DOCUMENT RESUME

ED 456 825 IR 020 881

AUTHOR	Sharif, Ahmad Mohamad; San, Kong Meow
TITLE	The Invention Curriculum: A Malaysian Experience. Innodata Monographs 11.
INSTITUTION	International Bureau of Education, Geneva (Switzerland).
PUB DATE	2001-00-00
NOTE	39p.
AVAILABLE FROM	International Bureau of Education (IBE), P.O. Box 199, 1211 Geneva 20, Switzerland. Web site: http://www.ibe.unesco.org.
PUB TYPE	Reports - Research (143)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Computer Assisted Instruction; *Curriculum Design; Curriculum Development; Foreign Countries; Instructional Design; *Instructional Innovation; Inventions; Learning Activities; Secondary Education
IDENTIFIERS	*Malaysia

ABSTRACT

This monograph describes a Malaysian innovation, the Invention Curriculum, or "Reka Cipta." This technology-based subject, which is multidisciplinary in approach, was introduced as an elective subject in 14 upper secondary schools in Malaysia in 1995 and has now been implemented in over 200 schools across the country. The objective of the innovation is for students to create a product which combines novelty and commercial value, in this way developing skills of creativity and problem-solving. The curriculum seeks to promote the practical application of abstract ideas and knowledge using up-to-date and appropriate technologies. In addition to innovation, it stresses knowledge and skills in marketing, intellectual property, and documenting of inventive processes and results. Since its inception, and in spite of its challenges for many teachers, the project has experienced growing success, with nearly 100% pass rates each year and over one-third of students achieving distinctions in the year 2000. The project falls in line with Malaysia's thrust towards advanced scientific and technological development through the fostering of expertise and innovation. The current practices of developing, implementing and monitoring the Invention Curriculum are related. Detailed descriptions of curriculum evaluation and follow-up activities are provided. The paper also highlights findings of case studies conducted in two schools. (Contains 20 references.) (AEF)

INNODATA MONOGRAPHS 11

Educational innovations in action

THE INVENTION CURRICULUM: A MALAYSIAN EXPERIENCE

Ahmad Mohamad Sharif

and Kong Meow San

INTERNATIONAL BUREAU OF EDUCATION

UNESCO

INNODATA MONOGRAPHS – 11

THE INVENTION CURRICULUM:

A MALAYSIAN EXPERIENCE

Ahmad Mohamad Sharif
and Kong Meow San

IBE

UNESCO

INTERNATIONAL BUREAU OF EDUCATION

About the authors

Ahmad Mohamad Sharif

Ph.D. (Louisiana State University) in technical and vocational education. Principal Assistant Director (Head) of Technology Education, Curriculum Development Centre, Ministry of Education, Malaysia. Project manager cum writer of several curriculum materials, such as resource books, modules and teachers' guides.

Kong Meow San

M. Ed. (University of Malaya) in science education and curriculum development. Assistant Director, Head of Living Skills and Invention Unit, Technology Education, Curriculum Development Centre, Ministry of Education, Malaysia. Project co-ordinator, writer and editor of several curriculum materials and published journal articles. Course designer and consultant on in-service teacher training, creative thinking and interpersonal skills.

Table of contents

Published in 2001
by the International Bureau of Education,
P.O. Box 199, 1211 Geneva 20,
Switzerland

Internet: http://www.ibe.unesco.org

Printed in Switzerland by PCL

Foreword

This monograph describes a Malaysian innovation, the Invention Curriculum or *Reka Cipta*. This technology-based subject, which is multidisciplinary in approach, was introduced as an elective subject in fourteen upper secondary schools in Malaysia in 1995 and has now been implemented in over 200 schools across the country. The objective of the innovation is for students to create a product which combines novelty and commercial value, in this way developing skills of creativity and problem-solving. The curriculum seeks to promote the practical application of abstract ideas and knowledge using up-to-date and appropriate technologies. In addition to innovation, it stresses knowledge and skills in marketing, intellectual property and documenting of inventive processes and results. Since its inception, in spite of its challenges for many teachers, the project has experienced growing success, with nearly 100% pass rates each year and over one-third of students achieving distinctions in the year 2000. The project falls in line with Malaysia's thrust towards advanced scientific and technological development through the fostering of expertise and innovation.

Introduction

In the wake of the country's effort to emerge as a fully developed country by the year 2020, Malaysia has placed paramount importance on science and technology, with special emphasis on technological innovation. Indeed, the sixth of the nine central challenges in Malaysia's Vision 2020 is that of 'establishing a scientific and progressive society, a society that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilization of the future' (Mahathir Mohamed, 1991, p. 7). Malaysian industries require the pioneering efforts and the aggressiveness needed to engage in product innovation and development. Such industries tend to depend heavily on imported technology, are preoccupied in lower level manufacturing operations and remain as contract manufacturers. This has impeded them from moving upstream into higher value-added operations or products (Ahmad Tajuddin Ali, 1995). As a step toward fulfilling the need to produce knowledge workers who are not only competent but also able to participate as innovators in the industrial world, in 1995 the Ministry of Education of Malaysia, among other things, introduced a new elective subject 'Invention', at the upper secondary school Form Four and Form Five levels (years 10 and 11).

The 'Invention Curriculum', or *Reka Cipta* as it is known in the Malaysian language, essentially encompasses a technology-based subject and is multi-disciplinary in nature. The 'Invention' subject aims at inculcating creativity and problem-solving abilities among students, through production of an artefact or product that carries novelty and commercial value. Conceptually, 'Invention' is a blend of three major elements (the 3Hs)—namely the head, the hand and the heart. The abstract and creative idea that evolves through the student's mental processes is transformed into a concrete and useful product using technological skills and experiences already acquired. Curiosity, patience and perseverance are some work attributes and values identified with this subject.

This monograph attempts to relate the current practices of developing, implementing and monitoring the Invention Curriculum. Detailed description of curriculum evaluation and follow-up actions are provided. The paper also highlights findings of case studies conducted in two schools of different settings. The findings may provide some critical factors indicative of the effectiveness of the programme.

Background

Malaysia has a 6-3-2-2 system of education, comprising six years of primary education, three and two years of lower and upper secondary education, followed by two years of post-secondary education. Technology-based education is first introduced at primary schools (years 4 to 6) and developed further at secondary schools (years 7 to 11). For this purpose, 'Living skills', a core subject which is compulsory for all students (years 4 to 9), has been mainly formulated together with elements of invention designed in it. Through this subject, students gain basic practical skills and knowledge founded on technology and entrepreneurship. The emphasis here is to develop students who are conversant with technology and economics, thus enabling them to adapt to the changing needs and demands of life. Thus, the DIY ('do-it-yourself') approach, coupled with elements of entrepreneurship and inventiveness, has become an integral part of the teaching/learning process. Positive work attitudes such as self-reliance, confidence, creativity, initiative and productivity are infused into the learning activities.

At Forms Four and Five (years 10 and 11), an array of technology subjects is available as electives for academic schools. From time to time, new technology subjects are formulated and offered for students' selection. Subjects like 'Invention' and 'Information technology' are the latest two additions to the list.

Whilst elements of 'Invention' are added as a new topic to the 'Living skills' subject (years 4 to 9), the full subject is offered as an elective at upper secondary school (years 10 and 11). This paper thus focuses on the teaching of 'Invention' at upper secondary school level. Students do research, design and create products using the problem-solving approach, with proper documentation of their work. They also undergo CAD ('computer-aided design') training.

The Invention Curriculum is an initiative by the top policy-makers, designed to meet the nation's industrial needs. It was first introduced as a pilot project in 1995 involving fourteen schools (one school for every state in Malaysia). In the following year, 114 additional schools started this curriculum. It is planned to increase implementation by fifteen to thirty schools per year. Currently, in the year 2001, there are 211 schools operating in the entire country.

