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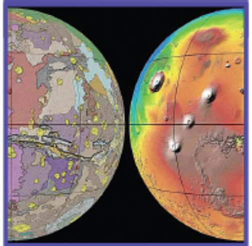
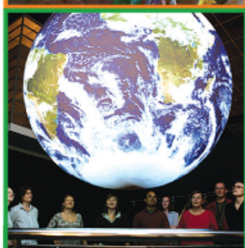
Inquiry-Based Science Education
10 Good Practices







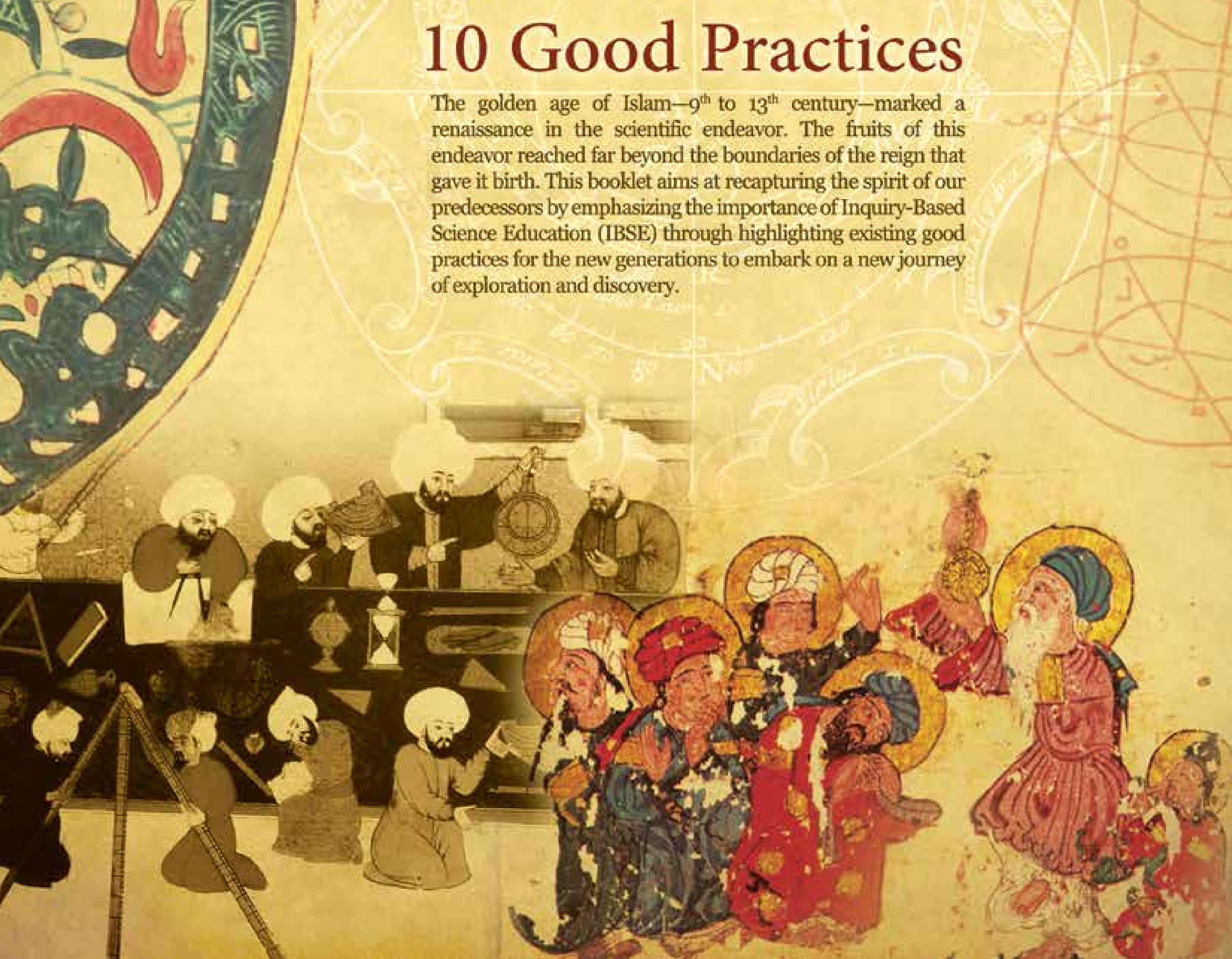



Planetarium Science Center

Inquiry-Based Science Education

10 Good Practices

The golden age of Islam—9th to 13th century—marked a renaissance in the scientific endeavor. The fruits of this endeavor reached far beyond the boundaries of the reign that gave it birth. This booklet aims at recapturing the spirit of our predecessors by emphasizing the importance of Inquiry-Based Science Education (IBSE) through highlighting existing good practices for the new generations to embark on a new journey of exploration and discovery.



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Foreword
by
Ismail Serageldin

The Inter-Academy Council, an organization created by the academies of science of the world, was tasked by these academies to undertake a major study on capacity building for Science and Technology (S&T). I had the honor to Co-chair the Panel that undertook the study and produced the report "Inventing a Better Future" in 2004. The report was presented by the Co-chairs of the panels to the Secretary General of the UN on behalf of the scientists of the world. It had a clear message: Governments of the less advanced societies must invest in building up their capacities in S&T in order to realize the promise of what science can do for the people of the world. The backbone of the proposals to build up that capacity is to strengthen education, especially science education, from kindergarten to post-doctoral levels. More importantly, given the rapid pace of change in scientific knowledge and in the introduction of new technologies, the concept of lifelong learning must become a real objective of all societies.

Accordingly, governments should invest funds and sustained efforts in renewing the traditional Science Education that is being offered to young students. This renewal is best achieved through Inquiry-Based Science Education (IBSE), an extremely promising approach to introducing children to the marvelous journey of discovery, that is Science. IBSE also helps to spread general science literacy in society at large. Yet, IBSE remains largely unknown in developing countries, and is only partially applied in advanced industrial countries.

Even the convinced education policy makers hesitate to implement large scale reform, including IBSE, because they have to deal with a number of obstacles including lack of educational and financial resources, and the shortage of adequately trained teachers, knowledgeable in S&T.

Furthermore, the world is witnessing an unprecedented revolution in Information and Communication Technologies (ICT) that is driving profound social change, opening up economic opportunities and even changing the very structure of knowledge as we have traditionally thought about organizing and developing it. Science education in the developing countries is more critical than ever, as these societies must become producers of knowledge and not just consumers of technology.

Realizing the importance of improved Science Education and the knowledge revolution, the Bibliotheca Alexandrina (BA) took the initiative to produce the "Inquiry-Based Science Education (IBSE): 10 Good Practices" booklet, with the generous support and technical contribution of the Islamic Development Bank (IDB).

The Booklet is a call for a global movement to address the pressing need for a scientifically literate population through introducing 10 IBSE Practices implemented by organizations from both developed and developing countries, benefiting various regions and adopting various approaches.

We sincerely hope that this Booklet will pave the way to launching more initiatives to boost IBSE all over the world through showcasing successful practices. We also aspire to influence the existing perspective about informal science education to pave the way to a lifelong learning concept worldwide.

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Acknowledgment

The Bibliotheca Alexandrina (BA) acknowledges with deep appreciation the Islamic Development Bank (IDB) for its generous support and technical contribution in preparing this booklet. The BA would also like to extend its appreciation to the experts who have graciously contributed to the production of this booklet.

Introduction

The role of Science Education (SE) in modern societies is growing with the increasing impact of science and technology on our everyday lives. The American Association for the Advancement of Science (AAAS) has declared, in 1985, that "Without a science-literate population, the outlook for a better world is not promising."1 There is an obvious need for a new practical approach to SE through engaging the recipients of knowledge rather than the classical imparting of knowledge, which is best achieved through Inquiry-Based Science Education (IBSE).

In 2014, the Bibliotheca Alexandrina (BA)—one of the leaders in informal SE in Egypt—took over the initiative to produce the booklet "IBSE: 10 Good Practices", with the generous support from the Islamic Development Bank (IDB). The booklet aims at showcasing good IBSE practices implemented worldwide, adopting various approaches; strengthening already existing projects in other countries; introducing these practices to newcomers; and convincing policy makers of the IBSE benefits.

The booklet presents ten IBSE practices implemented by organizations from different countries, namely Australia, Canada, Egypt, Finland, India, Malaysia, Netherlands, Thailand, and USA. All presented projects focus on actual inquiry-based practices that act as a motivating power for learning and strengthening students' creativity and critical thinking. These practices emulate the process of scientific research and discovery; they involve, under the experienced guidance of professional trainers, the elements of observing and gathering data, testing, analyzing, arbitrating disputes based on evidence, and accepting the contrarian view.

Selection Criteria

The BA has selected the projects carefully in cooperation with a number of experts, who have graciously contributed to the production of this booklet. The stories have been selected for their respective uniqueness in each of the following:

• **Added value** of each project's concept/idea and how it responds to the national/regional urge to reform existing science education systems by introducing inquiry-based learning and teaching models in a new science curriculum;

• **Operational methods,** considering resources needed and their deployment, among other relevant factors, as well as creativity and efficiency in the implementation strategies of each project;

• **Indicators of success,** highlighting the Key Performance Indicators (KPIs) of each project, as well as how and why they were chosen;

• **Sustainability measures** and how each project manages to continue over time;

• **Balanced geographic distribution,** covering different regions around the world with different cultures and backgrounds;

[1] International Council for Science - ICSU (2011). Report of the ICSU Ad-hoc Review Panel on Science Education. International Council for Science, Paris.

• **Variation of practices** in scope and content, covering various aspects of science, using different resources and methods; and

• **Sponsorship and funding** from various sources and through various means.

Each practice reflects a national and/or regional urge to expand scientific literacy and reform existing SE systems to encourage critical thinking, and to engage students, teachers, and families in scientific topics. Each project accomplished these goals by implementing inquiry-based learning and teaching models in a new science curriculum. Although the action plan for implementation of this reformed system in each case is different considering the varied ground realities, the end results have been encouraging so far. The potential for successful operation in the long run has been assessed to be high in each of the cases described in details in the related practices.

The implementation of the first project, **IBSE in Malaysia**, started after the Malaysian Ministry of Education introduced the Malaysian Education Blueprint 2013–2025 as part of its national education policy in its effort to stem the decline of Malaysian students over the last decade. Although the outcome of its implementation in phases is yet to be assessed fully, it has potential in making the required changes in the Malaysian school education system, particularly in science education is of a high order.

The **Inquiry -Based Science and Technology Education Program (IN-STEP)**, implemented in **Thailand**, declared to add the desired values to make science learning enjoyable through a hands-on approach, enhancement of literacy skills, and creation of a scientific culture among Thai people through introduction of an inquiry-based school science curriculum. The program has all the expertise at hand for implementation, and it will be interesting to observe how the program proliferates into the wider Thai educational scenario with absorption of the imported expertise by Thailand's own organizations in the days to come.

The **Science Clubs Initiative (SCI)** carried out in Alexandria, **Egypt**, as a pilot project on 300 schools, relies on children's curiosity and creativity to engage them in science learning and help them embark on a journey of discovery. It provides the necessary equipment and material to conduct simple scientific experiments, which aim at teaching children scientific content, creativity, critical thinking, analysis, problem solving, and teamwork, as well as presentation skills. Moreover, SCI offers teachers training courses which enable them to conduct workshops without being confined to the school curriculum, which helps them to better explain the formal school curriculum. This pilot project is still to be fully assessed when applied in schools in a wider segment. However, initial results are very promising.

The **Small Science (SS)** program is a pioneering initiative in **India** for reducing the gap between the desired objective of developing the skills for "learning how to learn science" in young students, and the actual achievement of this objective. It introduces cognitively appropriate inquiry-based learning through well-designed textbooks and contextually appropriate hands-on activities. Although the SS program started initially in one State only, it has now spread into 12 States in India. Moreover, schools in 17 States are using the SS series of books as reference material for teaching their science syllabus in primary schools.

