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roots

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Inquiry-Based Science Education

Panacea or passing fad – how good is IBSE?

Objects and questions: along avenues to learning

Teacher in the mirror – reflecting on practice and change

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First word

IBSE: a journey to the heart of learning

ENGLISH

There's nothing new about inquiry-based learning; its theoretical antecedents can be traced, for example, to the work on open learning by Dewey and Wagenschein from the first half of the last century. And were we to scroll back a couple of millennia, we'd probably find that the idea of encouraging students towards questioning self-knowledge would earn a nod of recognition from Socrates himself!

Inquiry-based learning is undoubtedly a robust and tenacious model and has come into its own again as evidence emerges, notably in the European Union, of a worrying decline in interest in science and scientific careers among young people. How to arrest and reverse this trend has preoccupied many involved in science education in the EU and culminated in the landmark Rocard report of 2007. This recognised the enormous potential of inquiry-based science education, IBSE, and triggered a number of pan-European initiatives, of which the BGCI-supported INQUIRE project, described below, is one.

In our latest edition of Roots we have invited authors from Europe and Asia to guide us across the current ISBE landscape. Where better, then, than to start with INQUIRE project member, Professor Justin Dillon from King's College London, who describes IBSE as the *zeitgeist* of European science education. In his article, Justin examines the history of IBSE and explores the question whether, in fact, inquiry-based approaches add anything new to solving the intractable problem of turning children on to science.

FRANÇAIS

Rien de neuf concernant l'apprentissage par la démarche d'investigation. Sur le plan théorique on retrouve ses traces, par exemple, dans les travaux de Dewey et Wagenschein sur l'apprentissage ouvert datant du début du siècle dernier. Et si nous retournions deux mille ans en arrière, nous constaterions certainement que l'idée d'encourager les étudiants à questionner les « autoconnaissances » recevrait une approbation de la part de Socrate en personne !

L'apprentissage par la démarche d'investigation constitue assurément un modèle solide et fiable, dont la reconnaissance s'est réaffirmée à travers l'émergence d'une perte d'intérêt inquiétante parmi les jeunes générations, notamment dans l'Union européenne, pour les sciences et les carrières scientifiques. La manière de stopper et d'inverser cette tendance a fait l'objet de nombreuses préoccupations pour les personnes impliquées dans le domaine de l'éducation scientifique au sein de l'UE, et s'est imposée dans le rapport Rocard de 2007 qui a été déterminant. Par ce biais, l'immense potentiel de la démarche d'investigation dans l'enseignement des sciences (DIES) a été reconnu et nombre d'initiatives paneuropéennes ont été engagées, parmi lesquelles le projet INQUIRE, décrit ci-dessous, soutenu par le BGCI.

Dans notre dernière publication de Roots, nous avons invité des auteurs d'Europe et d'Asie à nous guider à travers le paysage actuel de la DIES. Démarrage en force avec le Professeur Justin Dillon du King's College de Londres, membre du projet INQUIRE et membre du comité scientifique du projet Fibonacci, qui décrit la DIES

ESPAÑOL

No hay nada nuevo acerca del aprendizaje basado en preguntas; su teoría ancestral puede rastrearse, por ejemplo, al trabajo de aprendizaje abierto de Dewey y Wagenschein en la primera mitad del siglo pasado. Y si viéramos hacia atrás algunos milenios mas, probablemente encontraríamos que la idea de motivar a los alumnos a cuestionar su propio conocimiento, ¡era algo apoyado por el mismo Sócrates!

El aprendizaje basado en preguntas es sin lugar a dudas un modelo tenaz y robusto que se ha ido validando por sí mismo a medida que aparece evidencia, notablemente en la Unión Europea, de una preocupante falta de interés hacia las ciencias y carreras científicas entre los jóvenes. Cómo detener y revertir esta tendencia ha preocupado a varios de los educadores de ciencias en la UE y culminado en el reporte Rocard en 2007. Este reconoció el enorme potencial del aprendizaje de las ciencias basado en preguntas, IBSE (por sus siglas en inglés), y desencadenó una serie de iniciativas pan-europeas, una de las cuales es el proyecto INQUIRE apoyado por BGCI que se describe a continuación.

En nuestra más reciente edición de Roots hemos invitado a autores de Europa y Asia a guiarnos a través del panorama actual del ISBE. Y que mejor comienzo que con un miembro del proyecto INQUIRE y miembro del comité científico del proyecto Fibonacci; el Profesor Justin Dillon del King's College en Londres, el cual describe el IBSE como el 'zeitgeist' de la educación de las ciencias europea. En este artículo, Justin examina la historia del IBSE y

There are many approaches to inquiry-based science education – here young children share their observations of pollination (Sofia Botanic Garden, Bulgaria)

Professor Wynne Harlen, from the Fibonacci Project Scientific Committee, offers an insight into the challenges of spreading IBSE and IBME (mathematics education) throughout Europe. The ambitious three-year, EU-funded, Fibonacci Project was launched in January 2010 and Wynne outlines progress after two years of intensive training and tutoring. One encouraging outcome from the evaluations has been the effectiveness of spreading good practice through direct contact between staff working across the project.

In a change of pace, Ljuba Pencheva from the Sofia University Botanic Gardens, describes how the Bulgarian strand of the INQUIRE project has worked on developing the capacity among teachers and educators for experiential self-analysis and reflection on practice to enhance their IBSE expertise. It has sometimes been an uphill struggle, calling for sensitive modifications along the way by the project team.

From Seoul National University, Junehee Yoo and colleagues provide a South Korean perspective into an inquiry-based professional development programme for science teachers. Following a recent national curriculum review that highlighted the importance of creativity, evidence-based reasoning and communication in science education, the SNU team developed and ran its professional development programme in 2011-12.

Inquiry-based learning is not a single educational method, writes Emily Dutton, of the Horniman Museum and Gardens and University of Cambridge, comme étant la méthode d'enseignement scientifique européen dans l'air du temps. Dans son article, Justin analyse l'histoire de la DIES et examine si les approches basées sur l'investigation proposent en fait de nouveaux éléments quant à la résolution du problème difficile qui consiste à susciter l'intérêt des enfants pour les sciences.

Le Professeur Wynne Harlen, qui fait également partie du comité scientifique du projet Fibonacci, expose un aperçu des difficultés relatives à l'expansion de la DIES et de la DIEM (enseignement des mathématiques) à travers l'Europe. L'ambitieux projet Fibonacci d'une durée de trois ans, financé par l'UE, a démarré en janvier 2010 ; Wynne décrit les avancées après deux ans de formation intensive et de tutorat. Un résultat encourageant issu des évaluations correspond à l'efficacité de transmission des bonnes pratiques par contact direct entre les membres travaillant sur le projet.

À un rythme différent, Ljuba Pencheva des Jardins botaniques de l'université de Sofia décrit comment l'axe bulgare du projet INQUIRE a travaillé au développement des capacités des enseignants et des éducateurs en vue d'une auto-analyse basée sur l'expérience et d'une réflexion sur la pratique afin d'améliorer leurs compétences en matière de DIES. Cette démarche a parfois été difficile, et a engendré des modifications sensibles de la part de l'équipe du projet tout au long du processus.

Junehee Yoo et ses collègues de l'Université nationale de Séoul proposent une perspective sud-coréenne d'un programme de développement professionnel basé sur l'investigation destiné aux enseignants scientifiques. Suite à une récente révision des programmes nationaux qui a souligné l'importance de la créativité, du raisonnement basé sur les faits et de la communication dans l'enseignement des sciences, l'équipe de l'UNS a mis en place et mené son programme de développement professionnel en 2011-12.

La DIES n'est pas une simple méthode éducative, écrit Emily Dutton du musée et des jardins Horniman, également partenaire de PATHWAY, un autre projet financé par l'UE. Il s'agit plutôt d'une approche évolutive d'éducation qui incite à d'importants débats théoriques autour de ce qui constitue une activité d'investigation

explora la pregunta sobre si en realidad el aprendizaje basado en preguntas agrega algo nuevo para resolver el problema de falta de interés de los niños hacia las ciencias.

El Profesor Wynne Harlen, también del comité científico del proyecto Fibonacci, nos ofrece una mirada al interior del reto de difundir el IBSE y el IBME (aprendizaje de matemáticas) a lo largo de Europa. El proyecto Fibonacci, un ambicioso proyecto de tres años, financiado por la UE, fue iniciado en Enero del 2010 y Wynne remarca el progreso que se ha tenido después de dos años de intensos entrenamientos y capacitaciones. Un resultado alentador mostrado en las evaluaciones ha sido el efectivo esparcimiento de buenas prácticas a través del contacto directo entre los trabajadores del proyecto.