To implement this curriculum, the Ministry of Education has spent US$4.65 million in the Seventh Malaysia Plan for 1995–2000 (Government of Malaysia, 1996). The expenditure covers the purchase of computers and accessories, furniture and tools, CAD software and upgrading of computer laboratories. The cost of setting up a computer laboratory (renovated

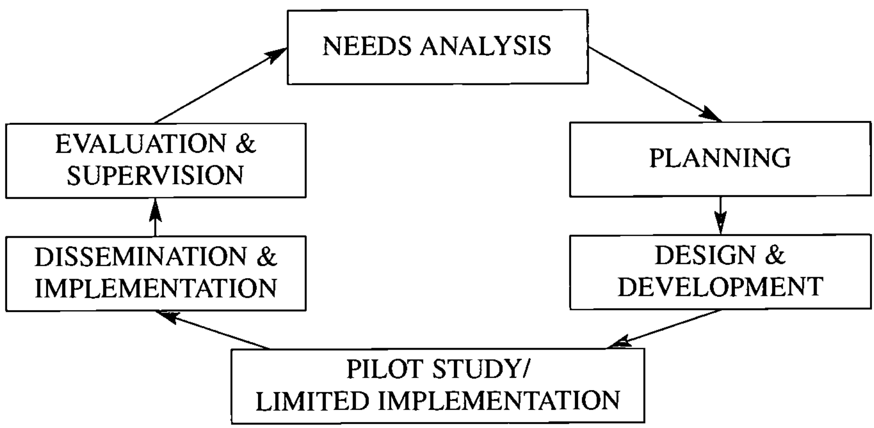
classroom), for a particular school equipped with twenty-one units of computers and CAD software, is approximately US$44,100. A school offering the Invention Curriculum is also given a launching grant for the purchase of basic power tools and equipment. Schools are also given a per capita grant for the purchase of tangible materials such as wood, metal and electronic components.

Curriculum development, implementation and monitoring

CURRICULUM DEVELOPMENT

Curriculum development in Malaysia follows a cyclic model (Figure 1), which consists of six processes—namely, identification of needs, planning, development, pilot study, implementation and evaluation.

FIGURE 1. Curriculum development model



Source: Curriculum Development Centre, Ministry of Education, Malaysia.

As for the formulation of a new subject or review of an existing one, the Curriculum Development Centre (CDC), Ministry of Education, conducts its own needs analyses using inputs from teachers and experts, reports from state education offices, findings from surveys and library research, including information on local and world trends.

Following the decision, a curriculum committee or project team is formed, consisting of CDC officers, subject specialists/experts, lecturers from teacher training colleges or universities, representatives from industries and training agencies. The first task of the project team is to prepare a concept paper to be presented to the Central Curriculum Committee (CCC). The CCC, the highest

decision-making body on professional matters, is chaired by the Director-General of Education with members from heads of professional divisions and relevant administrative divisions, selected state education directors and deans of education faculties of local universities.

In formulating the concept paper, the project team holds a series of workshops. Once the concept paper is approved by the CCC, the project team meets again for several workshops involving additional practising teachers and subject specialists. The approved concept paper is the basis for developing the syllabus, containing goals, objectives and content outlines. The proposed syllabus is then presented to CCC for further comment and approval. After obtaining syllabus approval from the CCC, the project team meets again and develops a curriculum specifications document stipulating, among other things, the goals and objectives, content and proposed activities, teaching and learning strategies, workshop requirements and layout. The curriculum specifications form the basis for the preparation of curriculum materials such as teachers' guides, resource books, teacher and student modules. As it involves finance, a budgetary request is forwarded to the Educational Planning Committee under the chairmanship of the Minister of Education. The whole process takes about eighteen months from the formulation of the concept paper to the development and approval of the syllabus and curriculum specifications.

THE INVENTION CURRICULUM

The Invention Curriculum is designed to enable students to be creative in their thinking, innovative and inventive. Students will be capable of creating artefacts that are beneficial and have commercial value.

The current Invention syllabus consists of five major topics: 'Making invention projects', 'Computer-aided design', 'Marketing', 'Intellectual property' and 'Documentation of invention'. Besides the 'Invention' syllabus and its specifications (Curriculum Development Centre, 1996*a*), several curriculum materials for teachers and students are developed and disseminated. These include a teacher's guide (Curriculum Development Centre, 1996*b*), a teacher's module (Curriculum Development Centre, 1996*d*), AutoCAD module (Curriculum Development Centre, 1996*e*), and a student's resource book (Curriculum Development Centre, 1996*c*). Basically, the syllabus emphasizes design processes rather than knowledge per se.

After five years of implementation, a recent curriculum review revealed that substantial knowledge and experience in design and technological skills should also be provided for students. Thus, the newly revised Invention Curriculum—approved for implementation in the year 2003—has two new topics added: 'Design' and 'Manufacturing technology'. The topic on 'Marketing' has been modified to focus on 'Marketing strategies'. Other topics like 'Intellectual property' and 'Documentation' remain as they were. Further details of the recent Invention Curriculum review are provided in the chapter on 'Curriculum evaluation'.

In the Invention Curriculum, students are exposed to the design processes, starting from problem identification and idea formulation to prototype making and evaluation. Students are also equipped with sketching skills and the use of 'Computer-aided design' software that enable them to design and produce two- and three-dimensional diagrams useful for model and prototype preparation. Students' technical skills, acquired from the 'Living skills' subject at the lower secondary school, are further enhanced through the topic 'Manufacturing technology' (in the newly revised version) that exposes them to use a variety of materials, machines and tools. In 'Manufacturing technology', the principles of engineering—covering several systems such as electromechanical, hydraulic and pneumatic—are introduced. To give students a better understanding of robotics and automation, robot kits have been introduced since 2000 as teaching and learning aids. The 'Invention' subject also includes 'the 4Ps' of marketing—namely, product, price, promotion and place. 'Intellectual property', as its name implies, makes students aware of the importance of intellectual property, the procedures and processes involved in patenting a particular product.

IMPLEMENTATION

The subject 'Invention' is taught in four forty-minute periods per week with an average class size of twenty to twenty-five students. The total contact time for the two-year course is seventy hours. To date, there are about 230 teachers from 211 schools throughout the country with a total capacity of about 8,500 students pursuing this subject. As there is no special workshop for students of the 'Invention' subject to conduct their practical activities, they normally carry out their model-making and prototype testings in the 'Living skills' workshops. However, some schools have special rooms converted into studios for this purpose. To initiate the 'Invention' subject, every school is provided an initial launching grant of US$1,315 followed by a per-capita grant of US$10.5 per year per student.

Each student is required to invent a product (utilizing his or her creativity) and produce an accompanying folio which represents systematically documented evidence of the individual's project work. As there is no written examination for this subject, the product and folio form the basis for assessment of student performance. Both product and folio are equally weighted for grade scoring in the national Malaysian Certificate of Education (MCE) examination. During the teaching/learning process, every student is required to design and produce his or her own individual invention. Each student proceeds with identification and definition of his or her individual proposal. The proposal, which is in the form of problem delineation and alternative solutions, is put forward during class discussions and critique sessions. Constant input and feedback from the class and teacher help the student to improve his or her project work. The teacher guides, advises and monitors the progress of the student's work from problem identification and product design to product making and testing. The MCE results of the 'Invention' subject for a five-year period are shown in Table 1:

TABLE 1. Malaysian Certificate of Education results for the 'Invention' subject, 1996–2000

Year taken	No. of candidates	% passes	% distinctions	% credits	% passes	% incomplete projects
1996	450	100.00	9.80	74.90	15.30	0.00
1997	2781	99.67	11.47	77.74	10.46	0.33
1998	3562	97.70	7.30	77.70	12.70	2.30
1999	3909	99.69	12.04	77.97	9.69	0.31
2000	3527	98.60	38.70	56.30	3.60	1.40

Source: Examination Syndicate, Ministry of Education, Malaysia.