The **Science Centre in School** Program, implemented in the **Netherlands**, brought together both a new hands-on approach for the students and provided an innovative in-service learning opportunity for educators. They did so within a broader European network that allowed for wide dissemination of their findings, which helped ensure the sustained impact of their results. The Program offers students also the opportunity for deep learning, not only in a scientific area, but also in any and all other arenas of knowledge.

The **Assessing Exhibits for Learning in Science Centers** project from **Canada** is a practical tool to assess learning at an interactive science exhibit; a Visitor Engagement and Exhibit Assessment Model. While having academic merit, the model developed is highly practical; it can, in principle, be applied in every science center, provided the organization decides to use it and invest the staff time needed. Once implemented, the method provides valuable information as to how to improve the learning experience at the exhibits.

The **Science Centers as Learning Laboratories** project from **Finland** presents four case studies conducted applying different methodologies, showing that science center education is a form of informal lifelong learning. The results of the study can be applied to strengthen the cooperation between the formal and informal education sector. Schools might use science center exhibitions to develop programs for students with learning difficulties. These students may be motivated and achieve better learning results by participating in such programs.

The **Interactives and Visitor Learning** project describes a collaborative effort carried out in 2001 by researchers in **Australia**. It is a major study showing what visitors learn from visiting science center exhibitions. The study was the first to report both short-term and long-term learning effects, thus carrying both academic and practical significance. The study helps to understand the learning effects occurring when people work with experiments and interactive exhibits in a science center or museum setting. Short-term learning effects have been reported previously in the literature, but the long-term effects on perspective and awareness were new to the field.

The **Juicy Questions** project is a model for easily transferred, sustainable, and low-cost additional value to any existing science center or family science program. It also serves as some confirmation that human mediation may be key to help museum learners take full advantage of their environment. This human interaction, coupled with the emphasis on family members' individual participation and collaboration, helps scientific questions, skills, and even concepts "stick" long after the visit to the museum.

Finally, the **Mars Student Imaging Project (MSIP)**, founded in 2002, has already proven its sustainability. It benefits from a stable online format, with instructions for students as well as teachers/guides, and a stable partnership with the Arizona State University Mars Education Program and the Principal Investigator of the THEMIS camera. The online guidelines lack the "human mediation" we see in the other projects, but they offer worldwide accessibility to all students, regardless of their location or their financial resources.

Lessons Learned

From the selected ten practices, it can be concluded that in order to improve science education, a new holistic approach, which links all SE components, is required rather than focusing on the efficiency of each of its practices. The common thread in the ten practices, which enhances the overall effectiveness, is that most of the hereafter factors worked together in an integrated manner, with continuous feedback:

1. Integrating Formal and Informal Education

The Integration of the inside-school/outside-school works helps in reducing the constraints of thinking, and promoting self-direction and self-selection. Based on that evidence, it does not seem wise to promote IBSE as the only approach to effective science education. A proper balance is needed between the formal teaching and the IBSE approaches through cooperation between government, civil society, and the teaching profession.

2. Curricula Reform

The common cross-cutting element in all the practices is the centrality of the curriculum in any learning environment. The approaches to the implementation of that curriculum and the inputs that support the delivery process are where the differences exist: teacher-centered *versus* student-centered; active participation *versus* passive participation; teachers as facilitators' *versus* teachers as transmitters of knowledge, amongst other factors that affect the overall educational experience.

Hence, the material should inform what is to be taught (content) and the accompanying teaching methodology (instructional procedures); thus representing an embodiment of a society's implicit consensus on what is worth knowing and worthwhile in shaping students' learning experiences. This requires close cooperation between formal institutions and experts in different fields, as well as continuous update of the curricula.

3. Learning Materials and Resources

Instructional IBSE materials and resources are diverse in the ten practices. The practice of "Small Science" from India elaborates on curriculum reforms and innovation, and highlights a learning process bottleneck manifested by the gap between the evolving curriculum and the implementation tools and learning materials available thereof. This alludes to the broader issue of access to material over and beyond those provided in the form of formal textbooks.

The Malaysians, on the other hand, are trying to address the need for access to open resources through the introduction of English language instructions. The American "Mars Student Imaging Project" as well includes web-materials with instructions, which are more appropriate for teachers, and those with little or no prior experience with IBSE.

4. Training Teachers on New Practices

The ten practices emphasize the need for continued and intensified teacher professional development, to create a critical mass of teacher trainers in design, delivery and mentorship. The practices also reinforce the continued need for the presence of a teacher (physical or otherwise through interactive means), but as a "facilitator" of the learning process. Thus, the issue of teacher recruitment policies, benchmarking of teacher competency, and motivation must be borne in mind by policy makers in charge of designing learning programs and the learning environment.

5. Involving faculty members in simplifying the latest scientific ideas.

6. Indirectly involving the families of learners, as a support mechanism.

7. Recognizing and respecting the individual differences between learners, and seeking an enhanced environment to incubate talents.

8. Close monitoring by one or more external entities, in addition to applying evaluation and reporting procedures for enhancing science teaching.

9. Creating incentives for all the stakeholders, including learners, teachers and school management. Most of the practices worked on the intrinsic motivations, as compared to extrinsic motivations.

10. Sustainability measures

Policy makers should be methodically engaged not only to scale up a good practice, but to influence and ensure sustainability of investments in the learning processes, for greater inclusiveness and broader outcomes.

All the above factors are required combined to build the fabric needed for improving the teaching and learning of science.

Envoi

Although this booklet includes few examples of good IBSE practices in various regions, what is required is further awareness and outreach efforts of the availability of such practices to education policy makers to pave the way to real science–literate problem-solvers worldwide.

Inquiry-Based Science Education in Malaysia

Malaysia
Ministry of Education, Malaysia
2013–2025

Source: SEAMEO RECSAM Official Facebook Page (2014).

The Ministry of Education of Malaysia maintains a standardized educational system throughout the country; the same science curriculum being taught in all schools using the same sets of textbooks. The inquiry-discovery approach has been one of the strategies to promote science learning with most of the inquiry initiatives embedded within the science curriculum prescribed by the Ministry of Education. The inquiry approach, incorporating thinking skills, thinking strategies, and thoughtful learning, is emphasized throughout the teaching–learning process under this curriculum. International Teachers Training workshops are successfully organized by the Regional Centre for Education in Science and Mathematics (RECSAM) regularly to prepare teachers in Inquiry-Based Science Education (IBSE) teaching practices.

Background

Although the performance of Malaysian students in science and mathematics has improved over the last few decades as indicated by the results of the three national examinations of Malaysia, it has been observed that this performance, when compared with the same of some other Asian countries, reveals a progressive decline in relative terms.

The education policy makers in Malaysia, therefore, decided to introduce a new curriculum following the guidelines of a National Education Blueprint to stem the risk of decline in evidence with an aim to position Malaysian 15-year-olds at par with the students from other countries scoring high in international assessments by 2025.

The blueprint envisaged that "The school curriculum at both primary and secondary levels will be revised to embed a balanced set of knowledge and skills such as creative thinking, innovation, problem-solving, and leadership. This curriculum will still stress student-centered and differentiated teaching, but have a greater emphasis on problem-based and project-based work, a streamlined set of subjects or themes, and formative assessments".

The National Education Blueprint of Malaysia, while addressing this issue, included a policy for benchmarking the standards of science education for Malaysian students as follows by recording that: "Every student will receive a strong grounding in literacy and numeracy—the foundational skills for all further learning—as well as in science, a key growth area for the Malaysian economy. They will be taught a curriculum that has been benchmarked to the standards of high-performing education systems, and this benchmarking will be validated by an independent party to build parents' confidence. The Ministry will also set and monitor performance targets for its performance".

Description

The Malaysian Education Blueprint (2013–2025) prescribes a uniform science curriculum applicable in all schools of Malaysia. The Curriculum Development Centre of the Malaysian Ministry of Education recorded the following in its policy document: the science curriculum aims at producing active learners. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experimentations. The inquiry approach incorporating thinking skills, thinking strategies, and thoughtful learning should be emphasized throughout the teaching–learning process.

The content and contexts suggested are chosen based on their relevance and appeal to students so that their interest in the subject is enhanced. In a recent development, the Government has made a decision to introduce English as the medium of instruction in the teaching and learning of science and mathematics. This measure will enable students to keep abreast of developments in science and technology in contemporary society by enhancing their capability and know-how to tap the diverse sources of information on science written in the English language.

The new curriculum emphasizes learning through various active approaches such as experience, investigation, and discovery so as to enable students to develop their critical and creative thinking skills that reach beyond the conventional rote learning. The curriculum also incorporates the following teaching and learning strategies to reinforce inquiry-discovery route of learning science:

Source: SEAMEO RECSAM Official Facebook Page (2014).

- *Constructivism:* Students learn as they construct their own understanding;
- *Contextual learning*: Students learn from their daily experiences and relate their learning to things happening around them daily; and

• *Mastery learning:* Students learn at their own pace with remedial and enrichment activities offered through the teaching learning process.

As far as teaching and learning methods are concerned, this curriculum provides for experiments, discussion, simulation, project work, visits and use of external resources, and use of technology, mainly ICT.

The science books followed in this curriculum have their contents organized on themes or subjects suitable for the particular forms or classes. The books clearly describe the learning objectives and learning outcomes on various learning areas of the theme.

The Curriculum Development Centre formulated the content of each lesson in the textbooks with clear suggestions on Learning objectives, *Learning activities, Learning outcomes, Notes and Vocabulary.* Teachers are encouraged to design other innovative and effective learning activities to enhance the learning of science.

The science curriculum is taught with the help of the following:

- Textbook: Primary learning material, written in simple and comprehensive language;
- Activity Book: Containing activities and experiments to reinforce understanding of the textbook lessons;
- Pupil's CD-ROM (MyCD): An interactive multimedia resource to complement the textbooks;
- Teacher's CD-ROM for Level 1: A reference material for teachers to plan teaching effectively;
- Teacher's Guide: A resource material for teachers to plan teaching strategies, activities and answers; and
- Practical Book: for recording observation and results of experiments.

Teachers Training Workshops organized by the Regional Centre for Education in Science and Mathematics (RECSAM) are important activities to sustain the effectiveness of the Inquiry-Based Science Education in Malaysia. These include training programs (regular, customized, and in-country courses), seminars/conferences/workshops, research and development, and publication of journals. RECSAM also provides consultancy services to SEAMEO Member Countries in these two areas. Over the years, RECSAM has adopted programs such as ATLAS (Active Teaching and Learning in Science) and more recently *La main à la pâte.*

Evaluation

The Honorable Malaysian Minister of Education, in his "Foreword" to the National Education Blueprint (2013–2025), commented "Over the course of the Blueprint, we will update you regularly on this transformation journey. We will establish an Education Delivery Unit (EDU) within the Ministry that will support the program. We will also share progress through annual reports that will highlight successes and gaps, with remedial action plans for continuous improvements when needed".

Source: Preliminary Report, Malaysia Education Blueprint, 2013–2025 (September 2012).

The Blueprint envisages a major overhaul of the existing education system by way of incorporating new curricula, introducing new textbooks, and supporting materials, improving infrastructure, training teachers, and following a phased delivery frame. The Blueprint has been in place very recently and many of the envisaged changes are in formative stages.

The delivery model has three phases or waves which are adequately elaborated in the Blueprint:

- **Wave 1 (2013–2015):** Improving the current curriculum and preparing for structural change; Refining and revising curriculum content to align with international standards.
- **Waves 2 (2016–2020) and 3 (2021–2025):** Rolling out new and revised curricula; these will incorporate the feedback, benchmarking, and stress-testing results from Wave 1. The Ministry will develop the new curricula using the total number of hours in the schooling year as the starting point, and remove non-priority content and skills to avoid overcrowding. The Ministry will also amend existing regulations to give schools flexibility over timetabling, as long as schools can still deliver the learning and content outcomes laid out in the curriculum.

As far as evaluation result is concerned, it is probably not conclusive enough now as the program has just started and not enough evaluation data is available. However, as planned in the Blueprint, the evaluation results are expected to come out regularly in the form of annual and other reports.