Por otro lado, Ljuba Pencheva del Jardín Botánico de la Universidad Sofía describe como la sección búlgara del proyecto INQUIRE ha trabajado en desarrollar la capacidad entre los maestros y educadores de una experiencia de autoanálisis y refección sobre las prácticas para aumentar el conocimiento del IBSE. En ocasiones ha sido una lucha cuesta arriba, requiriendo sensibles modificaciones a lo largo del camino por parte del equipo.

Junehee Yoo y sus colegas de la Universidad Nacional de Seoul brindan la perspectiva de Corea del Sur acerca de un programa para el desarrollo profesional del aprendizaje basado en preguntas. Siguiendo una revisión reciente del curriculum nacional que marcó la importancia de la creatividad, el razonamiento basado en evidencia y la comunicación en la educación de las ciencias, el equipo de la Universidad de Seuol creó y lanzó su programa para el desarrollo en 2011-12.

El IBSE no es simplemente un método de educación, afirma Emily Dutton, del Museo y Jardines Horniman el cual es parte de PATHWAY, otro proyecto financiado por la UE. Es una estrategia evolucionada de educación que está estimulando un considerable debate teorético sobre qué se considera una actividad efectiva de cuestionamiento en las escuelas y otros lugares. Emily habla desde su propia experiencia de aprendizaje basado en objetos, algo

UK. It is instead an evolving educational approach that's stimulating considerable theoretical debate around what constitutes effective inquiry activity in schools and elsewhere. Emily draws on her own experience of object-based learning, commonplace in museums, to illustrate how objects can stimulate questions that in turn lead down 'avenues of inquiry'.

The European INQUIRE Project's ethos is to foster 'inquiry-based teacher training for a sustainable future'. Three of its architects, Suzanne Kapelari, from Innsbruck University Botanic Garden and BGCI colleagues Asimina Vergou and Julia Willison, argue here that modern botanic garden education reaches beyond educational programmes for pupils and visitors to embrace training and support for the teachers and educators themselves. INQUIRE's course participants are encouraged to investigate a range of approaches to IBSE, sharing knowledge, experience and perspectives from their own individual and organisational backgrounds.

The Royal Botanic Gardens, Kew, is a key partner in INQUIRE. Kew's Gail Bromley explores the cultural shift that IBSE requires botanic gardens to make, as they move away from the traditional information-led models towards the student-directed inquiry approach. As Gail suggests, this is not something that comes easily to educators and some visiting teachers certainly find their preconceptions are tested! Overall, however, IBSE generates good learning outcomes and real student involvement.

Over the years, Roots has addressed many, if not most, of the key issues that engage our botanic garden education community. Nevertheless we would have no hesitation in arguing that this latest edition is among the most important we have ever published. For it goes to the very heart of what it means to be a botanic garden educator in these times of global environmental crisis, exposing our assumptions and practices to the disinterested gaze of a generation that is turning away from the science on which this planet's future depends.

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efficace à l'intérieur et hors du cadre scolaire. Emily s'appuie sur sa propre expérience d'apprentissage à partir d'objets, démarche courante dans les musées, afin d'illustrer la manière dont les objets peuvent stimuler les questions qui à leur tour mènent sur les 'chemins de l'investigation'.

La philosophie du projet INQUIRE consiste à promouvoir des Communautés basées sur une méthode d'investigation parmi les enseignants et les éducateurs. Trois architectes du projet, Suzanne Kapelari du Jardin botanique de l'université d'Innsbruck, Asimina Vergou et Julia Willison, collègues du BGCI, argumentent dans cet article que l'éducation moderne dans les jardins botaniques a une portée bien plus vaste que les programmes d'éducation destinés aux scolaires et aux visiteurs, pour inclure la formation et le soutien aux enseignants et aux éducateurs eux-mêmes. Les participants à la formation INQUIRE sont encouragés à explorer différentes approches de la DIES, tout en partageant les connaissances, les expériences et les perspectives à partir de leur propre contexte individuel et organisationnel.

Les Jardins botaniques royaux de Kew sont un partenaire clé du projet INQUIRE. Gail Bromley de Kew s'intéresse au changement culturel que la DIES requiert de la part des jardins botaniques, alors que ceux-ci s'éloignent des modèles traditionnels dont l'approche informative prédomine pour se diriger vers une approche basée sur l'investigation menée par les étudiants. Comme le suggère Gail, il s'agit d'une démarche difficilement adoptée par les éducateurs ; certains enseignants en visite en voient assurément leurs idées préconçues mises à l'épreuve ! Dans l'ensemble, la DIES produit toutefois de bons résultats d'apprentissage et une véritable implication de la part des étudiants.

Au fil des années, Roots a abordé bon nombre, voire la plupart, des thématiques clés qui engagent notre communauté éducative de jardins botaniques. Néanmoins, nous n'aurions aucune hésitation à soutenir que cette dernière édition est l'une des plus importantes que nous ayons jamais publiées. Elle s'engage au cœur de ce que cela signifie d'être un éducateur de jardin botanique en ces temps de crise environnementale mondiale, tout en exposant nos idées et nos pratiques au regard désintéressé d'une génération qui s'éloigne des sciences alors que leur rôle est crucial dans la réalisation d'un avenir durable.

común en los museos, para ilustrar como los objetos pueden estimular preguntas que después lleven a un camino de cuestionamiento.

La filosofía del proyecto INQUIRE es la de promover comunidades de cuestionamiento entre maestros y educadores. Tres de los arquitectos del proyecto, Suzanne Kapelari, del Jardín Botánico de la Universidad de Innsbruck, y Asimina Vergou y Julia Willison colegas en BGCI, argumentan que la educación moderna en los jardines botánicos va mas allá de los programas de educación para niños y visitantes y se enfoca también a la capacitación y apoyo para los maestros y educadores. Los participantes de INQUIRE son motivados a investigar diferentes métodos de acercamiento al IBSE, compartir conocimientos, experiencias y perspectivas desde sus propios contextos o los de sus empresas.

El Jardín Botánico Real de Kew, es un socio clave para INQUIRE. Gail Bromley de Kew explora los cambios culturales que el IBSE requiere que los jardines botánicos realicen, a medida que se alejan de los modelos tradicionales de información y se acercan a una estrategia de cuestionamiento por parte de los alumnos. Como sugiere Gail, esto no es algo que se de fácilmente entre los educadores, y varios de los maestros que visitan el Jardín, ¡se descubren cuestionando sus preconcepciones! Sin embargo, en general, el IBSE genera buenos resultados de aprendizaje y una participación real de los alumnos.

A lo largo de los años, Roots se ha enfocado a varios, si no es que todos, los temas que conciernen a nuestra comunidad de educadores de jardines botánicos. Sin embargo no tendríamos ninguna duda en argumentar que esta última publicación está dentro de las más importantes que hemos realizado. Ya que va directamente al núcleo de lo que significa ser un educador de jardines botánicos en estos tiempos de crisis ambiental, exponiendo nuestras prácticas a una generación desinteresada la cual está alejándose de las ciencias, quienes juegan un rol crucial para lograr un futuro sostenible.

Panacea or passing fad – how good is IBSE?

Inquiry-based science education (IBSE) is the *zeitgeist* of European science education, attracting funding worth millions of Euros. But does it actually offer anything new? Drawing on his experience with two of Europe's largest science education initiatives, **Justin Dillon** explores the history and current state of IBSE and examines its potential for botanic gardens.

Learning the concept of classification through hands-on inquiry activities at the School Biology Centre in Hannover, Germany (Schulbiologisches Zentrum, Hannover, Germany)

How different is IBSE from the process-based approaches that dominated school science in the 1980s? We need to take a look at the history of IBSE and examine whether it offers anything new. To what extent is it possible for schoolchildren to learn science through inquiry-based approaches? How similar are these approaches to how scientists work? Across Europe, from Belgium to Bulgaria, teachers and botanic garden educators have been finding out what inquiry-based science education is all about as part of a three-year project called INQUIRE. It focuses on biodiversity and climate change and is funded by the European Union. It's one of a number of initiatives aimed at improving science education across the continent.