As shown in Table 1, for the first four years (1996 to 1999) about 75% of candidates scored credits, while 10 to 15% managed to get passes. Candidates obtaining distinctions tend to fluctuate between 7 to 12%. The most recent MCE results, for the year 2000, show that 38.7% of 3,527 (i.e. 1,365) candidates obtained distinctions. This indicates a three-fold increase over the previous year's number of 470 distinction students. Plausible reasons for this impressive result are put forward in the 'Conclusion' chapter.

A good grade in MCE gives students an opportunity to pursue related courses, such as 'Design' and 'Technology', in local universities. Aside from examinations, students also participate in exhibitions and competitions conducted at state and national levels. The prize-winning products at national level are selected for international exhibitions and competitions.

MONITORING

CDC officers and state supervisors constantly monitor the programme through periodic supervision and survey. This is done through classroom observations, case studies and questionnaires. Inputs are gathered, discussed and taken into consideration for future improvement. Seminars and conferences are held to obtain feedback from teachers as regards issues and problems that may arise during implementation. Resolutions are also formulated for further consideration by policy-makers. Some of the issues and problems that surface during implementation are discussed below.

ISSUES AND PROBLEMS

Being technology-based and multidisciplinary in nature, 'Invention' requires teachers to be versatile in many areas of knowledge and skills. As there is no formal teacher training in this particular field, teachers have to equip themselves with a multitude of skills, e.g. technological skills, and skills in design and creativity. Therefore, intensive training in these particular areas is essential to develop effective teachers. Teachers trained in technical and design fields do not face problems in handling this subject, as compared to their fellow counterparts whose prior training is in the arts. This problem is further discussed on in the following sub-section 'Teacher professional development'.

As there is no written test in the final MCE examination, there is a tendency for some schools to select students from the low achievement group to pursue this subject. In these cases, teachers do meet with difficulties in managing practical classes with students of differing capabilities and interests and increased class size. This has a bearing, to some extent, on students' practical work and products. Ideally, students should be selected based on their capabilities and interests.

In terms of facilities, not all school workshops are sufficiently equipped with proper machines and tools. Teachers require advice and help regarding their selection and purchase. They also need to work with the school principal for budget support and wise utilization of the special launching grant and yearly per-capita grant provided to schools for this subject by the Ministry. There are also cases where computer laboratories are not adequately supplied with computers and CAD software. Such problems, when left unattended, can impede the smooth running of the programme.

At present, career prospects for 'Invention' students to pursue related courses at tertiary level are rather limited. Currently, there are only two institutions of higher learning, i.e. University of Technology Malaysia and Mara

University of Technology, that consider and recognize students' grade in the MCE as one of their entry requirements for admission. Other universities may not be fully aware of the relevance and prospects of this subject.

TEACHER PROFESSIONAL DEVELOPMENT

Schools that offer the Invention Curriculum have to meet certain criteria before they qualify for selection by the state education departments. Two such criteria are that the school concerned must have: (a) the necessary workshop facilities; and (b) a teacher who is interested to teach the subject. It is the task of the CDC to design and conduct training for these teachers.

Invention teachers are of varied educational backgrounds. Slightly more than 50% are university graduates in science or mathematics and have been teaching these subjects before. There are a majority of physics teachers in this group. About 30% have a technical background or are teaching 'Living skills' in the lower forms or are university graduates in technology. The technology graduates are mostly young teachers who have just started teaching or who have taught for only a few years. The others are teachers of art, geography, history or religion.

This has led to a unique situation in that, irrespective of their educational background, these teachers are willing to take on a very new subject, requiring a different style of operation. The teachers' willingness to venture into new terrain augurs well for the Invention subject.

It thus becomes a challenging task for CDC to develop a plan for the professional training of these teachers. The teacher development plan has to provide for substantive training in technical content, skills in CAD software applications, as well as pedagogical aspects of teaching for developing students' creativity. Other content areas to cover include intellectual property and marketing. In view of rapidly changing technological advancement, teachers also need regular updating. Hence the teacher professional development plan has to have certain levels of flexibility and progressive development. The training plan should also allow for mobility into new areas of the future.

To suit the purposes above, a radial model is used to implement the teacher development plan. A core course on orientation to the Invention Curriculum is designed as the first course for all teachers. This forms the nucleus. From this core experience the teachers' training radiates out into other more specific areas. As time progresses and needs change, courses that are more focused are then introduced to further enhance these teachers' capacities. For conducting such courses, expertise in the particular field is sought.

Table 2 shows the courses developed for Invention Curriculum teachers since the first year of implementation. These are one-week courses (some are held at certain technology training institutions). The number of teachers trained is normally more than as stated in the last column of Table 2, because state education departments make requests to train new teachers who replace those leaving the system.

The Orientation course, as the nucleus, contains various components to give the teacher a comprehensive view of the Invention Curriculum, its rationale, aims, objectives, content and assessment. There are special sessions on creativity, intellectual property and marketing. Teachers get exposure to practical sessions on basic electronics and technical drawing. From 1997 onwards, 'S-CAD' training was placed as part of the 'Orientation' course when that software was provided to schools and immediate training was needed. 'Technical drawing' was removed and offered in later, subsequent courses. From this nuclear 'Orientation' course, teachers training radiates out into other areas, such as 'Auto-CAD'. Courses focused on specific needs, e.g. welding, PLC (programmable logic controller) and design, are conducted to enrich teachers' experience.

In addition to the professional development of teachers at the central level, other forms of training for these teachers are also organized at the state level by the education departments.

TABLE 2. Courses for professional development of 'Invention' teachers

Year	Course	Teacher batch
1995	Orientation to the pilot programme	1995 (14 teachers)
	Auto-CAD	1995 (14 teachers)
1996	Orientation to the Invention Curriculum	1996 (114 teachers in two batches)
	Auto-CAD	1996 (60 teachers in two batches)
	S-CAD	1995–1996 (128 teachers from five zones)
1997	Orientation to the Invention Curriculum	1997 (15 teachers)
	Auto-CAD	1996 & 1997 (30 teachers)
	Woodwork and electronics	1995–1997 (143 teachers in three batches)
1998	Orientation to the Invention Curriculum	1998 (14 teachers)
	Auto-CAD	1996 & 1998 (30 teachers)
	Introduction to designing	1995–1998 (157 teachers in two batches)
	Gas & arc welding & PLC (programmable logic controller)	1995–1998 (157 teachers in several batches)
	PLC Intensive course	1995–1998 (60 teachers from zones 1–2)
1999	Orientation to the Invention Curriculum	1999 (15 teachers)
	Auto-CAD	1996 & 1999 (30 teachers)
	Design, technical drawing & model making	1995–1999 (teachers from zones 1–3)
	PLC Intensive course	1995–1998 (30 teachers from zone 3)
2000	Orientation to the Invention Curriculum	2000 (15 teachers)
	Auto-CAD	2000 (15 teachers)
	Design, technical drawing & model making	1995–1999 (teachers in zones 4–5)
	PLC Intensive course	1999–2000 (30 teachers)

Curriculum evaluation

CURRICULAR FEEDBACK

Feedback on the implementation of the Invention Curriculum is an on-going process. Invaluable information is received from various channels, as follows:

- Regular visits by CDC personnel to monitor the schools and meet with teachers and school principals.
- Annual co-ordination meetings between CDC and all the state education departments, with the latter also conducting state-level monitoring of schools.
- Reports from the Inspectorate of Schools.
- Resolutions from seminars on Invention, both at the national and state levels.

Often the feedback serves as input for teachers' professional development and curricular materials support. This process of feedback facilitates the taking of appropriate actions. Most times it involves providing clarification and advisory services or smoothening administrative procedures. Matters arising generally concern the provision of computers and software, launching grants, purchase of materials and equipment and enrolment of students for the Invention subject. An issue that often arises is the change or transfer of trained Invention teachers and the new replacement teachers who need fresh training.