Conclusion

As articulated in the National Education Policy, education in Malaysia is an ongoing effort towards developing the potential of individuals in a holistic and integrated manner to produce individuals who are intellectually, spiritually, emotionally, and physically balanced and harmonious. The primary and secondary school science curriculum is developed with the aim of producing such individuals.

Most of the inquiry initiatives are embedded within the science curriculum. Teachers are encouraged to use the inquiry method during the teaching and learning process in the classroom.

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Source: SEAMEO RECSAM Official Facebook Page (2014).

IN-STEP
(Inquiry-Based Science and Technology Education Program)

Phang Nga, Thailand
MSD Thailand
2007–2012

Source: IN-STEP Evaluation of the First Year (April 2008).

IN-STEP (Inquiry-Based Science and Technology Education Program) was launched in 2007 with sponsorship from MSD Thailand and funding support from its parent company Merck & Co. Inc.; over the following three years, it brought more than 50 schools and 120 science teachers in the province of Phang Nga under its fold. The pilot trial aimed at improving science learning and teaching, and also to have a clear picture of the support system required to implement the curriculum reform throughout Thailand in the years to come.

Background

The rapid growth of Thailand's economy in the past few decades necessitated employment of highly skilled persons from a home-grown human resource pool in the areas of science and technology to sustain the pace of growth and remain competitive. However, Thailand's performance in the Program for International Student Assessment (PISA) in 2006 was low, and therefore required careful investigation by the education policy makers of the country. The studies revealed that:

- The average time for teaching science subjects allocated in Thai secondary schools was by far lower than the time allocated in countries scoring high in PISA;
- Weakness in literacy skills and vocabulary appear to be major barriers to achievement in science, especially in small rural schools;

Less motivation among students to learn science subjects as Thai students apparently have a perception that science subjects are difficult and not related to their futures; and

Lack of exposure to the process of inquiry-based scientific understanding limit the ability of citizens to apply rational thinking in their personal lives and to their assessments of their country's science and technology initiatives. This, in turn, does not help in generation of a scientific culture among the youth.

The situation called for a reformation of the science curriculum in Thailand. It was felt that the average performance of Thai students, as well as the number of students scoring high in international assessments, particularly in science subjects, must improve substantially to sustain Thailand's economic growth already facing stiff competition in the region.

Description

The IN-STEP curriculum with seven key features was meant for Thai lower secondary schools. These features were described in the first evaluation report on IN-STEP published in April 2008 as follows:

"Curriculum modules organized around guided investigations that illuminate key concepts in the biological, physical, chemical, and earth sciences. Each module provides 6–10 weeks of instruction;

Intensive professional development workshops for each module that introduce teachers to the science content and investigations included in the module. Teachers receive 120 hours of training during the program;

Opportunities for accomplished teachers to gain professional development experience by designing and delivering the workshops on the use of the curriculum modules. Other accomplished teachers serve as mentors to teachers as they implement the modules;

Training for school principals to prepare them to support the participating teachers;

Support for teachers from mentors and newly-developed teacher networks intended to foster instructional improvement in science over time;

Activities designed to build student and community interest in science such as annual science days and science camps that bring scientists and adults together with students to conduct projects focused on community problems;

Careful documentation of the implementation by an evaluation team composed of researchers from Kenan Institute, Asia (K.I. Asia) and Institute for the Promotion of Science & Technology (IPST), and led by the Consortium for Policy Research in Education (CPRE) at Teachers College, Columbia. The primary purposes are to provide feedback to the IN-STEP team to improve the program and assess the impact of the program on teaching and learning".

The structure of the framework for implementation of the IN-STEP program was designed according to the parameters followed by Merck Institute for Science Education (MISE) in the USA. This framework, according to the same report had 12 nodal points that included among others, professional support and development, on-site support for proper implementation, evaluation and community engagement.

As a part of the operation of the IN-STEP, supporting activities are also conducted on a regular basis in the following areas:

- Workshops on professional development of teachers;
- Establishment of IN-STEP materials resource center for proper storage, and distribution of resource materials;
- Outreach support to schools implementing IN-STEP—trained teams visit schools to provide in-situ guidance;
- Workshop for mentors to teachers;
- Workshop for school principals to ensure support to the teachers and also for proper allotment of class-time for science;
- Organizing "Science Camps" for students; and
- Organizing "Science and Local Wisdom" camps—student groups with guide teachers meet community members to investigate the conventional local wisdom applied in solving common problems and try to help them apply science concepts learnt through IN-STEP.

Evaluation

According to the evaluation reports published by the K.I. Asia, the main tasks of the evaluation team were to assess:

- The impact of the IN-STEP curriculum materials and training on teachers' classroom practice;
- The impact of the changes in practice on learning outcome in science; and
- The factors that affect the implementation, sustainability, and spread of the IN-STEP concept.

The team also identified the major tasks involved in the evaluation process as:

- Documenting the teacher workshops to provide timely feedback;
- Documenting the use of the modules by the teachers participating in IN-STEP, and obtaining feedback from these teachers; and
- Assessing the impact of IN-STEP on teachers' classroom practice, and on students' learning outcome in science.

For feedback, the mentors are asked to file site visit reports on simple forms for each school, and the same are compared with the results from telephone interviews with a sample group of teachers. Telephone interviews are also to be taken with teachers during the period in which they are using the modules. Survey of the teachers is conducted in conjunction with site visit reports and interviews.

On the basis of the evaluations conducted in 2008 and 2009, the following recommendations have been made to the managers of IN-STEP:

- Participating schools to increase time allocations for science to approximately 250 minutes;
- Commitment of schools for implementing the program may be made more specific and binding;

Source: Kenan Institute Asia Annual Report (2013).

- Minimum expectation for implementation of the program may be limited to treating each module as enrichment rather than a complete replacement of the existing curriculum;
- Length of Teacher Training workshops may be shortened to reduce loss of vacation time for teachers, thus increasing their interest in participation in the workshops;
- The modules on physical sciences that cover the entire three years of studies may be broken up in parts aligned with the standards in respective grades;
- Modifying the text of materials used by students using simpler languages considering teachers' feedback on literacy problems in Thai schools;
- To add more inquiry-based projects in each module given the possibility of a recommended increase in the time available for science instruction;
- To include training on Classroom Management Skills in the Teachers Workshops;
- The Intensive Mentoring Program to be continued;
- The Teachers Network may be set up to provide support and incentive to teachers, particularly from the remote rural areas;
- To provide teachers with direct incentive for participation in the program;
- To plead for governmental action for reducing non-academic activities in schools.

Conclusion

The K.I. Asia described the achievement of the IN-STEP in their annual report 2012 as follows: "IN-STEP has sought to fundamentally transform the way science is taught in Thailand by promoting an inquiry-based approach to education. Since the project began implementation in 2006, more than 18,000 students in Thailand's Phang Nga Province have benefited from innovative science lessons …

Project monitoring found that IN-STEP was positively associated with higher performance on national standardized science tests, and teachers trained by the program in the inquiry-based approach realized marked improvements in students' analytical abilities and their attitudes towards science learning, compared to traditional "talk and chalk" methods. Moreover, IN-STEP master teachers are playing an important role in sharing good instructional practices which they have learned from the program to help improve teaching and learning in other educational improvement projects.

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Source: Kenan Institute Asia Annual Report (2012).

Small Science

India
Homi Bhabha Centre for Science Education, Mumbai
From 1998, ongoing

Source: Inopen Technologies Website (2014).

In response to the need for introducing a more hands-on science curriculum for primary schools, the Homi Bhabha Centre for Science Education (HBCSE), Mumbai, introduced the “Small Science (SS)” Program in the late nineties as an alternative curriculum for science education for young children.

The SS Program is a product of long research on pedagogy and new inquiry-based methods of science education. The Program is based on learning and teaching science in primary schools through hands-on inquiry-motivated activities rather than through rote learning following conventional textbook lessons. The books published by the HBCSE along with the teacher’s guide have become popular in India as seen by their growing acceptance in the existing school system.

Background

India has been emphasizing curriculum reforms and innovations for the past few decades with initiatives at the central and state levels. As a result, significant progress has been made in the conceptualization of curriculum at the primary, middle, and secondary levels; the pedagogy has also evolved to a more modern and relevant form. However, there is a gap between the agreed objectives of such evolved curriculum and their actual implementation through appropriate textbooks and teaching practices.

For the past few years, a unique science curriculum developed by the scientists of HBCSE has been on trial in primary schools in different States of India. Sets of books on science subjects under the title "Small Science" have been introduced to students. These books, including a teacher's guide, are based on systematic research activities and trial in classrooms. This new curriculum is based on child-centered inquiry responding to their questions and inquisitiveness and is designed to enhance the cognitive skills of young students.

The SS Program aims to deliver first-hand real world experiences to students at the primary level through a set of exploratory exercises that help them in their scientific concept development and in building a constructive mind-set to experiment, hypothesize, and analyze their observation.

Description

SS curriculum is founded on three types of books: Text Book, Work Book, and Teacher's Book. These books conform to the science syllabi of Grades 1–5 and are available in three languages: Hindi, English, and Marathi.

The key elements included in the lessons of these books are:

- A unique integration of physical, biological, and environmental sciences;
- Prepared through research, field-studies, and classroom trials;
- Concepts developed through carefully designed activities using easily available materials;
- Simple and child-friendly language;
- Thought-provoking questions and exercises; and
- Accurate level-specific illustration.

In the textbooks, the students find two characters—a girl and a boy—of the same age group who discuss many things taking place around them in an inquisitive spirit, and engage themselves in doing hands-on activities, reflecting on their observation and posing questions. These questions provide the students enough food for thought that often extends beyond the lessons of the books.

The activity based approach helps students in developing:

- Verbal and non-verbal expression through discussion, writing, drawing, and acting;
- Design, mathematical, analytical, and problem-solving skills;
- Independent thinking and creativity; and
- A sound basis for later abstractions in science.

Source: Homi Bhabha Centre for Science Education, Small Science Website (2014).

Each SS Text Book comes with a Work Book that is designed to record results of the student's activities as suggested in the textbook. A student is assessed continuously on the basis of the Work Book records.

The third part of the SS is the Teacher's Book that provides practical guidance to teachers using SS Text Books. The content of the Teacher's Book provides enough information to the teachers regarding Indian natural, historical, geographical, social, and cultural backgrounds as necessary input for successfully carrying forward the SS teaching philosophy.

Teachers training workshops are also conducted regularly as a part of the SS Program. During these workshops, videos on actual classroom teaching with SS Books are shown and activity sheets based on students' responses are worked out. Teachers are informed about various useful resources and innovations related to their work.

Evaluation

The SS Program is being practiced in schools from diverse geographical locations, media of instruction, and socio-economic-cultural backgrounds.

In 2005 and 2006, an evaluation was conducted in 34 classes of two urban schools. This evaluation was mostly teacher-centric and the purpose of evaluating the new curriculum was to understand the situated process of change. The broad question considered in this evaluation was how institutional practices and teacher practices affect the use of an inquiry-based primary science curriculum.

For collection of data by the "Participant Observer", the following were resorted to:

- Teacher interview prior to classroom observation;
- Observation in SS activity classes and textbook classes;
- Teacher feedback following a class observation;
- Teacher interview after concluding all classroom observations; and
- Videotaping of class activities.

This evaluation concluded that:

- Teachers from the school with exposure to progressive modes of education showed better ability and comfort in bringing in the innovative curricula in classrooms than the teachers from the school following conventional pedagogic approaches to teaching;
- The content, language, and simplicity of lessons were successful in making way to a descriptive "Observe-Do-Think-Record-Find Out" perception of science teaching from the conventional prescriptive "Facts and Information" perception of the teachers;
- The teachers studied the Text Book and the Work Book as much as they can but did not study the Teacher's Book to the extent needed for successful delivery of the new curriculum thereby missing the intellectual context of the curriculum;
- Lack of adequate and appropriate content knowledge weakens inquiry-based science teaching as the teachers are required to handle this curriculum by skillfully integrating the pedagogical approach with content knowledge; and
- Periodic evaluation of the SS curriculum in schools of diverse systems and settings is necessary.