Just to give some indication of the scale of investment, the European Union's 'Science in Society' programme has a budget of 330m euros and while only a fraction of that is spent on IBSE, the cost of the Fibonacci project, which was tasked with disseminating successful teaching approaches, was over 5 million euros, while INQUIRE itself received more than 2 million euros from the EU. Someone, somewhere, thinks scientific inquiry is the future of science education and around 67 million euros is expected to have been invested in disseminating IBSE approaches between 2010 and 2016.

That level of EU funding reflects concerns about the quality of science and mathematics education expressed by policy-makers, industry, parents and teachers for at least two decades past. In 1995, German students' poor performance in TIMSS, the international comparison of standards in mathematics and science education, raised eyebrows, but their performance in another international comparison, PISA, five years later was widely reported in the media and became a topic of national concern. In France, leading scientists railed against the poor quality science teaching they saw in schools. In both countries substantial investment was put into improving science and mathematics education.

Midway through the first decade of this century, an expert group under the leadership of Michel Rocard, former prime minister of France and member of the European Parliament, was set up to reflect on which initiatives seemed to be working in terms of raising science attainment. Rocard's group published *Science Education NOW: A Renewed Pedagogy for the Future of Europe* (2007) in the year before France assumed the EU presidency. The report concludes with an appeal to promote

inquiry-based science teaching and learning as a basis for improving the way science is taught in schools. In particular, Rocard's team identified two initiatives which seemed to be working well – the French Pollen project (www.pollen-europa.net) and the German German SINUS-Transfer (http://sinus-transfer.eu). France's presidency meant that science education became a fundamental concern of the EU.

The Pollen project was launched in 2006 and involved primary school students developing inquiry-based skills. Pollen had been spread to 12 seed cities throughout Europe with some success, suggesting that IBSE was transferable to other nations' education systems. SINUS-Transfer was aimed at secondary-school students. Based on the reported success of these two initiatives, the Rocard report concluded that a 'reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods' was more likely to increase 'children's and students' interest and attainment levels while at the same time stimulating teacher motivation' (p.2).

What 'inquiry-based' means

The traditional science education which had proved so unpopular (the 2005 Eurobarometer study *Europeans, Science and Technology* found that only 15 per cent of Europeans were satisfied with the quality of science classes in school) usually involved a good deal of transmission of conceptually difficult material to often uncomprehending students. The alternative, sometimes called the inductive approach, involved much more 'hands and minds-on' to develop both knowledge and scientific skills. Rocard invoked the notion of inquiry as, 'the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn, Davis and Bell, 2004)' (p.9).

While this approach might have been novel in some countries in continental Europe, teachers in the US and the UK had been using inquiry-based techniques for many years. Indeed,

Botanic gardens offer opportunities for students to see real science in action – for example here at the Millennium Seed Bank in Wakehurst Place, Royal Botanic Gardens, Kew (Royal Botanic Gardens, Kew)

when I was teaching in secondary schools in London in the 1990s the pendulum had swung too far towards the teaching of scientific processes to the neglect of the science content. The point of using investigations in science is to learn not just how to do science but to develop an understanding of science concepts. At the same time, students may develop a greater appreciation of how scientists build knowledge about the everyday world and beyond.

Scientists work in a number of ways – cosmologists are very different from tropical ecologists, for example. They use different skills and equipment. The idea that there is one scientific method is rather outdated and it follows that there isn't one way of doing IBSE. Early attempts to use the IBSE approach often centred too much on carrying out complete investigations, focusing on controlling variables and getting bogged down in an obsession with fair tests. Today the inquiry approach encompasses a number of teaching techniques including analysing data, modelling scientific processes and developing scientific models. At its best, IBSE is an enabling pedagogy rather than a narrow dogma.

Traditionally, though, it has been thought easier to devise scientific inquiries to teach the physical sciences than the life sciences. One of the challenges faced by botanic garden educators is to come up with activities that can be carried out during short visits of around three hours. The skill is not to be too ambitious and some elegant inquiry-based approaches have emerged. One such comes from Kew Gardens. In the 'Kew Plant Conservationists' role-play activity students find ten plants within the Palm House and discover why each plant is important, both biologically and to humans. The students are then told there is only enough funding to conserve six of the plants and they must decide which ones to save. The students have to come to a consensus based on their knowledge and their personal values. This is an engaging activity which requires developing an understanding of some plant science, as well as helping to develop the ability to evaluate options and then to justify the resulting decisions to other people. These are the sort of skills that employers want to see being taught, rather than those which have tended to form the staple diet of school science education.

Through projects such as INQUIRE the number of tried and tested activities has continued to grow and many are available online (see for example, www.plantscafe.net/en/home.htm). While many are aimed at younger children, an increasing number can be used by (or adapted for) older students. A number of recent EU-funded projects are looking at the assessment of inquiry-based approaches. Tools and

techniques should emerge in the next few years to improve the ways in which we assess students' inquiry skills. One of the exciting aspects of these IBSE initiatives is that many of them involve collaborations between teachers and botanic garden educators.

Does it work?

Is IBSE a fad – a bandwagon which people have jumped onto without really understanding what is involved? The answer is partly yes, although the Rocard report is unequivocal in asserting that IBSE works:

Inquiry-based science education (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainments levels while at the same time stimulating teacher motivation. IBSE is effective with all kinds of students from the weakest to the most able and is fully compatible with the ambition of excellence. Moreover IBSE is beneficial to promoting girls' interest and participation in science activities.

Such certainty should ring alarm bells. The idea that girls and boys have different interests, for example, is somewhat simplistic – there are some differences but the truth is that they have a lot of overlapping interests. The idea that IBSE promotes girls' interest and participation depends on the topics and the particular students involved. The thing to bear in mind is that like all teaching approaches, IBSE can be done well or badly.

In the largest evaluation of the potential of inquiry-based approaches, Minner *et al*. (2010) found that only 51 per cent of the 138 studies showed positive impacts of some level of inquiry instruction on students' content learning and retention. They commented that in '101 studies of student science conceptual understanding, we found that there was no statistically significant association between amount of inquiry saturation and increased student science conceptual learning' (p.493). The evidence, then, suggests that we need to consider very carefully how to make IBSE approaches work well. In that context, Minner *et al*. make some comments: 'the amount of active thinking, and emphasis on drawing conclusions from data, were in some instances significant predictors of the increased likelihood of student understanding of science content' (p.493). So, activities such as the example from Kew Gardens mentioned above, which focus on collecting and synthesizing information and coming up with a conclusion, may work better than those activities where the focus is solely on collecting data.

A number of botanic gardens have developed effective resources for IBSE which have been tried and tested. Students participating in the 'Kew Plant conservationists' must decide which plant species to save. (Royal Botanic Gardens, Kew)

Misunderstandings

In terms of advice to botanic garden educators, perhaps the most important thing is that because inquiry-based approaches have now been around for many years we do know what does and doesn't work – at least, we do in school science and some of these lessons can be transferred to out-of-school settings. The second thing to bear in mind is that over the years a number of misconceptions about IBSE have emerged. Like many wrong ideas they can be quite resistant, so it is worth rehearsing what we know.

Myth 1. IBSE must include hands-on activities

Many scientists don't use experiments in their day-to-day work. It is possible to build scientific knowledge by looking for patterns in data such as the distribution of plant species or the flowering times of plants. IBSE can involve the analysis and manipulation of data using computers and does not need to be hands-on. What does count is that any activity must be 'minds-on'.

Myth 2. Taking part in IBSE is like 'being a scientist'

It is probably more accurate to say that taking part in IBSE can help students to develop their science skills. Being a scientist involves many other things, including reading the scientific literature, seeking funding, developing a team and working over an extended period of time.

Myth 3. Teachers can't tell students anything during IBSE

Some years ago a number of science educators appeared to advocate an extreme form of IBSE in which teachers could only ask questions to encourage students to carry out their inquiries. This approach did not work and frustrated teachers and students alike. The secret of successful IBSE is balancing the students' need for information and their need to be left alone to work things out in their groups. Giving students information is fine; giving them too much information is not.

Myth 4. IBSE is better than other teaching strategies

The evidence for the effectiveness of IBSE is somewhat contradictory. In some cases students learn more effectively

when teachers use IBSE, but sometimes other teaching approaches can be just as successful. A good demonstration can be a powerful way of teaching students a new technique.

Myth 5. Students prefer IBSE over other methods

Not all students like IBSE methods. The evidence from research is that students tend to enjoy a mix of activities and can be bored if teachers use only one approach. Sometimes students need to be motivated to engage with IBSE methods.