This continuous feedback leads to various measures being taken to enhance the teaching of the 'Invention' subject in schools, including further production of materials, e.g. *Guide book on documentation skills*, provision of more teaching/learning kits (such as robot kits), creation and implementation of a student attachment programme to local industries in order for students to widen their experiences. These initiatives are driven by the feedback for continuous curricular improvement and enrichment, and are described below in chronological order.

STUDENT ATTACHMENT PROGRAMME TO LOCAL INDUSTRY

This is an initiative between the Ministry of Education and the private sector. The attachment programme is a form of work experience education at the local industry nearest to the students' school or home. Form Four students taking the Invention subject are exposed to technological skills in the industry, production processes and actual working environment. As the experience and facilities at school are limited, this programme is relevant and meaningful for expanding the students' concepts and perspectives regarding the Invention

subject. The linking of teaching and learning at school with industrial experience exposes these students to various problem-solving situations, social interactions, entrepreneurial practices and early preparation for the world of work.

This programme started as a pilot project in November-December 1998 during the long school vacation. A total of 162 students were selected from fourteen participating schools, one school from each state (there are fourteen states in Malaysia). A guidebook on the programme was developed for this purpose (Curriculum Development Centre, 1998*b*). At the end of the programme, a student is awarded a certificate of attendance by CDC and a letter of confirmation from the enterprise of the skills he or she is able to perform at the end of the attachment. With the concerted efforts of the CDC, State Education Departments, schools and forty-one local industry firms, the pilot project met with great success. In 1999, the number of participating schools increased to thirty-three, student participation rose to 322 and the number of participating firms to a hundred. Due to the encouraging response and effectiveness, this programme has now become an on-going activity.

To ensure the smooth running of this programme, committees are formed at the national, state and school levels. For effective co-ordination and implementation, CDC and the State Education Departments form the national central committee. At the state level, each State Education Department appoints its respective officers to co-ordinate. At the school level, the principal appoints the Invention teacher or guidance and counselling teacher as the organizer. The important tasks and responsibilities of the committees include:

- preparing guidelines and implementation schedules;
- identifying and arranging the placement of students in industry;
- co-ordinating and monitoring the running of the programme;
- evaluating and reporting on the programme's effectiveness.

For purposes of evaluation, standard questionnaires are developed by the CDC specifically for the industry supervisor/mentor during the students' attachment period. Another set of questionnaires are used by teachers, State Education Office and CDC personnel during their visits to the industrial sites to monitor the programme.

The industries involved are from varied fields, such as electronics, computers, multimedia and communications, food processing, furniture, landscaping, textiles and ceramics. These business concerns range from small-scale operations to big holdings and conglomerates. By being exposed to such environments, the students gain experience and strengthen their technical skills in current technologies. They get invaluable knowledge and ideas about production, services, finances and participation in the work force.

The participating industries have provided invaluable training for the students and also taken care of the students' welfare. Some provide allowances and transport facilities. From reports and visits on sites, this programme is effective in achieving its objectives. The students are actively involved with training schedules prepared by the firms concerned. Many of these participating firms, however, are of the opinion that two to four weeks of attachment is generally insufficient for the students to have a comprehensive understanding of the workings of a business concern and its production processes.

To date, the response from students, parents, schools and industry is very encouraging. The Ministry of Education looks forward to even greater participation from the private sector. The success of this 'Invention' attachment programme has provided invaluable learning points, confidence and a model for CDC to apply similar strategies and operations for future technology- and industry-based subjects which are currently on the drawing board and are targeted for implementation in academic schools.

DOCUMENTATION AND REPORTING SKILLS

A student's folio contains his or her systematic documentation of ideas, processes undertaken and the organization involved in designing and producing the invention products. For final assessment, the student's artefact together with the folio become the articles of proof in the Malaysian Certificate of Education examination. In the folio, a student is required to report the findings of his or her studies and surveys as well as the results of prototype testing. He or she also needs to include proposals for product marketing. There is also a short face-to-face meeting with the assessor. It is therefore important that a student masters such reporting skills, whether written or oral, for presentation of the invention work.

Since the introduction of the Invention Curriculum in 1995, there has been growing concern about students' skills in folio writing. Constant feedback from teachers and examiners of the Malaysian Examination Syndicate reveal many Invention students' inability to present, in written form, their ideas and proposals clearly and in logical sequence. They lack skills in clarifying their thinking and giving in-depth explanations to their research findings, rationale for alternative design solutions and final selection. In response to this weakness, a guidebook has been produced (Curriculum Development Centre, 1999*a*) for teachers to expand and improve students' skills in documentation. This guide is the combined effort of Invention Curriculum designers and implementers as well as personnel from the Malaysian Design Council.

With this guide, clear explanations, examples and illustrations are provided to direct students on how and what to document systematically in the areas of problem identification and analysis, research and investigation, generating and forming various ideas, synthesizing ideas for design of invention, planning and organization, and testing and evaluation. The guidebooks have been distributed to all schools offering the Invention subject and have been well used.

Feedback gathered after the distribution of the guide books reveals that this CDC production has stimulated concerted efforts at the state level to improve documentation and reporting skills. Some states take the initiative to provide further information based on the CDC guidebook for their teachers and students. There are states where special sessions are held for teachers to share and discuss the finer points of folio writing with those teachers who have successfully guided their students to brilliant performances. State Education Departments also conduct various student activities, e.g. holiday or weekend camps where students are given further practice and guidance in documentation writing and communication.

ROBOTICS

Another current initiative by the Ministry of Education is the provision to all secondary schools, starting from the year 2000, of several models of robot kits with accompanying user manual and teaching/learning modules. The assembly and manipulation of these miniature robots serve as teaching learning aids to stimulate students' interest in mechatronics and automation.

Different types of robots are selected. There are mechanical robots and mechatronic ones; robots with linear motions and robots that make full rotations; robots with sound sensors, infrared and light sensors; robots with timers, and programmable robots with microprocessors. The main purpose is for students to develop an early appreciation of robotic operations in a holistic, integrated and systematic manner. Manipulating the robots helps to further expand students' creativity and imagination.

Such exposure is most suitable for science- and technology-based subjects, e.g. Invention, Living skills and Engineering subjects. Every secondary school is provided with five sets of such robot kits, each containing seven robots of different model and make. An additional two sets were awarded to schools with outstanding performances in the Malaysian Certificate of Education examination in 1998 and 1999. Two sets are also supplied to all District Education Offices and several teacher-training colleges for training purposes.

The Teaching and Learning Modules developed by CDC (Curriculum Development Centre, 1999*c*) help teachers to utilize these kits during teaching/learning activities. These modules are designed to help the students to:

- understand the concept and mechanism of a robot;
- understand the functions and operations of various systems and sections in the robot, e.g. electronic circuits, sensors and gears;
- generate and develop creative ideas;
- apply ideas to other situations;
- explore the capabilities and limitations of the robot;
- inculcate curiosity and develop interest to explore;
- learn in an enjoyable and exciting environment.

At the national level, CDC has trained forty-five resource teachers in the usage of the modules and assembling of robots. With the help of these resource teachers, state-level training has been conducted for all secondary schools, involving at least one teacher per school. Teachers can select any robot model best suited to the curriculum content and ability level of the students. The activities can be conducted for individuals or small groups and the station method can be adopted. Currently teachers are learning to familiarize themselves with the robots.

Feedback from a recent evaluation study on the utilization of these robot kits in schools (Curriculum Development Centre, 2001) shows the robots do create an enjoyable, interesting and challenging learning environment for the students. Although some forms of activities are carried out in the class using these robots as teaching/learning aids, teachers do need more time, skills and confidence to manipulate the robots.