Another evaluation study, conducted in 2009, confirmed the need for improving the teacher's subject knowledge.


Source: Inopen Technologies Website (2014).

Conclusion

Although the SS Program started on a small scale in only one State, it has now proliferated into twelve States of India. Moreover, schools in seventeen States are using the SS series of books as reference material for teaching their science syllabus in primary schools. However, the use of the SS Program is mostly restricted to privately funded schools who have more flexibility in choosing their primary science curriculum than the schools funded by the Government.

There is skepticism about the learning outcome of this new method of learning as the evidence of student's performance through formal tests and term-end examinations, as the conventional system is not available in the SS Program, which mostly depends on continuous assessment on the basis of Work Book records.

Some of the schools have, therefore, adopted a compromise on the assessment procedure: 50% marks through continuous assessment from the Work Book, and the balance 50% through formal tests and exams. This solution has helped in reducing anxieties expressed by parents.

At present, activities such as content design, publication, and distribution of books, implementation of the Program, and evaluation of it are in different hands. HBCSE plans to integrate these activities for better performance of the SS Program.

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Science Clubs Initiative

Alexandria, Egypt
Planetarium Science Center, Bibliotheca Alexandrina
From 2006, ongoing

Source: BA PSC, Science Clubs Initiative (2014).

In the academic year 2006/2007, the Planetarium Science Center (PSC), affiliated to the Bibliotheca Alexandrina (BA), started implementing the Science Clubs Initiative (SCI). SCI introduces the principle of interactive activities in the study of science in schools to become an integral part of the framework of formal education.

The initiative helps students 4–16 years of age develop the skills of the 21st century, focusing on scientific knowledge, creativity, critical thinking, problem solving, and teamwork. It also aims to train teachers on the application of the scientific method through applying innovative communication methods in workshops and research, in turn raising their professional skills.

SCI works with selected school students as an activity outside the school curriculum during the school year. SCI has thus far covered 300 governmental schools affiliated to different Educational Departments in Alexandria in accordance with the schedule set by the BA and the Ministry of Education.

Background

Due to major economic, social, and political problems facing developing countries, education reform is not among the top priorities of the decision makers' agenda; the result is poorly structured formal educational systems. Moreover, long-term education reform plans are usually obstructed as strategies change with changing governments, which also reflects on individual and scattered efforts to upgrade the formal education system.

Most critics disparage formal education for its incapacity to fulfill the actual needs of students, whereas non-formal education is based on the notion that, in order to obtain effective results, it is necessary to identify and provide for the real needs of people. Learning science outside the classrooms breaks the barriers between school students and knowledge; it has a positive impact on decreasing students' reluctance to science.

Here comes the role of science centers, which are considered the most important source of information for school students outside their classrooms and their essential role is growing rapidly in developing countries. Consequently, upgrading the quality of scientific research at an early age is achieved through designing long-term programs and establishing science hubs/clubs in schools to offer extra curricula activities.

Description

The Science Clubs (SCs) allocated areas in schools are considered satellites of the PSC workshops located in distant, and in some cases, disadvantaged schools. They are considered miniature models of the Science Center workshop areas offering hands-on activities and supporting research programs.

Above all, the PSC offers SCI teachers training courses to equip them with the necessary teaching skills and resources that enable them to conduct workshops without being confined to the school curriculum. The training sessions introduce IBSE methodologies to teachers, and help them explore students' innovative ideas and increase their passion in Science and Technology (S&T). SCI teachers' training is based on the following methodologies:

- Pedagogical Philosophy: Based on breaking the barriers of classroom and curriculum to provide space for creativity and innovation, for both teachers and students.
- Thinking Skills: Offered through a minimum of three sessions to change the teachers' concept of practical science lessons. By the end of training, teachers have the capacity to transform theoretical scientific data to simple hands-on activities that students can easily understand.
- Six Teaching Methods: Training sessions are conducted to inform teachers how to mix and match the various teaching techniques based on the students' capacities and scientific content.
    - Training of Trainers (ToT): SCI trained teachers are required to train other teachers in the same school, to ensure the sustainable growth of the initiative.

Source: BA PSC, Science Clubs Initiative (2014).

SCI schools are directly linked to the PSC for continuous follow-up. Each school SC acts as a hub transforming the initiative to other neighboring schools in the school district; securing the sustainability and expansion of the initiative in Alexandria and other Governorates.

SCI also provides a program for teachers entitled "Fun with Science

Training". It uses a series of fables written by Dr. Gunter Pauli, containing messages aimed at developing the children scientific base, and enabling them to apply scientific knowledge as a creative tool. A major theme of the program is the introduction of "systems thinking", which aims to present the basics of systems thinking, and the possibility to apply this methodology in teaching.

Evaluation

Source: BA PSC, Science Clubs Initiative (2014).

The impact of SCI is evaluated based on a number of indicators:

- The participation rates at the SCs sessions on regular basis and the number of students who shift from being transient visitors to regular attendees;
- The number of students who participate in extracurricular scientific activities at the PSC;
- Science marks are considered an additional outcome of the sessions and not a direct measurable output of students' interest in science, although it is affected by it;
- The aspects discussed with students' parents, which could be presented quantitatively by the utilization of scientifically-based surveys, filled by several samples of parents;
- The number of high-school students who choose to complete their studies in a scientific field (this criterion is considered a long-term outcome rather than a direct output).

After the collection of the above data, an index is built to define the actual impact of the initiative on a ratio scale, which reflects a rather precise and efficient comprehensive picture. Hence, over three academic years, SCI was able to:

- Establish 300 SCs in governmental primary and preparatory schools in Alexandria, Egypt; from a total number of 1,122 schools in Alexandria according to the latest statistics;
- Conduct 40 teacher training sessions, 30 hours per session over five days for an average of 35 teachers, delivered by a PSC Coordinator and six teachers (core of ToT);
- Select three ToT teachers (science teachers) to be consultants to the project, to assist the PSC in coordinating the project through follow-up visits to the different SCs, and to deal with any technical problems at SCI schools;
- Train about 1,400 teachers;
- Provide SCs equipment and allocated space in each school;
- Distribute educational tools and scientific kits to the selected schools to activate the Clubs in each school as follows:
  - Two computers for each of the 300 SCI schools;
  - Scientific books containing experiments and activities to help participants in each school achieve and realize a scientific project;
  - "Fun with Science" kits, contain 11 scientific fables in addition to scientific facts for every story, to SCI elementary schools;
  - Two scientific kits (Chemistry and Electronics)—content development and fabrication carried out by the project coordinator and scientifically revised by academia, to 200 SCI preparatory schools;
  - Two environmental kits (Green Box), to 100 SCI preparatory schools.

- Target 1000 students as permanent students with regular visits to the SC (15 regular participants in each of SCI school). During the period 2010–2013, around 3000–4000 students were targeted, as temporary students, who were involved in a number of activities conducted at the SC (20 non-regular participants in each of SCI school); and
- Implement follow-up visits to each of the 300 SCI schools.

Conclusion

In a world increasingly shaped by science, technology, and innovation, science education is critical to the future employability of many young people; it also helps create scientifically literate citizens. The main impact of science edutainment facilities and activities is to encourage school students to follow their curiosity, hence indulge in science and join the international knowledge society.

Informal education is expected to complement the formal system at an affordable price; the long-term impact is to get students involved in science as a lifelong learning process outside the classroom. This is expected to result in creating the critical mass of youth who are interested in science and technology, and are willing to pursue careers in science; moreover, changing the culture of entrepreneurship and youth to be scientific-oriented and educational-focused is crucial in the development of countries.

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Science Center in School

Amsterdam, the Netherlands
National Centre for Science and Technology
2004–2007

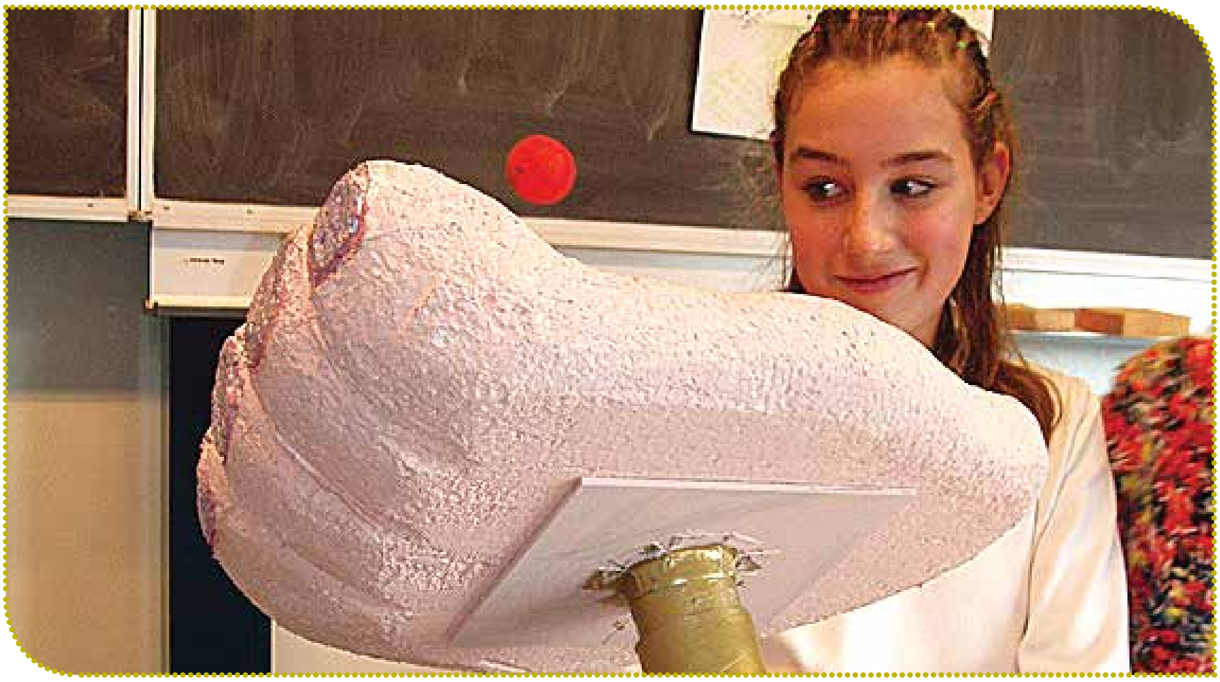

Photo by: Amito Haarhuis, Science Center NEMO, Amsterdam.

Progressive education has long held that one way to learn a subject very well is to teach it to others. Another way is to experience it, perhaps through kinetic or visual pathways in addition to aural ones usually associated with classroom learning. The Science Center in School project teaches science to children ages 11–12 years using a combination of both approaches. It asks students first to observe and reflect upon their own learning process in an interactive science center (specifically NEMO). Next, it asks students to create an effective science exhibit of their own.

Background

The project Science Center at School was created by the National Science and Technology Center (stichting Nationaal Centrum voor Wetenschap en Technologie–NCWT) in the Netherlands as part of a larger European Union (EU) effort under the Permanent European Resource Centre for Informal Learning (PENCIL).

Simply put, Science Center at School challenges 11–12-year-old students to envision, design, and build their own exhibits. These individual exhibits then become part of a larger exhibition in their own schools. The project is mapped onto eight half-day segments.

Working in pairs, students choose a subject, make a building plan (including technical drawings), build the exhibit, research the topic, and prepare a presentation. On opening day, the school (and invited guests) visit the exhibits where students give oral presentations of their research findings and discuss their work.

Description

The work all begins at the Science Center where an employee of the real science center "commissions" the building of the exhibits. The students' first step is to carefully evaluate multiple exhibits at the Science Center, following an evaluation form in the Science Center Workbook that anchors the various demands of this project.

For each exhibit, students are asked: What did you do at this exhibit? What scientific subject is behind this exhibit? What have you learned? How would you rate the clarity, attractiveness, and scientific explanations of this exhibit? At the end of the visit to the Science Center, students must also comment on the broader experience, noting which exhibit titles were more appealing, which subjects more interesting, and what "Do's and Don'ts" they might keep in mind for designing their own exhibits.