Myth 6. It's difficult to assess IBSE

A range of assessment strategies for IBSE have been tried and tested and more are on the way. They include strategies for assessing the quality of discussions that students have with each other, the quality of students' planning and carrying out of inquiries, and the level of presentation skills that students show when talking about their results. There is no 'right way' to assess IBSE.

Myth 7. Teachers and other educators can be trained to use IBSE quickly

Some people find IBSE difficult to implement. If you have a narrow view of the nature of science you may find it hard to use IBSE methods. Age is not an issue – what counts more is the commitment to exploring new ways to teach science and a willingness to try out different approaches.

In conclusion, IBSE offers an opportunity for botanic gardens to work together, with a shared focus on improving student attainment and motivation. A number of botanic gardens have developed effective resources for IBSE which have been tried and tested. IBSE is not a panacea for the ills of science education but used well it could lead to better quality science engagement in out-of-school settings.

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RÉSUMÉ

Un fantôme hante l'Europe: c'est le spectre de l'investigation. De manière plus précise, la démarche d'investigation dans l'enseignement des sciences (DIES) correspond à la méthode d'enseignement scientifique européen dans l'air du temps. Des millions d'euros ont été investis dans de nombreux projets paneuropéens visant à diffuser ce que certains décideurs considèrent comme une panacée pour combattre l'ennui pendant les cours de sciences. Toutefois, en quoi consiste la DIES, et quelles sont les preuves de son efficacité? Quelles différences y a-t-il entre la DIES et les approches basées sur les processus qui ont dominé les sciences à l'école au cours des années 80? En s'appuyant sur l'expérience acquise lors de la participation à «Inquire», qui s'attache à développer la DIES par l'éducation dans les jardins botaniques, et à Fibonacci, le plus grand projet de diffusion valorisant la DIES, cet article analyse l'histoire de la DIES et examine si celle-ci propose de nouveaux éléments. Dans quelle mesure est-il possible pour les scolaires d'apprendre les sciences par une approche basée sur l'investigation? Ces approches sont-elles similaires à la façon dont les scientifiques travaillent? Faut-il favoriser la DIES ou l'abandonner?

RESUMEN

Un fantasma recorre Europa, es el fantasma de la investigación. Para ser más concretos, la educación de las Ciencias Basada en la Indagación (ECBI), es el zeitgeist de la educación científica europea. Millones de Euros han sido invertidos en numerosos proyectos Pan-Continentales destinados a la difusión de lo que algunos responsables políticos ven como la panacea para la cura del tedio en las clases de ciencias. Pero, ¿qué es ECBI y que pruebas existen de que esto funciona?, ¿Cuán diferente es ECBI de los enfoques basados en los procesos, que dominaban la ciencia escolar en los años 80? Basándonos en la experiencia obtenida por la participación en INQUIRE (el cual introduce la ECBI en los programas educativos en los Jardines Botánicos) y en el proyecto Fibonacci (el proyecto más grande de difusión Europeo para fomentar la ECBI), este documento examina la historia de la ECBI y analiza si ofrece algo nuevo. ¿Hasta qué punto es posible para los estudiantes aprender ciencias a través de planteamientos basados en la indagación? ¿Cómo de similares son estos planteamientos a los planteamientos que los científicos usan? ¿Debemos elogiar la ECBI o debemos enterrarla?

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The Rocard report in 2007 called for inquiry-based science teaching and learning to be promoted as a basis to improve the way science is taught in school

La secuencia de Fibonacci: multiplicando la capacitación de maestros en el IBSE a través de Europa
La suite de Fibonacci : multiplier les formations sur la DIES pour les enseignants à travers l'Europe

The Fibonacci sequence

multiplying IBSE teacher training across Europe

Wynne Harlen introduces the Fibonacci Project, a European Union programme launched in 2010 to reverse the decline among young Europeans of an interest in science and mathematics and also encourage the take-up of scientific careers. The promotion of inquiry-based science and maths education in primary and secondary schools is fundamental to Fibonacci's development of teacher training centres around Europe.

The Fibonacci project is involved with the dissemination of inquiry-based science education (IBSE) and inquiry-based mathematics (IBME) to primary and secondary schools in countries across Europe. It is funded under the European Commission's 7th Framework Programme. It follows two earlier projects concerned with developing and extending practice in inquiry-based science and mathematics in Europe. The science project was called Pollen and involved a consortium of 12 European countries, coordinated by the *La main à la pâte* (similar to English 'lending a hand') project in France. The mathematics project, known as SINUS-transfer, spread IBSE and IBME across the German regional states. From these two schemes 12 centres (either universities or teacher-training institutions involved in teachers' professional development) were selected as 'reference centres' for Fibonacci. Centres were chosen on the basis that they already had a well-developed practice in inquiry-based education and were engaged in supporting and training teachers in local schools and neighbouring institutions for continuing professional development (CPD). The aim was to roll out this practice to other EU States where there was a vital need to update science and mathematics education in order to halt a decline in young people's interest and uptake of science-based careers (Osborne and Dillon, 2008). The European Commission (Rocard *et al*., 2007) endorsed the role of IBSE as valuable to this endeavour.

Twinning of centres

The approach adopted by the Fibonacci project was to link each of the original 12 reference centres with two 'twin' centres,

The Fibonacci project is training teachers to help students set up investigations, make predictions and check their results (Fibonacci project)

at least one of which had to be in a different country from the reference centre. Half of these twins were rather more advanced in their implementation of inquiry-based practices than the others. The project began in January 2010, providing the structure and funding for teams from the twin centres to visit the reference centres for three to four days on two occasions, once early and again later on in the 38-month project. Training, tutoring and some face-to-face contacts continue between field visits so that over a period of two years the 12 more experienced twin centres have themselves become reference centres, making a total of 24 centres able to conduct the training of others. In the final year of the project a further 26 centres have become involved, the total number of dissemination centres increasing like the numbers of a Fibonacci series – and hence the name of the project.

Cross-cutting topics

In addition to the training activities, each of the reference and the more experienced twin centres has been taking part in the development of materials related to one of five topics. The topics are cross-disciplinary approaches; using the external school environment; implementing and expanding a reference centre; deepening understanding of practice in scientific inquiry; and problem-based learning in mathematics. Work on a topic is conducted across centres and coordinated from one reference centre. Materials are developed through workshops and disseminated beyond Fibonacci project participants through three-day European training sessions.

To offer an example, the topic group on 'deepening understanding of practice in scientific inquiry' decided to go beyond the general definition of IBSE and investigate further what teachers actually do when teaching through inquiry and what pupils actually do when learning through inquiry. Once agreed on, these elements of the teaching/learning process were incorporated into tools for observing classroom practice. Rather than including all aspects of good practice in science education, the tools are focused on those aspects which are particularly indicative of inquiry. They have proven value in drawing attention to practices that foster the development of conceptual knowledge and understanding. For example, in many classroom and out-of-class activities, unless teachers consciously encourage pupils to interpret what they find, there is a danger of the experience going no further than superficial observation, missing opportunities to identify important connections and interdependencies among things in both the living and non-living world. The relevant tool helps to highlight aspects of practice that may need conscious attention.

Some aspects of the teacher's role in supporting pupils' investigations are shown in Box 1.

One version of the tool enables CPD leaders to diagnose where teachers need most help and to evaluate the impact of training. Another version is for teachers themselves to reflect on their own and their pupils' activity, identifying aspects of their practice in need of

Box 1: Actions of the teacher relating to supporting pupils' investigations

The teacher:

- encourages pupils to ask questions
- helps pupils to formulate productive (investigable) questions
- encourages pupils to make predictions
- involves pupils in planning investigations
- encourages pupils to check their results
- asks pupils to state their conclusions
- asks pupils to check that their conclusions fit with their results
- asks pupils to compare their conclusions with their predictions
- asks pupils to give reasons or explanations for what they found
- asks pupils to identify new or remaining questions
- encourages pupils to reflect on what they have done and found

further development. Trials of these tools have shown them to be relevant to primary and middle-school classes, with some modifications necessary for use at kindergarten level.

The Fibonacci project has developed IBSE materials to encourage students to use the external school environment (Fibonacci project)

Useful resources

Other activities involving all reference centres and twin centres include international conferences and seminars. Primary schools can also take part in the Greenwave project (www.greenwave.ie) by observing and reporting the arrival or appearance in spring of particular plants or animals and the daily temperature. Reports across a country or across Europe accumulate to show the evolution of spring and the effect of rising temperatures.