TEACHER PERCEPTIONS

For the purposes of this study, the writers interacted with the Malaysian south zone teachers attending an Invention training course on design, technical drawing and model making. The purpose was to explore their perceptions of the Invention subject. Two open-ended questions were posed to them: 'What is your view of the Invention subject? In what ways does the Invention subject help to educate the students?' The thirty-nine teachers responded in writing. From the various responses, common responses were clustered together and this resulted in twelve clusters of perceptions, as shown in Table 3.

The responses show that many teachers (67%) see the Invention subject as making contributions towards developing students' creativity. They find that this subject challenges the mind, integrates critical and logical thinking with creativity and imagination. The development of students' communication and problem-solving skills are also seen as a gain. The subject helps to train the

students to tackle a problem from various angles. The teachers also see 'Invention' as a way of training a productive work force to meet the nation's aspirations and vision.

The above positive results show that the teachers' perceptions closely correspond to the aim of the Invention Curriculum, which is:

> To produce students who are creative, innovative, inventive and are capable of adapting themselves and participating in current technological changes and development through creating inventions that contribute towards the technological development of the nation (Curriculum Development Centre, 1996*a*).

Table 3. Teachers' perceptions of the 'Invention' subject

	Perceptions	% teachers
1.	Creativity Students become more creative	67
2.	Thinking skills Challenges the mind, makes the students think, develops critical thinking	46
3.	Idea development Promotes the exploration of ideas and products, develops an open mind	46
4.	Communication skills Students learn to be receptive to other people's opinions, communicate and interact better without hurting others	36
5.	Problem-solving Students learn to solve problems in various ways	33
6.	National development Contributes to the nation and productive work force	33
7.	Multidisciplinary Not confined within certain subject areas	26
8.	Values and attitudes Develops independence, confidence, patience	26
9.	Real life and work Relates to world of work and real-life situations	18
10.	Suitable for all levels Highly recommended for all students	18
11.	Student-centredness Caters to students' needs and interests	15
12.	Recognition Invention Curriculum teachers win high recognition from their colleagues and are often approached for help	5

BROADENING THE CURRICULUM OUTLOOK

In 1997, two years after its initial implementation in 1995, a set of Invention Curriculum specifications (Curriculum Development Centre, 1997) was drafted in line with the Malaysian Smart School Conceptual Blueprint (Government of Malaysia, 1997). The 'Smart-School' concept emphasizes a 'fundamental shift towards a more technologically literate, thinking work force, able to perform in a global work environment'. Technology is used as an enabler for the school to access a great variety of external resources. The school culture is defined as one that is informed, stimulates thinking, creativity and caring. The Invention Curriculum may be seen as already very much in line with the 'Smart-School' concept (Kong, 1998). In the 1997 specifications, the Invention Curriculum gives a broader outlook on technology per se, in terms of its historical development, changes, trends, issues and effects on society. Global networking and interpersonal skills are emphasized together with creativity and inventiveness. Intended learning outcomes are explicitly stated and categorized according to levels of complexity for the students.

In the following year, at a National Seminar on Invention and Design 1998 held at CDC (Curriculum Development Centre, 1998*a*), teachers provided invaluable input concerning the existing Invention Curriculum. Amongst other issues, the seminar resolutions call for strengthening design aspects in the Invention Curriculum, to emphasize the importance of adding value to products and to place importance on both processes and product in the Invention subject.

In the early part of 1999, in the wake of reviews of design and technology subjects and their equivalents in different parts of the world for the new millennium, a comparison was made of the Malaysian Invention Curriculum with models of other countries. This study revealed certain areas for improvement in the existing Malaysian curriculum. Specifically, greater focus needs to be placed on design aspects and processes using different types of materials.

NATIONAL REVIEW OF THE INVENTION CURRICULUM

In the middle of 1999, a national review of the curriculum for all school subjects was undertaken (Curriculum Development Centre, 1999*b*), the objective of this major exercise being to produce knowledge workers with global perspectives. The curriculum is to be planned in totality from primary to secondary schools, taking into consideration new trends and development. The four pillars of education for the twenty first century (Delors et al., 1995)—learning to know, learning to do, learning to live together and learning to be—are taken into consideration for this curriculum review. The strategy includes various phases:

Phase One—Identify the need for change:

- Examine the strengths, weaknesses, problems, and issues.
- Map syllabus specifications from primary to secondary school levels.

Phase Two—Curriculum modification:

- Scrutiny of curriculum for content standards, involving removal of subject areas, reduction of subject load, adding of new areas, shifting of areas.

Phase Three—Preparation for implementation:

- Curricular materials production, teacher training and dissemination.

In response to Phase One of the curriculum review, the State Education Departments conducted curriculum evaluation exercises for all the subjects in the respective states (Ministry of Education, Malaysia, 1999). There was general satisfaction with the Invention Curriculum. There were suggestions to increase the per capita grant per year per student received by schools, recommendations regarding certain machines and more software to be supplied, as well as increased learning time for CAD. Feedback was also received on the need for students to do multimedia presentations of their inventions and the importance for students to conduct research and development studies on existing products.

With the above inputs from the State Education Departments, previous feedback and studies cited earlier, together with the Invention Curriculum specifications for the 'Smart School' as reference, the Invention Curriculum review entered Phase Two. Modifications of the Invention Curriculum are currently being conducted, with plans for materials production and teacher training in place for the implementation of the revised Invention Curriculum in the year 2003.

Success factors:
a case studies of two schools

For the purposes of this present study, the writers have chosen to present the dynamics of the Invention Curriculum as successfully implemented at the school level. Two schools were selected based on the impressive records in examination performance of their students in the 'Invention' subject. One school is in a rural setting and the other in an urban setting. The writers conducted a three-day visit to each school in order to make a comprehensive study of the school climate and culture, the staff and administration, as well as the students working on the 'Invention' subject. The focus was on delineating the factors for student success.

CASE STUDY 1: BULOH KASAP SECONDARY SCHOOL—A RURAL SETTING

School and principal

Buloh Kasap Secondary School is a rural school eight kilometres from Segamat town, in the state of Johor. The community is comprised mainly of farmers, smallholders of oil palm plantations, and small business people. The school has a student population of about 1,060 and a teaching staff of fifty-three. Mr. Boo Hian, the principal (this is his first posting in that capacity) is a university graduate in biology, with many years' experience of teaching mathematics. The 'Invention' teacher, Mr. Amir Sufari, also teaches mathematics. The school first started the Invention Curriculum in 1996 and presently has two classes at the Form Four level and one at the Form Five level pursuing the subject. The average number of students per class is twenty. Other technology subjects offered in the school are 'Information technology' (for upper secondary students) and the 'Computers in education' programme (for Form One students).

The school has a past record of 100% passes in the 'Invention' subject and is the top ranking school in this subject in the state of Johor. An impressive performance was shown in 1999: of the thirty-seven students, twenty-seven students (73%) scored a distinction and the rest a strong credit (C3). The students are average students from the art stream, with fairly good results in 'Living skills', science and mathematics in the lower secondary schools.

The 'Invention' teacher

Mr. Amir is a university graduate in physics and computer science with previous training in mechanical engineering at a technical school. In his four years of teaching, he has been responsible for 'Invention' classes. He is in charge of school discipline and is very active in co-curricular activities. These include heading the school's Beautification Unit (through projects to beautify the school, students are encouraged to love their school), as well as the Furniture Unit, where the 'Invention' students repair school furniture.

Mr. Amir is fully dedicated to the teaching of Invention and his active involvement is enhanced by his strong engineering, mechanical and physics background. To date he has attended five courses conducted by the Curriculum Development Centre (CDC), Ministry of Education, viz. the S-CAD training; Auto-CAD training; Course on Gas and Arc Welding and PLC (Programme Logic Control); Course on Design, Technical Drawing and Model Making; and Course on Robot Kits.

He is on the panel of assessors for the Examination Syndicate Malaysia and hence is very knowledgeable about the criteria for assessing 'Invention' artifacts and folios. He shares his expertise with other 'Invention' teachers at seminars and training sessions conducted by the Johor State Education Department.