Working from this baseline, students reconvene on the second half-day to peruse the Exhibit Design Book and choose a subject for their team's own exhibit. On this same day, once their topic is approved by the teacher, they exercise their technical skills as they design the exhibit on grid paper and make a list of necessary materials.

The physical construction of the exhibit occupies the third and fourth half-days. With this in place, students turn to research on the next half-day, again with the guidance of the Exhibit Design Book; here, students find ways to present the science behind the exhibit. The following half-day is devoted to creating posters that explain the exhibit and the science that informs; ultimately, students will create five posters with specific focal points, arranged on tables in zigzag fashion.

On the seventh half-day, students prepare a short talk about their exhibit and then share with their classmates; the culminating half-day is opening day for the new science center. Students welcome the rest of their school and their families into the classroom to explore, learn, ask questions, and provide feedback; they share their exhibits and their research.

Photo by: Amito Haarhuis, Science Center NEMO, Amsterdam.

As is likely clear from this specific syllabus, student learning exceeds that of the scientific skills at hand. Drawing the exhibit design to scale draws on math skills, while building the exhibit itself requires students to measure accurately, use tools safely, and promote a concept to physical existence. The project itself, spread over the course of five weeks, asks students to engage in long-term planning; understand how individual steps contribute to the project overall; sustain ongoing conversation and reflection; and practice patience and persistence.

Along the way, students no doubt find themselves practicing some problem-solving as well, whether it is a design flaw, or lack of materials, or dispute over the vision of the exhibit. Indeed, it is no less important in this process that students learn to communicate with their partners, to express themselves clearly, and to negotiate productively when necessary.

Creating the posters, titling the project, and creating an attractive exhibit overall requires students to think about their audience and to match their exhibit to that audience's interests and abilities. Finally, presenting their work orally to adults and other students requires thoughtfulness about self-presentation as well as public speaking skills.

Evaluation

The impact of the Science Center in the school project is multifold; by bringing the Science Center into the schools, it explicitly links in-class and out-of-school activities. Students are encouraged to see learning and sharing knowledge with friends across a sustained continuum, rather than the segregated activities of school and field trips.

Additionally, while its positive impact is most powerful for participating students, that impact radiates well beyond them; students visiting the newly-fabricated Science Center, many of them younger schoolmates, are inspired not only by the exhibits themselves but also by the children who created them. One of the five posters required, for example, is one that introduces the pair of students who created the exhibit, including pictures.

A further benefit of the project is that, from the very first activity at the actual Science Center, it guides and demands critical thinking from students. That is, when the students visit NEMO or comparable science center and evaluate specific exhibits, they are asked to consider not only what science the exhibit teaches and how, but also how the exhibit is framed; how the exhibit does or does not attract students; how it directs student activity at the exhibit; how its design does or does not facilitate exploration and learning; and so on. By asking young students to think carefully about how their own learning happens and how a particular exhibit tries to teach, this project offers them tremendously powerful practice at critical awareness—a tool that will serve them well in any discipline.

The NEMO program brought together both a new, hands-on approach for the students and provided an innovative in-service learning opportunity for educators. They did so within a broader European network that allowed for wide dissemination of their findings. This wide dissemination also helped ensure the sustained impact of their results.

Photo by: Amito Haarhuis, Science Center NEMO, Amsterdam.

Furthermore, the NEMO project was created in the context of a flexible Dutch curriculum and a government that had recently adopted policies to more fully include science in the national primary school curriculum. In effect, the NEMO project doubled the amount of science elementary students were exposed to in a typical year.

The NEMO team realized that it was important to include teachers in not only the implementation phase but also the design phase of future projects.

Given the significant goal of deepening an interest in and understanding of science on a national level, NEMO quickly learned from the teachers that they needed to extend the evaluative phase to include attitudinal surveys of students, teachers, and parents, among other measures.

Through these additions, they were able to determine that the primary school students most valued the opportunity to do something different from what they typically did when learning "science" in their school. They liked both the hands-on aspect and the tangible products. Parents appreciated that their children could clearly demonstrate their learning to others.

Conclusion

This project challenges and encourages the social, physical, verbal, artistic, and intellectual development in its young designers. It offers students the opportunity for deep learning, not only in a scientific area, but also in any and all of these other arenas of knowledge. Science Centers in schools offers schools everywhere a template for creating a photogenic, exciting, beautiful spectacle of science learning for the whole school while simultaneously nurturing the many facets of growth necessary for successful future scientists.

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Photo by: Amito Haarhuis, Science Center NEMO, Amsterdam.

Science Centers as Learning Laboratories

Vantaa, Finland
Heureka, the Finnish Science Centre
1990–2001

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

Science Centers as Learning Laboratories present four case studies conducted at Heureka, the Finnish Science Centre, applying different methods. These studies show that Science Center education is a form of informal learning. The results of knowledge tests showed clear learning effects and that motivation is important. A series of visits to a science center seemed to have positive effects on the motivation of all students. This review focuses on the case study dealing with motivating students with learning difficulties.

Background

The role of informal learning is increasing in modern societies, as science and technology have a greater influence on our everyday lives. Lifelong learning needs new practical forms, and informal science learning is a strong candidate for this effort; in this context, Science Centers are essential partners.

Science Centers aim to increase science engagement, and to further public understanding of science. They strive to create positive attitudes towards science and technology, encourage young people to learn science and to take up careers in science and technology, and to maximize the opportunities in society for scientific applications.

A science center is a learning laboratory in two senses. First, it is a place where visitors can learn scientific ideas by using interactive exhibit units. Second, it is a place where informal science education can be explored in an open learning environment without the rigors imposed by traditional school curriculum considerations.

Science education is not only the question of advancing technology or of the need to develop a scientifically qualified workforce; it is also a social goal. Future citizens need to be scientifically literate and to function in a world deeply influenced by science and technology.

Heureka is renowned for its interactive science exhibitions, which consist of traditional hands-on experiments, computer stations, and high-technology based audio-visual setups.

The development of these exhibitions is carried out through the best available expertise from universities, research institutes and private companies. In this way, the scientific and technological content of its exhibitions is reliable and based on up-to-date knowledge and research. In planning the exhibitions, educational aspects are essential; Heureka works in close co-operation with teachers, school administrators, and teacher training departments at universities.

Heureka's exhibitions are interdisciplinary. The themes of its temporary exhibitions are varied and broad; which is an excellent environment for science and technology learning.

Description

Everyday knowledge suggests that students are eager to learn in informal settings. Field trips, school camps, visits to corporations, or excursions to a museum or science center, are positive occasions in students' minds. This positive attitude arises from the freedom of leaving the classroom. To take advantage of the motivating effects of freedom and physical context is an aim of science center pedagogy.

Motivation is usually divided into extrinsic and intrinsic motivation. Extrinsic motivation consists of situation and instrumental motivations. Situation motivation is motivation that grows from a new situation; this kind of motivation is typically short-lasting and easily disturbed, and learning may be oriented towards irrelevant subjects. Instrumental motivation is based on a need to get a reward or to avoid punishment; typically, the goal may be to pass an exam. Isolated facts are learnt, but connections are not; facts are easily forgotten.

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

Intrinsic motivation refers to a real interest in the topic studied; the student sees the value of the studies and plans to use the knowledge or skills in the future. Typical features are a critical attitude towards learning, seeing the connection between isolated facts, and understanding the link between theory and practice. Learning is based on curiosity, interest, and problem-solving.

The study contained several cases of which this review focuses on the research question about a difference in motivational patterns among students who have learning difficulties and those who are gifted, as well as those from other groups.

Motivation was measured by a test containing 19 different attributes of motivation. Seven of them represent the characteristic features of intrinsic motivation and twelve represent the characteristic features of extrinsic motivation. In addition to measuring motivation, a cognitive and visual reasoning test was conducted; it contained 48 visual multi-choice items to be solved within 12 minutes. A mechanical reasoning test was used to measure the ability of students to engage in logical thinking; the test has 67 multi-choice items.

In the first two case studies, a connection between having intrinsic motivation and being gifted was found. The purpose of the third case study was to investigate whether the learning and motivation can also be created for students having learning difficulties in school.

The subjects of the study were 158 pupils of Finnish secondary schools; one of the groups, which included 12 students, was chosen from a special education class having learning difficulties. The results were compared to 18 ordinary secondary schools students and 30 gifted students, who also made a series of visits to Heureka. As a control group, which included 98 students, there were students who did not visit the Science Center, but had the same content for their science curricula in the classroom.

Evaluation

Cognitive tests were given to the groups before the visits, and motivational tests before and after completing the visit program. The students in the gifted groups were chosen based on assessment by their teachers. When tested by the cognitive reasoning and the logical reasoning tests, the gifted students scored much higher than the other groups; the learning difficulties group scored lower than the others. These differences were statistically significant.

When subjected to the motivational tests, results indicate that intrinsic motivation of both the gifted and the learning difficulties group grew during the project. The results of the learning difficulties group are encouraging; their intrinsic motivation increased, although it decreased in the control group and in the ordinary group. Generally, the intrinsic and instrumental motivation decreases in Finnish secondary schools over the age of 12–15 years. This is evident for the control group of this study.

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

The results of the instrumental motivation study of the learning difficulties group are very interesting. Students in this group had distinctly lower scores in the instrumental motivation pre-test. It seems that students with learning difficulties lack an understanding of the value of their studies in secondary school. However, the motivation of this group clearly improved during the project, and the difference was statistically significant. It seems that the Science Center visit increased the self-confidence of the learning difficulties group; they experienced success without external pressure. Their instrumental motivation increased, opposing the trend for their age group.

Programs linking schools and Science Centers in meaningful learning initiatives may be used to minimize teenagers' decreasing motivation for learning. The right cognitive level is important, but the same exhibit units and exhibitions apply for different students with different motivational and knowledge backgrounds, if the guided introduction is carried out in a pedagogically appropriate way. The meaningful content of the exhibition is crucial.

Conclusion

The results of the knowledge tests show clear learning effects resulting from a Science Center visit. Since a visit is rather short, the focus must be on the quality and not the quantity of learning; this points to motivation as a key factor.

The series of visits to a science center seems to have had a positive effect on the motivation of students. School students having intrinsic motivation gained both better cognitive results and tended to apply deep-learning strategies in the learning process.

Gifted students seemed to get more motivated than others during the Science Center visits. However, by using programs linking the school science curricula with Science Center exhibitions, encouraging motivational results were obtained for the group of students with learning difficulties.

This study indicates that Science Centers are an important factor in informal learning. At Science Centers, well planned educational programs are needed. These need to be evaluated by valid educational research.

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Interactives and Visitor Learning

Sydney and Perth, Australia
Powerhouse Museum, Scitech Discovery Centre, Institute for Learning Innovation and Curtin University of Technology
2001

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

This review presents a study conducted at the Powerhouse Museum in Sydney and Scitech Discovery Center in Perth by researchers at the Institute for Learning Innovation and Curtin University of Technology. The study focused on visitor perceptions of interactivity and the types of short-term and long-term learning that resulted from the use of interactives in these two Institutions.

The study showed that multiple types of learning outcomes occurred at the interactives studied. The types of learning presented were: Knowledge and skills; Perspective and awareness; Motivations and interest; and Social learning. Visitors enter the Museum with pre-existing knowledge, experience and interest, and these pre-existing conditions strongly influence the in-museum learning. There is a significant difference in short-term and long-term learning outcomes: short-term outcomes relate predominantly to knowledge and skills, while long-term outcomes relate to perspective and awareness.

Background

In the Science Center and Museum fields, practitioners often make claims about their institutions being part of the learning landscape, with effects on attitudes toward science and technology. While a multitude of studies support the claim of actual learning taking place in a museum, the effects on attitudes and awareness have been dealt within rather few studies.

There is also a scarcity of studies dealing with long-term effects of a visit to a science center or a museum on an individual's learning. This is due both to practical obstacles in carrying out such investigations; that is, the methodology to be applied, and the cost of the research. By using various investigative techniques related to in-depth interviews, analysis of self-reporting and personal meaning mapping these obstacles can be overcome.

