent purity are known. Such calculations will explain what a given fertilizer is composed of and what it is supposed to accomplish.

*Example 14*

Farmers need to estimate the yields per acre for a given crop (say) for quoting a price to a buyer, computing storage needs, labour requirements during the harvesting season, probable income from a crop. Several sampling techniques may be used and these provide effective exercises in arithmetic and statistics.

The Development of Exemplar Identification Instruments for a Science and Technology Education Talents Programme