As well as the practical *Companion Resources* produced by the topic groups, there are *Background Resources* of a more theoretical nature, written by the members of the Fibonacci Scientific Committee. They define both the general principles of inquiry-based science education and inquiry-based mathematics education, and their implementation. All materials are being made freely available through the Fibonacci website (www.fibonacci-project.eu).

Lessons learned

The project has been externally evaluated throughout. Independent assessors have attended and sought feedback from participants in all workshops, conferences and training sessions. The reports show a

IBSE is helping to halt the decline of young people's interest in science (Fibonacci project)

very high level of satisfaction among participants in the joint activities of centres. Field visits and other contacts were perceived as being of value to the reference centres as well as the twin centres and there is the expectation that the collaboration between centres will continue beyond the end of the project. Not surprisingly, the value was greater when the needs of the twin centres were carefully analysed in advance. In the first half of the project, obstacles to good cooperation were encountered where there was a large difference between linked centres in the contexts and systems of education and in the views of IBSE or IBME and how to promote it. Recognizing these issues at an early stage enabled them to be addressed in the course of the project through better communication and information about the needs of twin centres.

Overall the project has been marked by immense enthusiasm for using inquiry approaches. Almost all those involved are disseminating these approaches to others through their work in teacher initial or in-service education, through presentations at conferences and to local, regional or national decision-makers in education. Changing teaching practice needs time and resources. The project has shown what can be done when these are used to bring teachers and teacher educators together to learn from each other.

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RÉSUMÉ

L'objectif du projet Fibonacci est de diffuser la démarche d'investigation en éducation scientifique (DIES) ainsi que la démarche d'investigation en éducation des mathématiques (DIEM) à travers l'Europe. Le nom de ce projet s'inspire de la volonté d'augmenter, comme dans la suite de Fibonacci, le nombre d'écoles et d'élèves utilisant ces démarches. Le projet, financé par l'Union européenne, par le biais du 7ème programme-cadre, a commencé en janvier 2010 et s'est poursuivi ces derniers 38 mois. Il se traduit par le jumelage entre 12 centres (institutions impliquées dans le développement de l'enseignement professionnel) où la démarche d'investigation a déjà été mise en œuvre, et 24 centres ayant la capacité mais pas l'expérience de diffuser l'un ou les deux projets DIES et DIEM auprès des écoles primaires et/ou secondaires. Après deux années de stages et de formations, ces centres sont devenus des lieux de formation pour 26 centres qui ont rejoint ce projet au cours de la dernière année. Le stage implique des visites sur place des équipes, en commençant par les centres les moins expérimentés et en terminant par ceux qui ont le plus d'expérience. Tous les centres participent également à l'un des cinq groupes thématiques qui ont développé des outils et des ressources éducatives pour améliorer la pratique de la démarche d'investigation dans l'enseignement des sciences et des mathématiques, et sa diffusion. Les conclusions d'une évaluation externe montrent la remarquable efficacité de la diffusion de bonnes pratiques par le biais de contacts directs entre les personnels des différents pays et des différents centres.

RESUMEN

La finalidad del Proyecto Fibonacci es divulgar la educación de las ciencias basada en la indagación (ECBI) y la educación de las matemáticas basada en la indagación (EMBI) en toda Europa. Su nombre surge del intento de aumentar el número de colegios y alumnos que usan estos métodos igual que aumentan los números en una serie de Fibonacci. El proyecto, financiado por la Unión Europea dentro del Séptimo Programa Marco, comenzó en Enero del 2010 y tiene una duración de 38 meses. Funciona a través del emparejamiento de 12 centros (instituciones involucradas en el desarrollo profesional del profesor y donde el aprendizaje basado en la indagación ha sido puesto en práctica), con 24 centros que poseen la capacidad pero no la experiencia para divulgar bien ECBI o EMBI o los dos, en colegios de primaria y/o secundaria. Después de dos años de formación y prácticas, estos centros han comenzado a dar formación a otros 26 centros que se unieron al proyecto en su año final. El aprendizaje supone visitas de los equipos procedentes desde los centros menos experimentados a los más experimentados. Además, todos los centros participan en uno de los cinco grupos temáticos, los cuales han desarrollado las herramientas y los recursos necesarios para una mejora de la práctica y la divulgación de la educación de las ciencias y las matemáticas basada en la indagación. Resultados de una evaluación externa del proyecto, muestran la notable efectividad de extender una buena práctica a través del contacto entre el personal procedente de diferentes países y centros.

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Encouraging young people to consider science as a career needs to begin early (Fibonacci project)

Teacher in the mirror
reflecting on practice and change

The challenging reality of encouraging teachers and educators to reflect on their practice and contemplate change is highlighted by **Ljuba Pencheva**, who describes a pilot training course on IBSE for teachers and educators run by the Sofia University Botanic Gardens, Bulgaria. The task called for more than just theoretical background and methodology and tested the adaptability of the project team.

The Pilot INQUIRE Course aimed to develop teachers' reflective skills (Sofia Botanic Garden)

An acquired skill

All activities based on communication provide us with information about ourselves by reflecting the way others see us. So what is the skill of reflection? It is the ability to read properly – that is, to understand – the signals from people we associate with. Communicating with children, a process teachers are engaged in every day, is particularly valuable as it offers a very genuine picture. Further, reflection requires the ability to step aside from our ego and to see ourselves through the eyes of constructively appraising specialists. These skills develop through experience. The 'magic' separation from ourselves and the ability to see ourselves from another's perspective can both be achieved with specific techniques we learn, adapt and apply.

Pilot INQUIRE

Sofia University Botanic Garden in Bulgaria (UBG) is a participant in the INQUIRE project. A total of 14 botanic gardens are involved in the project, each of whom is developing a 60-hour teacher training course focused on using inquiry-based science education (IBSE) in practice, promoting outdoor learning and discussing problems of biodiversity and climate change. INQUIRE also aims to build a community of practitioners (CoP). Keen to engage teachers and educators in a CoP, the pilot course at UBG set itself a target to develop the reflective skills of the participants. The process turned out to be difficult, but the team enjoyed the challenge.

To begin with I will briefly describe the educational system in Bulgaria, as it was when we were growing up and is still

today. The teacher's role is to be the expert, presenting (verbally or in a more interactive way) information to the students, who absorb it and should later on be capable of reproducing it. Their success in remembering and/or understanding is directly related to the marks they receive. And whether teachers are thought to have done a good job is also determined by the achievements of the students.

Professional development

However, real personal development we know does not stop there. According to Abraham Maslow, famous for his studies on human needs, there is a stage beyond the so-called 'esteem' level (respect for and by others) which he calls 'self-actualization'. The process of attaining this further level involves reflection on both professional and personal development.

The real essence of the process of reflection relates to restructuring our experience and knowledge so that we may cope with our tasks in a quicker and more professional way – in other words we need to raise our competency. At the same time, the role of the teacher as we understand it in the process of inquiry-based learning, is to enable students to expand their knowledge, to raise their level of understanding of processes and phenomena so they can grow up to be thinking, capable and successful people. A similar process of development is needed to happen with the teachers and trainers participating in the project.

In Bulgaria, the participants in the pilot INQUIRE course (PIC) included people with years of experience as well as some just beginning in the profession; all were individuals motivated to acquire good European practice and develop their competencies. They were open to the IBSE ideas to differing degrees – some had long experience in applying elements of this methodology, others expressed strongly their feeling that the approach is difficult to apply. Due to these differences, reflecting on practice with the intention of improving it was tackled in a quite individual way.

Teachers' practice

Reflection in teachers' practice is in the nature of the profession. Teachers communicate with many children during classes but rarely with colleagues. Thus they need to develop competences to analyse their own performances. During the pilot course they also have the opportunity to receive feedback from the INQUIRE trainer who is engaged to observe the work in class. Moreover, teachers may discuss the question of IBSE in Bulgarian schools with colleagues, as part of a Community of Practice.

Teachers reformulating questions as IBSE questions – a particularly useful exercise in helping teachers understand what IBSE methodology is (Sofia Botanic Garden)

During the pilot training process, monitoring the application of IBSE methodology and getting feedback from the participants as well as listening to their discussions, we found that they needed additional support and motivation to develop the skills to reflect on their colleagues' work, to be able to take on board comments about their own practice, and also to work independently to improve practice. We organized a special workshop on this topic. Through a presentation and following discussion, participants were encouraged to consider the benefits for both teachers and educators of applying IBSE, the need to allocate time to analyse the process of learning through IBSE in relation to the educational objectives and the achieved outcomes, as well as the challenges in applying IBSE in Bulgarian schools.