Opinions of teachers, principal and students on the high performance in 'Invention'

Although separate detailed discussions were held with the school principal, the 'Invention' teacher and other senior teachers, there were similarities in their responses. The common opinions revealed the following as pertinent contributing factors to the students' success:

- The 'Invention' teacher's experiences as assessor helps the students to thoroughly assess their own work. The teacher, together with the individual student, evaluates the student's work, using a checklist. This common evaluation is done three times yearly so that the students are well versed with explaining and defending their work and are conscientiously improving their work quality.
- The teacher takes an interest in the students' work. In certain cases, where students are absent from school, the teacher makes home visits, bringing the work to the students and supervizing them at their homes. Parents show interest in their children's work after witnessing the teacher's dedication.

- Projects thus have direct application to real life and the students' surrounding. The intention is that, on leaving school after Form Five, these student artifacts should be good enough for immediate use. This teaches the students to be pragmatic in the design process.
- The teacher's strong technical background and 'Invention' training enable him to guide the students to focus on practicality—some designs cannot be realised as the principles of physics do not allow it.
- Students are highly committed to work on their own 'Invention' work and also to make projects for the school. It is common for teacher and students to stay in after school hours and on weekends.
- There is strong commitment from the principal and other teachers. The principal gives full support to the 'Invention' subject and provides a school climate conducive to learning. Students can approach the 'Living skills' and physics teachers for advice in specific areas like electronics. Apart from providing sufficient funds for purchasing equipment for the 'Invention' projects, the principal comes in early together with the 'Invention' teacher to tend to the school projects (examples of these are cited later), including on weekends. This is leadership through example for the students to emulate.

Why students select the 'Invention' subject

Ten students, five boys and five girls, were interviewed and asked why they decided to take up the 'Invention' subject. Their enthusiasm is reflected in the reasons given in the accompanying box.

All in all, what attracts students to the 'Invention' subject is that it is very different from other conventional subjects. It cuts across borders. It leads to self-discovery of their potential, making them realize that they can think creatively and that they are capable of creating products that are beneficial to many people. They learn how to communicate better and work together with others. It is tension-free, in the sense that there are no formal examinations and they can evaluate their own progress.

Teaching and learning

The four periods per week for 'Invention' class are combined together as one long stretch once a week. Extra sessions are the norm, at least once a week, in the afternoons or on weekends. Special programmes to enrich the students' practical skills take the form of making projects for the school, as indicated in the next section. The students also use these extra sessions to prepare for and participate in competitions and exhibitions (and the school has won prizes in the past). The students are very enthusiastic and look forward to these extra

sessions. The teacher shares with the students what he has gathered upon returning from a training course. Students also make organized visits to the city to get fresh ideas about designs and products.

Form Four students concentrate on project selection, information gathering and model making, whilst Form Five students further refine their projects, complete the product and finalize their documentation of the process.

REASONS GIVEN BY CHILDREN FOR LIKING THE 'INVENTION' SUBJECT

- To acquire new skills which other subjects do not provide, e.g. making sketches, welding, technical drawing.
- This is the latest subject. The other subjects are more or less the same. This subject applies thinking, is interesting and flexible.
- This is a technology subject which is more technically oriented and not so theoretical. It is more practical and therefore more interesting.
- The subject is wide. It goes beyond the classroom.
- It challenges us to come up with ideas and show others what we can really do.
- It increases creativity and thinking because you have to come up with a product.
- It generates ideas and improves one's capability to solve problems.
- It focuses not just on one but on many aspects.
- To produce new things for our country and therefore reduce imports.
- Innovation is needed in many areas, e.g. the need to find safer, quicker and easier ways for cutting vegetables and opening durians (a very popular local fruit).
- It trains one to communicate—how to ask questions and express oneself.
- It trains us how to get information from others, how to approach other people during busy business hours.
- The product is beneficial to many people, according to the surveys done.
- It releases tension because I can come to school on Saturday or Sunday to work on my project or make projects for the school. Building the robots is a great new experience for me.
- Teamwork. We contribute ideas and get to work with friends.
- No stress because the teacher is understanding and supportive.
- No monthly test and yet I know my progress because the teacher checks on my progress regularly.

Student projects and documentation

Some former student projects that were awarded distinctions in the examination include the following:

- 'Super Brand' for flat dwellers, a clothes-drying device using electromagnets.
- 'Foldable Carrier', a foldable wheelbarrow using the conveyor system.
- 'Auto System Fast', a flood detector for home use, using siphon system and electrolysis.
- 'Systematic Coin Dispenser', a device that separates and counts the coins in stacks.

These devices have been thoroughly thought through and are realistic projects with direct applications to real-life situations. Folios are well planned and written with various designs and drawings.

The students select their projects with guidance from the teacher. Students purchase small parts that they need when necessary and parents are supportive. The students do not face major problems in getting materials, as they have consulted the teacher earlier to confine their projects to manageable proportions. The students get practical help from the teachers as often as they need, even after school or on weekends.

A very interesting feature of this school is that the teacher and his 'Invention' students have won the recognition of the other staff and students. The principal has entrusted this 'Invention' team to make projects for the school. Thus, whenever a need arises, the principal and other subject teachers seek the help of the'Invention' team. The following are some examples from an impressive list of projects designed, improvised and constructed for the school by the 'Invention' team:

- School goal post specially designed with studs to prevent the post from falling. This was a request by the sports teachers.
- Environment-friendly bin, specially designed for easy removal of rubbish using a wheelbarrow, thereby avoiding the use of plastic refuse bags. The bin has an attractive green paint coating and is made from discarded oil drums and rubber piping. The students intend to make a few more for the school, as it is a great hit.
- Trolley for fixing the engine model for demonstration purposes in the 'Living skills' workshop.
- Fixing a chain to a manual bell for the school, in case of fire when the electric bell does not work.
- School fruit garden where a simple and effective sprinkler device is designed to water the longan (fruit) trees that the teachers grow for the school.

- Designing and making permanent plastic signs for classrooms and the 'Corridor of History' (a school corridor showing various historic events which students can read as they walk by). This is a request from the history department.
- Designing and constructing a car shed for teachers' cars.
- Designing and making a Science Stop (covered shed where science students can conduct out-door experiments and exhibit their science projects). This is a request from the science department.
- Making periscopes for science students.

Such DIY projects have saved the school a lot of expense. Moreover, the projects have led to a sense of pride and school ownership on the part of the 'Invention' students.

Workshop facilities and equipment

The students use a classroom that is converted into an 'Invention' workshop. The strong school culture of DIY has the students making workbenches for their own workshop. Students and other teachers contribute non-functioning equipment, e.g. old TV sets, electrical goods, from which the students can salvage the spare parts for their projects. The workshop has the basic tools and some useful machines, e.g. metal cutter and a portable welding machine. However, it lacks storage space and it is planned to get another room as a workshop. The 'Living skills' workshops for metal work, woodwork and electricity are also available for the students.

The computer laboratory has twenty-one units of NEC computers supplied by the government and two units from private bodies. All are well maintained and functioning, except for one with a motherboard problem. The S-CAD (a simplified local CAD version) software is used more than the Auto-CAD. Students use the laboratory when needed.

Problems, measures and future plans

The facilities available around the school are limited and many electronic and mechanical parts have to be purchased in the big towns by the teacher. The students are from the art stream and their basic knowledge is limited. The teacher has to ensure that sufficient guidance and help are made available to them.

When a new workshop is provided, the existing one will be used for exhibiting students' work and for storage. The school intends to participate more actively in the annual glider competition organized by the University of Technology Malaysia. The school also plans to continue its development of the 'Invention' subject so that more schools will be encouraged to offer this subject.