Description

The purpose of this study was to broadly investigate learning outcomes in interactive exhibit elements, to examine this interactivity in two different contexts—a museum and a science center—and to extend the timeframe of the investigation beyond the immediate museum experience.

It was conducted at the Powerhouse Museum in Sydney, Australia, and at Scitech Discovery Center in Perth, Australia. Researchers from the Institute for Learning Innovation in Maryland and the Curtin University of Technology in Perth participated. Eight interactive exhibits—four at each Institution—were chosen for the study; the study was carried out in 2001.

Visitors were selected randomly, and interviewed by researchers before the visitor engaged with the exhibit, following the experience, and four to eight months following the visit. In addition to open-ended questions, researchers used personal meaning mapping. In the pre-visit interviews, visitors were, inter alia, asked about their perception of the venue. After the engagement, they were asked to describe their experience and what they had learned. In the follow-up interviews by phone four to eight months later, every effort was made to capture visitors' exact words and ideas.

The interview data were analyzed both quantitatively and qualitatively. Content analysis allowed the researchers to identify, code, and categorize patterns or themes within the responses. Altogether, 100 persons were interviewed at Scitech and 99 at the Powerhouse Museum; 70% of those interviewed on site participated in the follow-up interviews four to eight months later.

The selection criteria were that the sample should include adults of different age groups and fairly equal numbers of both sexes. Of the visitors, 47%–55% had a university or postgraduate degree, 86% of the Scitech visitors were accompanied by children, whereas only 18% of the Powerhouse visitors were young children. Scitech visitors were more oriented towards fun and education for children, whereas the Powerhouse visitors were more oriented towards knowledge and collections.

Evaluation

There were a number of key findings of this study namely:

- Four major categories of learning outcomes resulted from the visitor interaction with the various interactive exhibits: Knowledge and skills; Perspective and awareness; Motivations and interest; and Social learning. These learning dimensions have been validated in other studies, as well. These findings demonstrate that interactive exhibits can support the learning of facts, as well as perspective and social learning.

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

- More than one short-term learning outcome is possible from interacting with an interactive exhibit. These results support the hypothesis that learning is individual and no two people learn exactly the same thing from an exhibit.
- The types of short-term learning outcomes varied across interactives and was not affected by the type of institution—museum or science center—where the exhibit was held.
- An individual may derive multiple short-term outcomes from the same exhibit. Interestingly, a single individual was likely to derive multiple outcomes even from a single experience with an interactive exhibit.

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

- Visitors arrive with perceptions, expectations, interests, and knowledge that influence the learning occurring at the interactive exhibit. In this study, the researchers explored a whole range of variables that might have influenced the outcomes. These included: age and gender, presence of children, prior knowledge and interest, prior visits and expectations for learning. These variables are collectively important in explaining the variance of learning outcomes, but no one alone is capable of predicting outcomes. There is a strong correlation, however, between knowledge about science and interest in science.
- Short-term learning outcomes do not predict long-term learning outcomes. Sixty percent of the long-term learning outcomes can be placed in the "Perspective and awareness" category. Visitors were more likely to indicate social outcomes in their long-term learning patterns. There was limited correlation between short-term and long-term learning outcomes.
- The major learning outcome over time was a positive shift in visitors' perspective and awareness. In 27% of the cases, no long-term outcomes were reported. However, the vast majority, 73%, of visitors could articulate an outcome after several months of elapsed time. Most of them reported that they gained new perspective and awareness.

Conclusion

The study confirms that the public values interactive exhibits in science centers and museums. Interactivity is a major expectation when visiting a science center, but less so when visiting a museum. However, when interactive exhibits are used in a museum, they influence the perception of the institution itself. These perceptions are likely to persist over time and help reduce the picture of museums as old and dusty.

One of the key findings was that more than one type of learning resulted from each of the interactive exhibits studied. This study provides empirical data as proof of this conclusion. This strengthens the view that museums support multiple learning outcomes.

The study also shows that visitors enter with pre-existing perceptions and knowledge, and that these pre-existing conditions influence their in-museum learning, at least to some extent. Learning results from an interaction of their personal context and the institutional setting.

The most surprising finding was the difference in visitors' short-term and long-term learning outcomes, and the fact that long-term outcomes were not predictable from short-term outcomes. This is the first study to show such effects; these results help position museums and science centers in society.

When visitors were interviewed in the museum or science center immediately after their visit, they overwhelmingly reported that changes in knowledge and skills were the main type of learning outcomes that they experienced from the interactive exhibits. Some of the interactive also influenced perspectives and awareness. Many of the exhibits were designed to facilitate changes in visitors' knowledge and skills, so from the designers' standpoint these results are encouraging.

In this way, science centers and museums become part of the fabric needed to build a knowledge-based society, reaching out to audiences beyond the formal education system. Museums and science centers may become instrumental in bringing about a greater understanding of research, science and technology.

The data from this study also cautions us to generalize about long-term learning based on short-term learning outcomes. What visitors said when they exited the museum or science center is significantly different than what they recalled half-a-year later. This is especially important as almost all research on museum learning is carried out in the museum, as short-term studies.

Reference

John H. Falk, Carol Scott, Lynn Dierking, Leonie Rennie and Mika Cohen Jones (2004). *Interactives and Visitor Learning. Curator* 47, 171–198.

Source: Heureka, the Finnish Science Centre; www.epressi.com (2014).

Assessing Exhibits for Learning in Science Centers

Sudbury, Canada

Science North and Laurentian University

1997–2007

Source: Science North Annual Report (2011–2012).

The tool of assessing exhibits is based on observing the visitor behavior when the visitor is engaging with an exhibit in a science center. Observation shows three stages of visitor engagement: initiation, transition, and breakthrough. A distinctive visitor engagement profile can be constructed for each exhibit and used in exhibit development. For exhibits studied at Science North and Laurentian University—both located in Sudbury, Canada—typically 20%–80% of the visitors reached the transition stage and 10%–60% reached the breakthrough stage. The breakthrough stage behavior can be considered empirical proof that learning has occurred in the exhibition.

Background

Learning is a complex human activity that involves all of us. It encompasses all ages, from babies mastering language to seniors learning computer use; all walks of life, from studying the environment to managing political affairs; and all activities, from making music to sport.

The outcomes of science and technology are all around us, and affect our everyday lives. Media and the World Wide Web provide access to science, as do museums and science centers through their programs and exhibitions. They are often referred to as informal learning settings where free-choice learning occurs. This is in contrast to the formal education system, which largely dominates the learning of science.

In the school system, learning is formally organized, guided by curricula, and led by teachers; in a science center setting, the learner interacts directly with the phenomena of the natural world. In free-choice learning, there is a large degree of self-direction and self-selection involved; there is a considerable choice on the part of the learner as to what to learn.

Assessing the learning that occurs when a visitor interacts with an exhibit in a science center can be very challenging. It cannot be accomplished with the same methods that are used in formal teaching, where participation is obligatory and the learning outcomes are focused on cognitive aspects. In a science center setting, the learning is multi-dimensional and any assessment of free-choice learning must take that into account.

In the formal education system, cognitive learning goals have been set a priori, and these can be assessed by tests. In a free-choice learning setting, this does not apply, as the learner may opt for a different path than the exhibition planner, for example, and may still experience learning. This personal learning may be highly relevant for the learner, even if the outcome does not correspond to the aims set by someone else.

Description

Learning is an interaction between ideas that learners currently hold and newly presented experiences; this constructivist approach focuses on how individuals engage in the making of meaning from an experience.

Observing visitors and analyzing their interactions and conversations has become an accepted methodology in assessing visitors' learning experiences. Early studies focused on reading signage, asking questions, and duration of time spent with an exhibit; such behaviors were considered indicative of learning. Later studies showed a strong relationship between learning levels and observed behaviors.

The visitor engagement and exhibit assessment tool consists of the following elements: a visitor engagement framework of observable behaviors; the arrangement of those behaviors into learning categories; a visual representation of the level of engagement; and a model that indicates where intervention might increase engagement.

This method of assessing visitor learning has been in use at Science North for over ten years. The framework consists of seven discrete learning behaviors that occur when a visitor interacts with an exhibit. The behaviors can be grouped into three categories that reflect increasing levels of engagement and learning: initiation, transition, and breakthrough.


Source: Science North Annual Report (2011–2012).

Initiation behaviors consist of carrying out the activity and spending time watching others performing the activity. Transition behaviors include repeating the activity and expressing positive emotions in reaction to engaging in the activity. Breakthrough behaviors include referring to past experiences while engaging in the activity, seeking and sharing information with others and being engaged and involved.

Evaluation

The staff at Science North uses the model as a tool to better understand the impact of their exhibits on visitor learning experiences. After being trained into using the visitor engagement framework, the Science Center staff observes visitors as they interact with an exhibit and record the learning behaviors they see.

Information about initiation and transition can be acquired by simple visual observation. For breakthrough behaviors, the staff needs to hear and analyze conversations between visitors and others—friends, family, or staff. Proper protocols to study humans need to be followed.

The levels of engagement shown by visitors at a particular exhibit can be depicted as Visitor Engagement Profiles. Each of the three engagement level categories is represented by a bar showing the percentage of visitors who show one of more of the behaviors characteristic of a category. The baseline of a Visitor Engagement Profile is the number of visitors who approach a particular exhibit; the profile does not measure attracting power of an exhibit.

Different exhibits show different Visitor Engagement Profiles. The method produces an automatic 100% initiation state; the transition behaviors are reached by 10%–75% of the visitors, and breakthrough behaviors by 0%–55%. Typically, transition behaviors are reached by more visitors than breakthrough behaviors, but there are examples of exhibits that produce more breakthrough behaviors than transition behaviors.

The Visitor Engagement Framework and the Visitor Engagement Profiles were combined into a Visitor Engagement and Exhibit Assessment Model. The model is a process for analyzing the engagement elicited by an exhibit and using the analysis to modify the exhibit. It is a visitor behavior-based method of formative evaluation. Modification of the visitor experience so as to elevate engagement is the overall goal.

As an example, the work to improve the Sprint Track exhibit at Science North in 2004 can be mentioned. It is a ten-meter track where visitors are timed and encouraged to exit out of the starting blocks—as professional athletes—by a video coach and a replay video. The Visitor Engagement Profile showed good levels of transition behaviors (55%), but the breakthrough behaviors were lower than expected (below 10%).

It was found that the video coach and playback option were not used as intended. The exhibit was modified, in 2005, by repositioning the coach and replay monitors and relabeling. Transition behaviors rose to over 80% and breakthrough behaviors to 40%.

Exhibits with low transition and breakthrough categories might be judged ineffective. By altering the exhibit and studying the ensuing learning behaviors, by a reiterative process if necessary, a higher degree of successful learning may be accomplished. In the process, listening to the visitors and conversations are important. The social context may amplify breakthrough behaviors.

Source: Science North Annual Report (2011–2012).

The cumulative impact of a group of exhibits is more subtle and complex than simply the sum of the Visitor Engagement Profiles. In assessing the engagement it may be important to distinguish between circumstances when floor staff are present to talk with visitors and when they are not. Presence of floor staff may result in a higher level of engagement.

For Science North, applying the methods described above has enabled the staff to make improvements to the visitor learning experience. The model empowers staff to use data to make changes to exhibit design. It fosters a research culture that encourages reflection in developing the visitor experience. To reach its full potential, the method needs to be applied consistently over a number of years.

Conclusion

In the method developed by Chantal Barriault, learning is deduced from observing visitor behaviors. Even if this method does not necessarily deliver information about what was learned, it does show that learning actually occurs in the Science Center. In this way, it can be considered empirical proof of learning in a science center.

One might argue that this is the only empirical proof available of learning occurring in the Science Center setting, as cognitive tests may incorporate learning results obtained elsewhere. In a free-choice learning environment, the relevance of actual learning outcome is determined by learner. Even if it was something else than determined by the planner of the exhibit, the learning that occurred clearly was meaningful to the learner.