The workshop presentation focused on the principles of gathering information and putting together a portfolio of evidence. The very process of gathering data, analysing them and describing experiences and ideas is an example of formative assessment. Having a prepared portfolio of evidence can be useful in the future as summative assessment – for example, to compare the achievements of different practitioners. We also discussed the various types of evidence, including methods of gathering it and complying with the ethical guidelines of the INQUIRE project; the benefits of keeping a diary; the opportunities of discussing within the community of practice specific teaching situations and provocative aspects of practice, as well as among their peers in the teacher teams; and providing virtual space for facilitating discussion and the opportunity to exchange experiences with practitioners abroad. The participants listened to all these aspects in a positive and interested way.

Personal contact

The process of training however presented a new challenge: despite the targeted attention on the importance of developing skills of self-analysis and self-perfection, the above mentioned methods turned out not to have any adherents among our participants. We therefore decided to rely primarily on personal contact as a form of interaction

During the course, participants were observed delivering an IBSE lesson in the botanic garden (Sofia Botanic Garden)

that is flexible and can be adapted to individual needs. The teachers were made aware that a representative of the University Botanic Gardens would always be available for questions and sharing in a manner convenient to them, whether by e-mail, telephone conversation, or face-to-face meetings. Unsurprisingly we found that the prefered method of communication to reflect on the learning process was face-to-face meetings.

Another strategy applied during the course was that the INQUIRE trainers observed participants delivering an IBSE lesson in their own teaching environment (either school classroom or botanic garden).The observations provided evidence of the effectiveness of the course, but also gave valuable feedback to the participants on how effectively they were implementing IBSE. During observation the trainer took notes and photos and after each lesson discussed with the teacher or educator how it had gone. This discussion was held in an informal way, but was crucial for encouraging the teacher or educator to reflect on their practice. More specifically the teacher or educator shared their thoughts on how the session had gone, gave their opinion on how well the students had learnt during the lesson, which approaches they applied and why, alternative techniques they could have used and future plans for implementing IBSE.

The experience showed that, to a large degree, teachers already have well-developed abilities of appraisal in this respect and in some cases it was difficult for me to bring anything new to the analysis. During some of the conversations, however, a difficulty emerged of differentiating the tasks as inquiry-based or not inquiry-based. For some reason the IBSE methodology was not always fully understood by the teachers and they tended to relate it to any practical activity, even within the rigid frames of implementation of a planned-in-advance task, eg when a teacher asks children to make a model of a cell, using plasticine. So it may require more time to allow the teacher to understand the specifics of an IBSE approach. Teachers did build up a truer understanding of active learning at a later stage of the INQUIRE training, when they developed or adapted lesson plans.

For this we used a very good exercise on reformulating questions in an IBSE style activity designed by Sue Hunt at the Royal Botanic Gardens, Kew (www.inquire botany.org/en/resources.html).

Communities

One way of encouraging reflection during the INQUIRE course is through the development of communities of practice. A community is formed spontaneously in schools where there is more than one participant on the course. The daily meetings between colleagues encouraged these participant-experts to share ideas about their practice and present the principles of the project to others. In this way we started to build a community of practice and we plan to continue the process during the next course by setting up more interim meetings.

Developing lessons

The in-depth understanding of the real essence of inquiry-based learning came about in a natural way during the drafting of the lesson plans – the last part of the training in terms of our programme in

Using a model to look at flower structure – one of several IBSE activities shared by partners (Sofia Botanic Garden)

Bulgaria. Despite repeated encouragement to share their experience, the Bulgarian teachers chose to discuss their lesson plans solely with the training supervisor (except for the participants in one school). However, the process showed a satisfactory result in that the course prompted teachers to systematize their acquired knowledge, to focus on the topics they worked on in their practice, and thus to build a good beginning for personal development as teachers practicing inquiry-based science teaching.

Our experience in the PIC, together with feedback from the practitioners, revealed that Bulgarian teachers already feel overburdened with work-related demands and are not ready to take on additional record-keeping such as a diary or case-study. At the same time, the one-to-one meetings easily turn into friendly communication and when guidelines are followed the dialogue runs in both a natural and constructive way. To improve teachers' IBSE techniques we will focus on forming a community of practice, and in future training we plan to organize more face-to-face meetings. We also want to stimulate peer discussion on different IBSE topics. Addressing the needs and capabilities of Bulgarian teachers has confirmed our belief that the inquiry-based approach will aid their motivation as co-learners in the process of opening the minds of our schoolchildren to the wonders of science.

RÉSUMÉ

La réflexion peut être considérée comme la capacité de mettre notre ego de côté et, comme si nous étions dans un espace magique, de nous percevoir comme nous voit une personne étrangère. C'est également une compétence qui se développe par l'expérience. Durant la formation pilote sur la démarche d'investigation qui a été réalisée par les jardins botaniques de l'Université de Sofia, en Bulgarie, les enseignants et les animateurs ont été encouragés à utiliser la réflexion pour leur développement professionnel. La formation, qui avait pour but de développer l'expertise des participants à la démarche d'investigation en éducation scientifique (DIES) a fourni aux participants les fondements théoriques et les méthodes pour réfléchir sur leurs pratiques et permettre ainsi une auto-analyse et une auto-amélioration. Engager les enseignants et les animateurs dans la réflexion sur leurs pratiques s'est avéré être une tâche difficile. Une approche individuelle a été adoptée par la suite dans la formation. Il a été proposé aux participants un soutien personnel pour développer leurs compétences en enseignement par une démarche d'investigation. Afin d'établir des pratiques communes entre les enseignants et les animateurs, et partager leurs réflexions lors des prochaines formations «Inquire», un plus grand nombre de groupes de discussion en tête à tête sera organisé.

RESUMEN

El fenómeno de la reflexión se puede considerar como la capacidad para dejar nuestro ego a un lado y, como si estuviéramos en un espacio mágico vernos a nosotros mismos desde una perspectiva ajena a nosotros mismos. La reflexión es una capacidad que se desarrolla a través de la experiencia. Durante el curso piloto de formación INQUIRE, organizado por la Escuela Universitaria de Jardines Botánicos perteneciente a la Universidad de Sofía, Bulgaria, se animó al personal docente y educadores a usar la reflexión en su desarrollo profesional. El curso, que tenía como finalidad el fomentar las habilidades de los participantes en la Educación de las Ciencias Basada en la Indagación (ECBI), dotó a los participantes de los conocimientos teóricos y métodos necesarios para reflexionar sobre sus prácticas docentes y llevar acabo un autoanálisis que les condujera a la mejora de las mismas. Animar al personal docente y educadores a usar la reflexión sobre su práctica docente fue una tarea difícil. Por ello, más adelante en el curso de formación se adoptó un enfoque más individualizado y se ofreció a los participantes una ayuda personalizada para discutir temas relacionados con la mejora de su destreza en la educación basada en la indagación. En el próximo curso de formación INQUIRE se organizarán más grupos de discusión para que los profesores y educadores puedan compartir sus conclusiones y constituir así una comunidad de práctica.

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Integrating IBSE with traditional teaching

a South Korean synthesis

In South Korea, following a recent review of its national curriculum that accentuated the importance of creativity, evidence-based reasoning and communication in the provision of its science education, Seoul's National University organised and ran its own IBSE professional development programme. **Junehee Yoo, Heui Baik Kim, Youngdal Cho, Seyoung Hwang** and **Jee Young Park** report.

The recent national curriculum review in Korea highlighted the importance of encouraging creativity and personal development in students, and in this context scientific argumentation has been regarded as a core classroom activity allowing students to engage in a collaborative learning process during scientific inquiry. The research team, based in Seoul National University (SNU), developed and set up a professional development programme for science teachers that aims to provide them with the knowledge and skills necessary for implementing scientific argumentation in ways that integrate with their existing pedagogical content knowledge. During a four-day intensive workshop, teachers gained a theoretical basis of scientific argumentation and 'hands-on' experiences with a number of inquiry tasks.