CASE STUDY 2: TAMAN MELAWATI SECONDARY SCHOOL—AN URBAN SETTING

School and principal

Taman Melawati Secondary School is situated in a residential area in Ulu Kelang town, in the state of Selangor. The community consists largely of professionals and business people. The school has a student population of 2,400 and a teaching staff of 111. Mrs. Rohani Abu Bakar, the school principal, is a history graduate with twenty-three years of teaching experience and three years experience as a school principal. Two teachers are teaching the 'Invention' subject—Mrs. Hong Ai Beng (who also teaches 'Living skills') and Mr. John Ebinezer (who also teaches 'English' and 'Mathematics'). The school first started the Invention Curriculum in 1996 and presently has a class of thirteen students in Form Four and fourteen students in Form Five. The other technology programme offered in the school is 'Computers in Education' for Form One students.

The school has a past record of 95% to 100% passes in the 'Invention' subject. An impressive performance was shown in 1999: of the nineteen students, eight students (42%) scored a distinction and the rest a strong credit (C3).

Invention teachers

Mrs. Hong is a university economics graduate with eleven years' teaching experience, including five years' experience of teaching 'Invention' classes. Mr. John Ebinezer is a university graduate in TESL (teaching English as a second language). He has twenty years of teaching experience, including two years of teaching 'Invention' classes.

Both teachers show a keen interest in the subject and have substantive technical knowledge, although their specializations are not in the technical field. Mrs. Hong has attended the orientation course on the Invention Curriculum and Auto-CAD course, both conducted by the Curriculum Development Centre (CDC), Ministry of Education. She is also involved in the school Living Skills Club. Her interest in electronics grew when she was teaching 'Living skills'. Mr. Ebinezer has also attended three CDC conducted courses on Orientation to Invention Curriculum, Auto-CAD and Design. He is involved in the school Invention Club and sports. Both teachers find teaching 'Invention' an interesting challenge. The school conducts in-house training for 'Invention' teachers twice a year.

Opinions of teachers and principal

The teachers attribute the success to the students' initiatives and dedication. Students' interest in the subject drives them to pursue their goals further, to research and access various types of information. This is also supported by well-equipped 'Living skills' workshops in the school. Another important factor is very strong parental support.

The school principal attributes the success to the competent teachers who are also highly committed to the 'Invention' subject. Another factor is that the students taking the subject are capable and above average. They are science stream students. The principal also identifies students' initiatives and interest as well as strong parental support as contributing to the students' success. The school offers the 'Invention' subject for better job prospects.

Why students select the 'Invention' subject

The students themselves indicate their interest and parental support as reasons for taking this subject. Many explain that it is their parents who encourage them to take the 'Invention' subject as their parents are mostly professional career people.

Teaching and learning

The teachers follow the normal class timetable. Previously, extra classes were held twice a month; but there was poor turn-up as the students have their own after-school activities and commitments, e.g. tuition classes. The students spend about nine months designing and making their artifacts and about five months preparing their folio. However, in addition to normal classes, the students participate in exhibitions, competitions and conduct visits.

A two-period teaching/learning session conducted by Mrs. Hong was observed. It was a critique session involving thirteen Form Four students. An assignment given to the students a month before required them to present their concept model to the class during this critique session. Guided by the teacher who played the role of a facilitator, students took ten to fifteen minutes to present their case. It was observed that the students showed active participation during this questioning and discussion session. The presenter demonstrated the model to the class explaining the underlying concepts, tools and materials needed, commercial value and benefits. During the session, students were given the opportunity to make verbal comments on how a particular product can be improved. Innovative ideas were noted and taken into consideration for further improvement.

Such sessions help the students to develop self-confidence and communication skills. The subject, as a whole, trains students to plan, organize and manage work. It also helps them to research, collect and organize information through library searches or simple surveys. The students are also required to analyse and document their information in a folio for presentation and assessment.

Student projects and documentation

An example of a student's project graded with distinction is that of a sound metronome, a device to identify music tone and rhythm for beginners. Another project was that of a water pollution detector, a device to measure the level of pollution. These devices use sensors for detection and are accompanied by well-written folios.

The students determine the project themselves, consulting the teacher at times. Sometimes the students face problems in getting materials for their project work. When necessary they consult a mechanic, but otherwise no practical help is sought.

Workshop facilities and equipment

The 'Invention' students use the three existing 'Living skills' workshops for electricity, woodwork and metal work. These workshops are well equipped with woodwork and piping tools, electricity and electronics tools and components.

The computer laboratory has twenty units of government-supplied Pentium I computers. All are well maintained and functioning. There are twenty units of S-CAD (a simplified local CAD version) and five units of Auto-CAD which students use for making sketches. Students use the laboratory about six to eight weeks per year for their 'Invention' projects.

Problems, measures and future plans

A student concern is that academic performance in the 'Invention' subject has not received wide recognition for entry into institutions of higher learning. Another concern is that the 'Invention' subject is misconceived as a subject for science students only. The school therefore plans to offer this subject to all students, irrespective of their academic background.

SUCCESS FACTORS

Although the two schools studied have different settings, the students show a very keen interest in the 'Invention' subject. This can be attributed to strong parental encouragement and advice as seen in the Taman Melawati school or support through a strong school culture and climate, as is found in the Buloh Kasap school. The latter encourages a love for and ownership of the school. Leadership through example, as clearly practised by the principal and 'Invention' teacher, becomes a model for the students.

Another factor is the regular evaluation of student performance for the Buloh Kasap school students—they need more guidance from the teacher, since other sources of information and guidance are limited in a rural setting. By evaluating their own work with the help of the teacher, these art stream students receive clear directions on their progress and can introduce prompt adjustments where required.

The above two case studies demonstrate common denominators of effective schools (Townsend-Butterworth, 1992). These include qualities such as:

- effective principals with strong leadership but realistic expectations for their students and staff;
- dedicated and qualified teachers working as a team and caring about the school;
- good instruction that is lively, creative, flexible and attuned to the interest and abilities of the students;
- a sound teacher development plan to update the teachers;
- a curriculum not confined within the school walls but where students learn problem-solving, do research and test out their ideas;
- a school atmosphere that gives the teachers and students a sense that they are engaging in important work;
- parent and community involvement in meaningful ways to enrich the students' educational experiences.

The uniqueness of the practical, problem-solving based approach utilized in the Invention Curriculum is a pertinent factor to consider. Such an approach requires the students to conduct research activities that can involve wide information sourcing. Subsequently, the students need to make their own decisions about which area of the problem they would like to focus on and tackle. They undergo the processes of searching and designing creative solutions, trying out new ideas and providing alternatives when other ideas fail. The Invention subject requires them to transpose their thoughts and ideas into material artifacts, thereby concretizing image into reality.

Further, the 'Invention' subject facilitates students' quest for continuous learning and product improvement. Aside from the students' meticulous testing on their prototypes or working models, the critique sessions held in class provide good training ground for students' development of communication skills and an open mind. Such an approach takes the students beyond classroom texts and confines and contributes to building the students' confidence and sense of pride in knowing that they have the capacity and capability to develop products that are beneficial for others.

Conclusion

Students' creativity and thinking skills, which form the thrust of the Invention Curriculum, are in parallel with the nation's vision towards technological innovation. The Ministry of Education is strengthening science and technology education as well as emphasizing thinking skills in the Malaysian school system. Further, with the current focus on information and communication technology in the knowledge-economy era, the Invention Curriculum will be of even greater prominence in the coming years. Thus, the 'Invention' subject will undoubtedly be a crucial part of the school curriculum and the nation's manpower requirement plans.

Authentic assessment, as currently practised to evaluate a student's artifact and folio (documentation) for final examination, is very much in line with contextual learning, project-based and independent study approaches that are promoted by the ministry. This form of assessment invites more students to pursue this subject—the academically as well as the non-academically inclined. For the latter group, the attraction stems from the fact that there is no formidable written examination at the end of the course, thus reducing examination tension for these students.