Reference

Chantal Barriault and David Pearson (2010). *Assessing Exhibits for Learning in Science Centers: A Practical Tool.* Visitor Studies 13, 90–106.

Juicy Questions

San Francisco, California, USA
Exploratorium
Ongoing Research

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What typically happens when children and families visit science centers? Are they inspired? Do they learn? The answers are often assumed; of course, exposing people to a range of exhibits sparks interest and encourages learning. The staff at the Exploratorium in San Francisco, California, however, decided to probe a bit further.

They asked: Were some visitors, rather than being enriched by the Museum environment, simply overwhelmed by the volume of information and the overwhelming range of stimuli? Did the visual prompts of a typical exhibit provide enough of an anchor to help maximize impact? Was there a better way to stimulate curiosity and facilitate learning?

These, and other questions, led to an ambitious project to first explore and then improve upon how visitors experience exhibits.

Background

The first phase of the project, a research study known as GIVE (Group Inquiry by Visitors at Exhibits), involved designing a "best case" program for small groups of casual visitors under ideal circumstances (that is, a research laboratory separate from the main floor). The goal was quite simply to create new programming where groups could learn the scientific inquiry habits of working practitioners while visiting the Museum.

Starting from earlier research that suggested that families learned more effectively through open-ended rather than one-size-fits all exhibits (Borun and Dristsas, 1997), staff at the Exploratorium designed the research study to observe and test a range of program structures to determine the ideal format and content.

Researchers focused on two types of groups: families with children between ages 8–13 years, and field trip groups from schools. Using a randomized control trial, they tested the relative efficacy of four experimental designs:

- **Juicy Question game.** As participants explored the exhibit, they were each given “Pick a Juicy Question” card with a picture of an orange slice on it. Then the group brainstormed juicy questions—that is, a facilitator from the group or family encouraged each person to come up with a question (that he/she did not know the answer to) inspired by the exhibit. The group then chose one juicy question and returned to the exhibit to try to answer it (a discovery card with a picture of a blackboard on it accompanied them at this step). Finally, they returned to the discussion to explain their findings.
- **Hands Off game.** In this game, families and student groups explored the exhibit as they liked; at any time though, any participant could call out “Hands Off!” and announce either a new discovery (“I figured out that ...”) or a plan for inquiry (“I want to try ...”). Again, two illustrated cards labeled “Discovery” and “Plan”, respectively, to help children remember the rules of the game. Similarly, a parent or chaperone was given cards with guiding questions to help children focus on the game.
- Pure Control—no game or intervention. Families merely experienced the Museum on their own, with no interventions from Museum staff.

- Exhibit Tour—an energetic docent-led description of the exhibit’s history and science content.

Researchers measured impact by a range of factors, including the number of questions visitors asked, how often they interpreted answers they found in the exhibit, the length of time a group chose to spend in an exhibit, and the frequency of collaboration amongst group members. Researchers also conducted follow up interviews to determine the “stickiness” of the exhibits—the degree to which, three weeks later, students and families retained inquiry skills, curiosity, and a sense of happy engagement with the museum.

Description

Given the success of the Juicy Question and Hands Off games in the GIVE research study, the Exploratorium staff sought to find ways to incorporate their core elements into the bustling everyday life of the Museum.

Science museums are inherently social and multigenerational spaces. Most people visiting science museums only scratch the surface in terms of understanding the content of what they are viewing. When visiting, most people focus on lower level content-based questions rather than on those questions that develop higher-order thinking skills. Instead of trying to understand the science, a process that requires deeper inquiry, they tend to focus on the manipulatives in the exhibit and emphasize the "doing" over the "thinking".

Given these premises, the staff designed a project to deepen the visiting experience for both school groups and families. That is, the staff realized that by offering visitors a more guided approach to engaging the exhibits, the Museum could offer a more meaningful and longer-lasting experience. The Staff found a variety of ways to incorporate Juicy Questions into the Museum experience, for both families and field trip groups.

For families, they may offer an initial Juicy Question or interesting challenge for an interactive aspect of an exhibit, or they might just prompt families with broader "What if?" questions connected to a given exhibit. After experimenting with different ways of "advertising" the Juicy Questions game, staff realized what worked best was simply to have an "Explainer" cordon off part of an exhibit and sit inside, playing with the materials. When curious visitors and families wanted to see what was happening, the Explainer invited them to do "something fun" with the exhibit, they gathered inside the cordons, and the Explainer used one of the types of Juicy Question prompts above.

For field trips, they might introduce the game in a quiet classroom space before children enter the exhibits, or alternatively introduce it midway through the children's exploration, in small groups. With a large group, Explainers have had success using a card trick to model the Juicy Questions approach: the Explainer does a card trick, and then children call out questions/ requests that might reveal the secret behind the trick (holding the deck a different way, for example).

Evaluation

The results of the GIVE study indicate that the kind of targeted teaching of inquiry skills represented by the Juicy Questions and Hands Off games led to more integrated questions, fuller consideration of the answers they find to their questions, and more conversations about what they were learning about and wondering about.

That is, having learned even just one of the inquiry skill games, families and field trip groups came up with questions that "built on each other to create a line of investigation, rather than being lots of unrelated questions". Creating "linked investigations" led participants to interpret their results with greater frequency and in a "consecutive, collaborative" give-and-take with each other.

Conclusion

Scientific inquiry—defined by this project as "observation, exploration, hypothesizing, experimenting, creating models, arguing, explaining, making inferences"—is fundamental, not only to science, but also to developing critical thinking skills for any discipline.

The Juicy Questions game offers children and adults a richer experience at every level. At the Museum itself, they have a way to focus their attention and learning rather than being only dazzled by the range of stimuli; they generate their own questions, their own paths for finding answers to those questions, and their own results. Leaving the Museum, they carry with them not only a new understanding of, or appreciation for, a scientific concept, but also the potential for a new habit of observing the world around them and for approaching problem-solving.

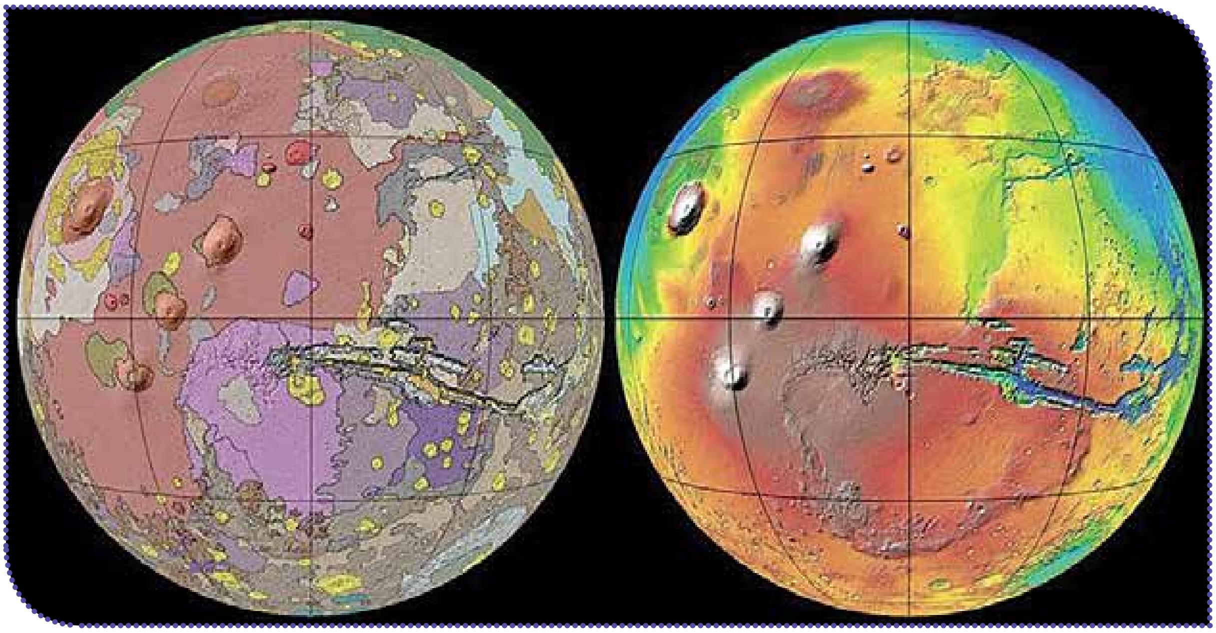
The Juicy Questions method of teaching inquiry skills offers museum-goers an efficient, rich, and powerful mode of learning the science at hand, as well as the practice of science itself.

Reference

http://www.exploratorium.edu/vre/visitor_research/give/index.html

Mars Student Imaging Project

Worldwide
Mars Education Program, Arizona State University
2002–Present



Source: NASA, Mars Exploration Program Website (2014).

Teachers in any part of the world often identify a conundrum. On the one hand, we have tremendous, stunning access to technological and scientific information; on the other, we face the daunting task of organizing rigorous, inquiry-based research for students that takes full advantage of online without diluting students' inquiry or learning. Put another way: the Internet no longer serves the purposes of science education when students perceive that the answers are too plentiful, too sophisticated, and too final.

The Mars Student Imaging Project (MSIP) offers a solution to this puzzle. MSIP offers students access to images of Mars taken by the Thermal Imaging System (THEMIS) aboard NASA's Mars Odyssey orbiter. With the guidance of scientists and educators at the Arizona State University (ASU) Mars Education Program, students use this extraordinary field of data to embark on the scientific process: observing, questioning, hypothesizing, testing, analyzing, presenting findings, and understanding implications.

Description

Founded in 2002, MSIP has served 35,000 students with on-site and distance learning opportunities to work with Mars images from NASA spacecraft orbiting the planet. MSIP offers these students, in Grade 5 through sophomore year in college, "an immersive and transformational way"[1] to learn the conventions and rigors of scientific inquiry—with genuine research questions about real, cutting-edge data.

[1] Boonstra, Sheri Klug and Christensen, Philip (February 2013). *Mars Student Imaging Project: Real Research by Secondary Students.* Issue of SCIENCE, Vol. 339. American Association for the Advancement of Science, USA, p. 920.

Students, working in teams of eight or more, begin by planning a timeline for their research with the help of online Pacing Guides. Next, they begin learning about Mars and turn to in-depth analysis of Mars images. MSIP guidelines move them from everyday observations of the images to the more sophisticated, precise study that can lead them to find patterns and anomalies. From this, students generate questions about the images, and with the help of their teachers, generate hypotheses from these questions.

The next step is to propose a research plan, to be submitted to the ASU Mars Education Program scientists, that lays out the investigation process and requests images from THEMIS that permit students to test their hypothesis. A successful proposal yields the necessary images; here, the analysis begins in earnest. Students' research culminates in a presentation at the MSIP conference (in person or virtually), where working Mars scientists discuss this work with the students. Furthermore, some student discoveries have also appeared in peer-reviewed presentations and publications.

Meanwhile, the students' teachers have access to online training for the Mars project, as well as virtual office hours. MSIP resources offer avenues for teachers to connect the project to education standards in the US and to traditional subjects such as Earth science, chemistry, and biology.

MSIP may draw students in through the inherent drama of spaceships, the Red Planet, and perhaps even the glimmer of possibility of Martian life. However, soon the students are swept up in the more particular, and no less dramatic, questions of wind streaks, dust devil tracks, collapsed lava tubes, and landslides.

An example here seems pertinent and points to the specificity and thoroughness of the online NASA materials for MSIP students and teachers. For example, to demonstrate the way that a "big picture question" becomes a hypothesis and a set of research questions, one such student guide draws on the persistent intrigue around the notion of life on Mars.

As clichéd as it is captivating, the idea of life on Mars is emphatically not one limited to science fiction; rather, MSIP teaches it as the sort of question that, if held to scientific standards of inquiry, can lead to productive research projects and even careers.