What argumentation offers

The most notable consequence from undertaking argumentation in the science classroom is that it offers a number of ways to consider what the claim is, what the lines of supporting evidence show, and what the relationship is between the claim and lines of evidence. This means it helps students to become actively engaged in their knowledge-making process and in constructing their arguments (Jiménez-Aleixandre et al., 2000). It also provides a way to master routine memorization of numerous scientific propositions (Duschl *et al*., 1997).

Similarly, in inquiry-focused science lessons, through stressing the process of constructing arguments by using experimental data to link with a given scientific explanation in textbooks, it allows students to generate data, to carry out an investigation, to use data to answer a research question, and to write and be more reflective as they work (Sampson *et al*., 2011). A considerable number of studies show the importance of scientific argumentation on constructing knowledge and undertaking practice in the science classroom (Driver *et al*., 2000; Duschl and Osborne, 2002).

The science education faculty at Seoul National University believes that teachers should be the main agents for changing classroom culture towards an inquiry-based learning environment (Seoul National University)

In Korea, national science education guidelines state the importance of argumentation, although only within the recommendations, not as educational goals *per se* (KMOE, 2011). This means that teachers should seek to improve students' ability to explain scientific knowledge by demonstrating evidence and the relationship between evidence and explanation. However, research has consistently shown that argumentation is not a common activity in the science classroom. A key factor is that science teachers are not prepared to guide argumentation-focused lessons, perhaps because they are not familiar with such methods, not having learned to use argumentation strategies themselves during their preparation courses and teacher training programme.

The SNU project

The science education faculty at Seoul National University has been a leader in both teacher training and research as the nation's oldest and largest group in this field. Recently, professors and researchers in the faculty pioneered an innovative approach to inquiry-based science education in secondary schools, including scientific argumentation and scientific model construction (Lee and Kim, 2011; Lee K. *et al*., 2012; Kang *et al*., 2012; Lee S. *et al*., 2012).

The team is strong in all four domains of physics, chemistry, biology and earth science. (Other than the authors of this article, our team members include Dr Dae Hong Jeong, Dong Wook Lee, Eun Hee Lim, Sun Mi Yun and Jongho Baek.) In early 2011, the idea for an in-service teacher professional development programme focused on scientific argumentation was conceived, in the belief that teachers should be the main agents for changing the current classroom culture toward an inquiry-based learning environment. During the initial planning phase, we worked intensively to develop a methodological framework for linking theoretical rationales of scientific argumentation to participant teachers' needs and motivation.

In September, the team's proposal of developing a research-based programme on scientific argumentation was accepted by the College of Education as a one-year research project. We detailed in the proposal a rationale of our programme in terms of teachers' pedagogical content knowledge (PCK) development. Throughout the planning and implementation phase, the programme was designed to actively pursue the integration of scientific argument-related knowledge into the participating teachers' existing knowledge and beliefs about science teaching.

Korean science teachers practicing scientific argumentation during a professional development workshop (Seoul National University)

The actual programme development then proceeded with a pilot study involving 11 volunteer teachers, focusing on the two following aspects. Firstly, through a literature review we set out a theoretical knowledge base of scientific argumentation based on the elements of PCK. Within this framework we developed various survey and task elements to give insight into teachers' perceptions on introducing scientific argumentation into their teaching practice. Secondly, we developed prototypes of hands-on inquiry tasks covering all four science domains: photosynthesis, colour perception, Charles' Law, and whirling tornadoes in a sink (see Box 1).

Teacher volunteers completed a task in a small group setting, and feedback was gathered concerning whether the inquiry procedure, as well as the topic, was designed well enough to foster teachers' interest and contrasting opinions. There was an issue over the fact that many teachers were familiar neither with solving open-ended inquiry tasks nor in constructively arguing with each other. The research team devised an explicit guide for each phase of the programme that would assist teachers to think reflectively on their current teaching practice and to develop a positive disposition towards considering scientific argumentation as their new teaching strategy.

A tentative model

After the revision phase, the programme ran in June 2012 in collaboration with the Department of In-service Training, Seoul Science Park and Seoul Metropolitan Office of Education. Although it took place during term time, 18 highly motivated teachers volunteered to participate in a four-day intensive workshop. Each day comprised four hours of lectures and/or activities. On the first day, teachers were introduced to the rationales of scientific argumentation-based instruction. The traditional lecture was complemented by an ensuing small-group discussion on their teaching practice and potential implications of scientific argumentation as a new strategy.

On the second and third day, teachers were fully engaged with two inquiry tasks chosen by them. We encouraged teachers to 'take off their educator's hat

Tasks for teacher trainees	Tasks for instructor
• To imagine a scientist's diet at the South Pole • To recall the factors that increase photosynthesis	• To engage teachers in the task • To pose the question: How can plants' photosynthesis rate increase in relation to the colour of light?
• To build a group hypothesis with given 'information bank' sheets (inherently the problem cannot be solved with the limited information) • To design an experiment and carry out the experiment to test the hypothesis	• To provide an encouraging environment • To encourage teachers to talk in a group • To guide the use of experimental materials
• To criticize their hypothesis or to discuss reasons for errors in experimental results	• To encourage teachers to find various ways of explaining their experimental data
• (Reference: New 'information bank' sheets, which show experimental errors and consider other related factors) • To build a new group hypothesis or elaborate upon the previous hypothesis • To conduct a new experiment and find a group solution on the given problem	• To discuss group solutions through whole classroom talk

Box 1. Prototype for hands-on activity focusing on photosynthesis

and put on an enquirer's hat', with the aim of becoming immersed in the cognitive process, as their students would have to do. The next session involved putting their educators' hats back on, to consider whether the same task could be used in their teaching practice, and if so, what issues should be addressed. The last day was then devoted to the design of science lessons that introduce scientific argumentation as a central part of the student learning process. In the same small groups, teachers began to collate the personal and collective ideas that had arisen during the workshops.

Each group was able to come up with an inquiry topic which had not been introduced at the workshop. The day concluded with a group presentation session during which participant teachers' positive disposition to adopt an argumentation-based instructional strategy was presented, albeit tentatively. Equally important, we used surveys to identify their concerns and dilemmas, such as lack of time and instructional materials, and overcoming students' passive attitudes. In terms of teacher's PCK, it seems that subject matter knowledge related to inquiry topics, together with an understanding of scientific argumentation, are the prerequisites for teachers to adopt this approach more confidently. Indeed, the four-day workshop whetted teachers' appetites, and currently an action research project is under way with a small number of teachers to bring about sustainable professional development.

During the training programme, teachers engaged in an inquiry task both as 'enquirers' and 'educators' (Seoul National University)

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RÉSUMÉ

Dans cet article, nous abordons un programme de développement professionnel pour les professeurs de science centré sur l'argumentation scientifique. La révision récente du programme national d'éducation a mis en lumière l'importance d'encourager la créativité et le développement personnel des étudiants et, en particulier, le raisonnement basé sur des preuves et les compétences en communication dans l'enseignement des sciences. Dans ce contexte, l'argumentation scientifique a été considérée comme une activité essentielle dans les classes qui permet aux étudiants de s'engager dans un processus d'apprentissage collaboratif durant l'investigation scientifique. L'équipe de recherche basée à l'Université nationale de Séoul (UNS) a développé et conduit un programme de développement professionnel pour les professeurs de sciences entre 2011 et 2012. Le raisonnement derrière le programme UNS est de fournir aux professeurs de sciences des connaissances et des compétences qui leurs permettent d'utiliser l'argumentation scientifique de façon à intégrer les contenus pédagogiques actuels. Pendant quatre jours intensifs de formation, dix-huit enseignants ont acquis des bases théoriques en argumentation scientifique ainsi qu'une expérience pratique sur les tâches d'investigation portant sur le thème de la photosynthèse, de la perception des couleurs, de la loi de Charles, et des tourbillons d'eau dans un évier.

Following the successful training programme in June 2012, a small number of teachers are involved in an action research project to bring about sustainable professional development (Seoul National University)

RESUMEN

En este artículo, presentamos un programa de formación profesional para los profesores de ciencias de Corea centrado en el razonamiento científico. La reciente revisión del plan nacional de estudios ha destacado la importancia de fomentar la creatividad y el desarrollo personal de los estudiantes y en concreto, el razonamiento basado en la demostración y sus habilidades de comunicación en el aprendizaje de las ciencias. En este contexto, el razonamiento científico ha sido considerado, como una actividad principal en las clases, que permite a los estudiantes participar en un proceso de aprendizaje cooperativo durante las actividades de investigación científica. El equipo de investigación de la Universidad Nacional de Seúl (UNS), desarrolló y llevó a cabo un programa de formación para profesores de ciencias entre el año 2011 y 2012. La finalidad del programa de la UNS, era proporcionar a los profesores de ciencias el conocimiento y las habilidades necesarias para integrar el razonamiento científico con sus conocimientos pedagógicos y de la materia. Durante un taller intensivo de cuatro días, dieciocho profesores adquirieron las bases teóricas para el razonamiento científico y experiencia práctica en el desarrollo de tareas de indagación sobre temas como, la Fotosíntesis, Percepción del color, Ley de Charles, y simulación de tornados en un desagüe.