The most recent MCE results (Year 2000) for the 'Invention' subject indicate a remarkable success, particularly in the distinction category. The percentage of candidates who scored distinctions has more than tripled (38.7%), as compared to the previous result (12.04%). This success could possibly be attributed to the student's guidebook in folio writing, produced recently in 1999 (Curriculum Development Centre, 1999*a*), which helps students to improve their skills in project documentation. Indeed, project documentation carries half of the total marks in the final examination. Another possibility is the one-week course on 'Design and model making' conducted for all 'Invention' teachers throughout the country in 1999 and 2000. This course enhances teachers' understanding and skills in the processes of designing and model making, which in turn strengthens teachers' abilities in guidance and facilitation of students' practical work. Other contributing factors may include weekend students' camps and constant supervision at the state levels.

A most recent move, started in 2000 by the Economic Planning Unit of the Prime Minister's Department, is to equip all schools with computer laboratories and Internet facilities. This ongoing effort will further enhance the Invention Curriculum, especially regarding CAD software usage by the students. It will make it easier for students to access and utilize relevant information for their research work in design creations.

In conclusion, from the Malaysian experience of designing, developing and implementing the Invention Curriculum, several pertinent factors can be seen as contributing to its success. Teachers are one such critical factor – the teachers' attributes, such as competence and knowledge, as well as commitment and dedication are vital. Students' readiness to pursue the subject, supported by parental encouragement, is another factor. Students must have the aptitude and interest in 'Invention' plus the element of creativity. The school—its principal and other staff—together with the community support of the parent/teacher association and industrial sectors act as a catalyst for the students' growth through the Invention Curriculum. A well-equipped workshop and facilities are definitely important as well.

From the pedagogical perspective, the practical, problem-solving approach utilized in the Invention Curriculum provides the students with self-sufficiency and responsibility for their own learning and progress. Students have to apply their own ingenuity and creativity to seek and concretize solutions that are functional and pragmatic. Information gathering and learning go beyond the formal classroom. This approach has a particular appeal to the students.

From the macro perspective, effective monitoring systems at the national and state levels provide a constant gauge of situations and problems that need addressing, and actions for rectification or creation of new alternatives and future strategies. All in all, it is the creation of an environment of caring and the availability of a strong and constant source of support, together with proper planning and insight that augur well for the successful implementation and sustainability of the Invention Curriculum in schools. From the Malaysian experience of the Invention Curriculum, lessons learned and wisdom gained provide direct spin-offs to better formulation and implementation of other technology-based subjects for Malaysian schools in the future.

Acknowledgement

The writers would like to express their deepest appreciation to their Director, Dr. Sharifah Maimunah bte Syed Zin for his advice, encouragement and support during the conduct of this study. The writers are also indebted to the officers and staff of the Living Skills and Invention Unit, Curriculum Development Centre for their contributions of invaluable information and updates. A very special thank you too to the principals, teachers and students of Buloh Kasap Secondary School and Taman Melawati Secondary School for their co-operation and help in making this study possible.

References

Ahmad Tajuddin Ali. 1995. Public/private sector partnership in science and technology. *Prosiding persidangan perkhidmatan awam* [Proceedings of the national conference on public service]. Kuala Lumpur.

Curriculum Development Centre. Ministry of Education, Malaysia. 1996*a*. *Sukatan pelajaran dan huraian sukatan pelajaran reka cipta sekolah menengah atas tingkatan 4 & 5* [Syllabus and specifications of 'Invention' for upper secondary school, Forms 4 & 5]. Kuala Lumpur.

——. 1996*b*. *Buku panduan guru reka cipta sekolah menengah atas tingaktan 4 & 5* [Guidebook for 'Invention' teachers in upper secondary school, Forms 4 & 5]. Kuala Lumpur.

——. 1996*c*. *Buku sumber pelajar reka cipta sekolah menengah atas tingkatan 4 & 5* [Resource book for 'Invention' in students upper secondary school, Forms 4 & 5]. Kuala Lumpur.

——. 1996*d*. *Modul guru reka cipta* [Module for 'Invention' teachers]. Kuala Lumpur.

——. 1996*e*. *Modul reka bentuk bantuan komputer (CAD) dalam kurikulum reka cipta sekolah menengah atas tingkatan 4 & 5* [Module on CAD in the 'Invention' curriculum for upper secondary school, Forms 4 & 5]. Kuala Lumpur.

——. 1997. *Reka cipta sekolah bestari.* ['Invention' for the smart school]. Kuala Lumpur.
——. 1998*a*. *Prosiding seminar pendidikan reka cipta dan reka bentuk peringkat kebangsaan* [Proceedings of the national seminar on invention and design education]. Kuala Lumpur.
——. 1998*b*. *Panduan program sandaran pelajar reka cipta di industri tempatan* [A guide to the Invention student attachment programme to local industry]. Kuala Lumpur.
——. 1999*a*. *Panduan penyediaan folio reka cipta sekolah menengah atas* [Guide to preparing an invention folio for upper secondary school]. Kuala Lumpur.
——. 1999*b*. *Cadangan strategi penyemakan semula kurikulum persekolahan* [Proposal of strategy for school curriculum review]. Kuala Lumpur.
——. 1999*c*. *Modul pengajaran dan pembelajaran kit robot untuk sekolah menengah* [Module for teaching and learning robot kits for secondary schools]. Kuala Lumpur.
——. 2001. *Laporan penilaian penggunaan kit robot di sekolah menengah* [Evaluation report on the usage of robot kits in secondary schools]. Kuala Lumpur.
Delors, J., et al.. 1995. *Learning: the treasure within.* Paris, UNESCO. (Report of the International Commission on Education for the Twenty first Century.)
Government of Malaysia. 1996. *Seventh Malaysia plan 1996–2000.* Kuala Lumpur.
——. 1997. *The Malaysian smart school: a conceptual blueprint.* Kuala Lumpur.
Kong, M.S. 1998. Reka cipta dalam senario sekolah bestari [Invention in the smart school scenario]. *Prosiding seminar pendidikan reka cipta dan reka bentuk peringkat kebangsaan* [Proceedings of the national seminar on invention and design education]. Kuala Lumpur.
Mahathir Mohamed. 1991. *Malaysia: the way forward/Vision 2020.* Paper presented by the Prime Minister at the Inaugural Meeting of the Malaysian Business Council. Kuala Lumpur.
Malaysia. Ministry of Education. 1999. *Laporan penyemakan semula kurikulum KBSR KBSM oleh Jabatan Pendidikan Negeri, dibentangkan di mesyuarat Ketua Sektor Pengurusan Akademik 3/99* [Report on the review of KBSR/ KBSM curriculum by State Education Departments, presented at the meeting of the Heads of Academic Management Sector 3/99]. Sandakan, Sabah.
Townsend-Butterworth, D. 1992. *Your child's first school.* New York, Walker.

INTERNATIONAL
BUREAU
OF EDUCATION

INNODATA

This series of case studies of selected innovative projects and approaches in education continues the long tradition of the International Bureau of Education (IBE) of reporting in a variety of ways on change and innovation in educational practice. The series should be seen as complementary to INNODATA, the Bureau's databank of educational innovations available on the Internet. The monographs provide readers with more detailed information on selected innovations from the databank which have had considerable levels of success to date and are considered to be of great interest and relevance to educational policy-makers and practitioners around the world. The case studies are written by individuals who have close experience with the innovations being described, in some instances having been directly involved in their creation and development.

Through the dissemination of quality information on exemplary initiatives in educational practice which may have applicability in diverse contexts, the IBE is continuing its quest to contribute to the improvement of primary and secondary education provision world-wide. The case studies have also been made available on the IBE's website (see below). The website also provides regularly updated information on all other activities of the Bureau within its new programme focus on strengthening the capacity of countries to adapt the content of education to the challenges of the twenty-first century.

http://www.ibe.unesco.org

NOTICE

REPRODUCTION BASIS

- [x] This document is covered by a signed "Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

- [ ] This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").