In one module, MSIP directs students to consider the question of the Valles Marineris on Mars; the "big picture" question is how the valley formed. One hypothesis is that it was formed by water, as the Grand Canyon; the corresponding research question would investigate evidence of water inside the Canyon. Another hypothesis attributes Valles Marineris to plate tectonics; the research question in this case would have to do with the presence of other evidence of plate movement on Mars. Thus, the question of life on Mars becomes one of water on Mars, which quickly becomes a specific, tangible, and researchable query.


Source: NASA, Mars Student Imaging Project Website (2014).

All the while, MSIP keeps the students' focus on what is referred to as the "evidence and claim cycle" in scientific inquiry and argument. What exactly do the students see in a particular image? What interpretive claim can they legitimately make, based on the evidence? How does the evidence support (or contradiction) such an interpretation?

As ASU Mars Education Program Director Sheri Klug Boonstra and Geological Sciences Professor and THEMIS Principal Investigator Philip Christensen state in *Science*, "MSIP participants learn that, in science, it is the evidence and defensible interpretation through discourse that will determine the answer"[2].

Evaluation

MSIP offers a valuable opportunity to students in any locale. The flexible nature of the program allows for both a school-based and individual approach, permitting an impressive scope of students reached. Furthermore, it has proved a sustainable model, as well as a program still flourishing eleven years after its inception. What stands out about MSIP are the extensive, well-crafted student and teacher materials available at each of the process, as well as the meaningful and wisely designed opportunity for students to identify and pursue their own particular research interests.

Like any distance learning model that does not provide individualized instruction, MSIP's success in a given learning community does depend on adequate resources, clear on-site structure for students, and adult guidance. Furthermore, the on-site portion of the program, while available to all students, is not accessible to most. With travel funding solely the responsibility of the student teams, on-site participation in conferences is out of reach for many participants.

Moreover, the MSIP has already proven its sustainability. It benefits from a stable online format, with instructions for students as well as teacher's guide, and a stable partnership with the ASU Mars Education Program and the Principal Investigator of the THEMIS camera. The online guidelines lack the "human mediation", but they offer worldwide accessibility to all students, regardless of their location or their financial resources. In the hands of a good teacher, the online portions of the project can offer all the richness of a guided experience in scientific inquiry.

Students participating in MSIP explore questions that astronomers have not yet answered and are working on themselves. MSIP offers its participants a chance to work with real data in real time—and rather astonishing data at that, given that it not only involves images taken by the THEMIS camera aboard NASA's Mars Odyssey orbiter but images from the orbiter that were taken at the direction of the students.

Source: NASA, Mars Student Imaging Project Website (2014).

Thus, MSIP provides a brilliant platform for scientific inquiry for a wide range of students, and its benefits for students (to date, 35,000 of them) range from the simple but crucial step of learning the scientific process to the contributions some students have made—in publications and conference presentations—to Mars research.

[2]Boonstra, Sheri Klug and Christensen, Philip (February 2013). *Mars Student Imaging Project: Real Research by Secondary Students*. Issue of SCIENCE, Vol. 339. American Association for the Advancement of Science, USA, p. 921.

Conclusion

Given a capable teacher and reliable Internet connection, students in MSIP can soon be conducting original research on the Red Planet and directing multi-million dollar machinery. More important, the budding young researchers develop the scientific and communication skills necessary for their future success. Rather than answering questions derived by others, students follow their instincts and interests. Those who are organized enough and persuasive enough soon find themselves with the pictures in hand necessary to test a genuine hypothesis and to generate new ones.

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About the Authors

Ingit Mukhopadhyay

Ingit Kumar Mukhopadhyay is engaged in popularizing science in India since 1978. He took over as the Director-General of the National Council of Science Museums (NCSM), India, in 1997. During his leadership in NCSM, a large network of science centers and museums has been developed in India. Mr. Mukhopadhyay has developed numerous exhibits and educational programs for science centers in India and abroad. For his contribution to the field of science communication, he has received the prestigious Roy Shafer Experienced Leadership Award from the Association of Science and Technology Centers (ASTC), USA, in 2008. He served as a member of the International Advisory Board of ASTC, and the Program Committee of the Science Centre World Congress. Following retirement from the service of NCSM in 2009, he is currently offering consultancy services in the science center field.

Per-Edvin Persson

Professor Dr. Per-Edvin Persson, is former Director of the Federation of Finnish Scientific Societies (1983–1987); Director of Science at Heureka, the Finnish Science Centre (1987–1991); and Director of Heureka (1991–2013). Prof. Persson is former President of the Nordic Science Centre Association (1987–1991); President of the European Science Centre network ECSITE, Brussels (1997–1998); and President of the International Branch Organization Association of Science-Technology Centers (ASTC), based in Washington, D.C. (2004/2005). He served on the ECSITE Board 1991–2001, and again 2007–2013. He served on the ASTC Board (1993–2007); Chairman of the First Science Centre World Congress in Finland (1996); and the Program Committee of subsequent World Congresses. Under his leadership, Heureka, the Finnish Science Centre developed into a science center of international renown. Prof. Persson is ASTC Fellow for Outstanding Contribution, Ecsite Honorary Member and Recipient of the ASPAC President's Award.

Simeon Brodsky

Simeon Brodsky heads Center for Talented Youth (CTY) International, a unit of Johns Hopkins University dedicated to identifying and developing bright young people throughout the world, and to connecting students and practitioners to their global peers. As Director, Simeon draws on his background in University-level teaching and 25 years' experience in gifted education; to date he has worked with over 15 countries to enhance learning opportunities for bright students. Prior to heading CTY International, he led efforts in program development, research, and evaluation for CTY's summer programs in the USA; he also supervised multiple residential programs in the USA, developed programs in China and Spain, directed a CTY program in Nanjing, and collaborated with Northwestern University to co-found CTY's Civic Leadership Institute. Simeon's more recent work includes training teachers and providing technical assistance in Kazakhstan, launching programs in Egypt, Greece, Kuwait and Malaysia; consulting in Saudi Arabia, and opening CTY's office in Hong Kong.

The Planetarium Science Center

The Planetarium Science Center (PSC) is an affiliate center of the Bibliotheca Alexandrina. It is a not-for-profit edutainment center dedicated to increasing the public's understanding and appreciation of science, mathematics, and technology through scientific activities, shows and interactive exhibits. It is considered one of the leading Egyptian informal education organizations and has implemented multiple projects in the field of informal science education, thus supporting the education reform initiatives in Egypt.

About the Bibliotheca Alexandrina

The New Library of Alexandria, the Bibliotheca Alexandrina (BA) is dedicated to recapture the spirit of openness and scholarship of the Ancient Bibliotheca Alexandrina. The BA is much more than a library, as it contains:

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- Four Museums for (i) Antiquities, (ii) Manuscripts, (iii) Sadat, and (iv) the History of Science
- Planetarium
- An Exploratorium for children's exposure to science (ALEXploratorium)
- Culturama: A cultural panorama over nine screens, the first ever patented 9-projector interactive system. Winner of numerous awards, the Culturama, developed by CultNat, allows the presentation of a wealth of data layers, where the presenter can click on an item and move to a new level of detail. It is a remarkably informative and attractive multimedia presentation of Egypt's heritage across 5000 years of history to these modern times, with highlights and examples of Ancient Egyptian and Coptic/Muslim heritage.
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- Ten academic research centers: (i) Alexandria and Mediterranean Research Center (Alex Med), (ii) Arts Center, (iii) Calligraphy Center, (iv) Center for Special Studies and Programs (CSSP), (v) International School for Information Science (ISIS), (vi) Manuscript Center, (vii) Center for the Documentation of Cultural and Natural Heritage (CultNat, located in Cairo), (viii) Alexandria Center for Hellenistic Studies, (ix) Center for Democracy and Social Peace Studies (CDSPS) and (x) Center for Development Studies.
- Fifteen permanent exhibitions (i) Impressions of Alexandria: The Awad Collection, (ii) The World of Shadi Abdel Salam, (iii) Arabic Calligraphy, (iv) The History of Egyptian Printing, (v) The Artist's Book, (vi) Arab–Muslim Medieval Instruments of Astronomy and Science, (vii) Mohie El Din Hussein: A Creative Journey, (viii) Raaya Al-Nimr and Abdel-Ghani Aboul Einein, (ix) Seif and Adham Wanly: Motion and Art, (x) Selected Artworks of Adam Henin, (xi) Selected Artworks of Ahmed Abdel–Wahab, (xii) Selected Artworks of Hamed Saeed, (xiii) Selected Artworks of Hassan Soliman, (xiv) Permanent Sculpture, and (xv) My Digital World.

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• A Conference Center for thousands of persons.

The BA is an Egyptian Institution of international character. It is devoted to the promotion of enlightened values, good governance, and sustainable development in Egypt and the Arab world, as well as elsewhere in the world. It is governed by an international Board of Trustees, and is not part of the Egyptian Government. It was established in October 2002 by a special law (Law No. 1 for 2001) that attaches it to the Head of State.

The BA receives more than 1.5 million visitors per year, and its website receives around one million hits per day. In addition, the BA holds about 700 events and organizes over 300 Arts School classes annually. The BA employs around 2,226 staff, of whom 50.4% are females (not counting security and custodial level staff), and 74% less than 35 years of age.

About The Islamic Development Bank

The Islamic Development Bank (IDB) is an international Institution established in December 1973. It started its operations in October 1975. The IDB's **vision** is that, by the year 2020, it shall have become a world-class development bank, inspired by Islamic principles, that has helped significantly transform the landscape of comprehensive human development in the Muslim world and helped restore its dignity. Its **mission** is to promote comprehensive human development, with a focus on the priority areas of alleviating poverty, improving health, promotion education, improving governance and prospering the people. IDB **financial yea**r is the lunar Hijra year (H) and its **accounting unit** is the Islamic Dinar (ID), which is equivalent to one Special Drawing Right (SDR).

IDB's **membership** rose from 22 countries at inception to 56 countries currently. Its authorized **capital** is ID 30 billion, and its subscribed capital is close to ID 18 billion. Out of this amount, 4.6 billion was paid up as at end 1433 AH (2012). The main shareholders are Saudi Arabia (24%), Libya (9%) Iran (8.5%), Kuwait (7.2%), Egypt (7.2%), UAE (7.15%), Qatar (7%), Turkey (6.6%) and Nigeria (5.5%). In May 2013, the Board of Governors of the Bank, decided to raise the authorized capital to ID 100 billion (about USD 150 billion) and the subscribed capital to ID 50 billion (about USD 75 billion).

IDB Group comprises five entities: Islamic Development Bank (IDB), Islamic Research and Training Institute (IRTI), Islamic Corporation for the Development of the Private Sector (ICD), Islamic Corporation for the Insurance of Investment and Export Credit (ICIEC), and International Islamic Trade Finance Corporation (ITFC). In addition, the IDB has various specialized funds and programs: Islamic Solidarity Fund for Development, Waqf Fund, Awqaf Properties Investment Fund, World Waqf Foundation, IDB Infrastructure Fund, Special Assistance Program, and Scholarship Program. It manages the Saudi Arabian Project for the utilization of Hajj Meat.

The Board of Governors is composed of the 56 Member States (Ministerial level) and meets once a year. The Board of Executive Directors meets seven times a year, and is composed of representatives of the nine major shareholders and of nine groups of other countries. The President of the Bank chairs the Board of Executive Directors and the boards of the Group Entities. As at end of 2012, the IDB Group had 1128 staff.

IDB is headquartered in Jeddah (Kingdom of Saudi Arabia) and has four Regional Offices in Rabat (Morocco), Kuala Lumpur (Malaysia), Almaty (Kazakhstan) and Dakar (Senegal). Country offices were opened in Turkey and Indonesia, and will soon be opened in Bangladesh, Egypt, and Nigeria.

IDB Group is engaged in a wide range of activities including: project financing in public and private sectors (using various modes such as loan, leasing, istisna'a, installment sale, equity participation, lines of financing), technical assistance (capacity building; project preparation), economic cooperation among Member States, trade financing, insurance and reinsurance coverage for investment and export credit, research and training programs in Islamic economics and banking, Awqaf Investment and financing, special assistance (health and education) for Muslim communities in non-member countries, scholarships, emergency relief, advisory services for public and private entities.

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