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Objects and questions
along avenues to learning

There's no single pathway to inquiry-based learning, writes **Emily Dutton**. From her experience in object-based learning at the Horniman Museum and the University of Cambridge, she argues that objects can be catalysts for questions that lead down avenues of inquiry.

Objects, carefully selected, stimulate questions and can thus nudge students down avenues of inquiry. At the same time the objects themselves contain clues – the evidence required to help progress the inquiry. In my own practice I have come to view object-based learning as process of inquiry in its own right. I hope to show you here that this is an approach that can be adapted to any learning environment to stimulate the natural curiosity of the learner.

At the Horniman

I have been working in the Learning Team at the Horniman Museum and Gardens since 2008, developing education sessions that link the museum collections with its 16 acres of gardens. As part of its collections, the museum houses an extensive handling collection of over 4,000 objects that reflect the Horniman's three specialist areas: natural history, anthropology and musical Instruments.

As the name suggests, the handling collection can be explored using all of our senses and especially touch. It plays an integral role in the museum's education and public engagement programming, which is underpinned by a philosophy that learning should always occur through and from exploration of objects rather than simply be about them. In this way, the learning is open-ended with multiple possible outcomes. It is a learner-centred approach that does not start from an explanation of what an object is. In our view this would be to close down the learning process and miss opportunities to explore alternative thoughts, interpretations, ideas or understandings. In object-based learning, students are encouraged to ask and answer the sorts of questions that draw on prior knowledge, open up discussion and promote shared meaning-making (Falk and Dierking, 2000).

An object lesson

In using objects as the stimulus for learning, I have found time and time again that the natural curiosity of the learner is instantly engaged and never more so than when they are confronted

The Horniman hands-on base, home to the handling collection (Joel Knight)

Objects used in the Green Plants and People session (Andra Nelki)

with an object that they have not come across before. Take for example, the dialogue below between myself and three year-4 students (ages 7 and 8) during a school session called Green Plants and People. The session first looks at what plants need to grow and the functions of different parts of plants and moves on to explore a range of anthropological objects from around the world made from plants.

Three students are exploring an object from Kenya made from carved and dried gourd. It has a leather lid and handle, and decorative beads, and was used to carry milk:

Me: *What is it made from?*
Child 1: *Wood.*
Child 2: *Yeah wood.*
Me: *What makes you think it is wood?*
Child 2: *It is brown and it feels like wood.*
Me: *What if I told you that it does come from a plant but is not wood?*
Child 3: *It's not wood? (Sounds surprised)*
Me: *What else could it be?*
Child 1: *Is it a branch?*
Me: *Good idea. It's not a branch though. I guess you could say it grows from a branch.*
Child 3: *Um. . . what grows from a branch? Leaves?*
Me: *Yes, leaves do grow from branches – but does it look like a leaf?*
Child 3: *No. It looks like wood.*
Me: *It certainly does. But it didn't look like this when it was still growing on the tree.*
Child 1: *Oh, why not?*
Me: *Because it has been dried out.*
Child 1: *Oh. So was it this colour before?*
Me: *Yes, this sort of colour but it wouldn't have been so shiny or hard to touch. Can you think of things which grow on trees?*
Child 3: *Conkers!*
Me: *Yes, on horse chestnut trees the seeds are conkers.*
Child 2: *So is it a really big seed?*
Me: *It used to contain the seeds. What part of a plant contains seeds?*
Child 3: *The fruit!*
Me: *Yes, this is a fruit.*

Here the students built their ideas by combining evidence from the object itself with their prior knowledge.

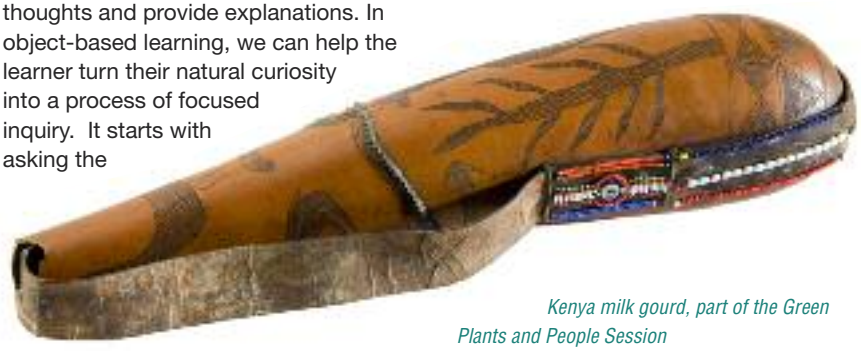
They developed new ideas as they were challenged to communicate their thoughts and provide explanations. In object-based learning, we can help the learner turn their natural curiosity into a process of focused inquiry. It starts with asking the kinds of questions which encourage the learner to think critically. They must weigh up and analyse evidence, form explanations, make connections and contest and communicate ideas. These are the skills of inquiry.

7-step framework

Devised as part of a literature review for the EU-funded PATHWAY project, Levy *at al*. (in preparation) propose a framework for inquiry-based science education (IBSE) comprising seven related but non-sequential features of IBSE that can all vary in terms of the amount of direction provided by the teacher (Figure 1). It is exactly these sorts of skills that, I argue, are being developed in the process of object-based learning and it is our role as facilitators of the process to provide the right level of structure or challenge.

The right question

The questioning of objects is an integral part of object-based learning and by investigating an object students start to construct theories and ideas. Talboys (1994) provides a useful introduction on how to build question layers when working with objects. It starts with questions that can be answered through observation – such as size, weight, colour, shape, texture, markings, damage and inscriptions. Questioning can then progress to the more speculative –what it is made from, how was it made, what tools might have been used, how might any visible damage have occurred? In the upper layers, questions become more subjective, for example they might relate to the type of value that can be assigned to an object. You will find that one question will lead to another. Some may involve a personal response and often there may be multiple answers and alternative points of view.



Kenya milk gourd, part of the Green Plants and People Session

Essential features of IBSE	Variations 1 (Open)	2 (Guided)	3 (Structure)
Question: students investigate scientifically oriented question	Student poses a scientifically oriented question	Student selects from a range of, or refines, a scientifically oriented question provided by the teacher, materials or other sources	Student is given a scientifically oriented question by the teacher, materials or other sources
Evidence: students give priority to evidence	Student determines what constitutes evidence/data and collects it	Student selects from data/evidence provided by the teacher, materials or other sources	Student is given data/evidence by the teacher, materials or other sources
Analyse: students analyse evidence	Student decides how to analyse evidence	Student decides from ways of analyzing evidence provided by the teacher, materials or other sources	Student is told how to analyze evidence provided by the teacher, materials or other sources
Explain: students formulate explanation based on evidence	Student decides how to formulate evidence based on evidence	Student decides from possible ways to formulate explanation given by the teacher, materials or other sources	Student is given a way to formulate explanation based on evidence
Connect: students correct explanations to scientific knowledge	Student independently finds and examines other resources and forms links to scientific knowledge	Student is directed to other resources and shown how to form links to scientific knowledge	Student is given other resources and shown the links with scientific knowledge
Communicate: students communicate with audience(s) and justify explanation	Student chooses how to communicate and justify explanations	Student is given broad guidelines on how to justify and communicate explanations	Student is given all the steps to justify and communicate explanations by the teacher, materials or other sources
Reflect: students reflect on the inquiry process, responses to their work, its value and impact, and their learning	Student decides independently how to structure reflection on the inquiry process and his/her learning	Student is given broad guidelines to structure reflection on the inquiry process and his/her learning by the teacher, materials or other source	Student is given a structured framework for reflection by the teacher, materials or other source
	More .....Amount of student self-direction.....Less		

Figure 1: Seven essential features of IBSE. Levy et al (in preparation) adapted from Asay and Orgill (2010)

Exploring a Native North American birch bark model canoe (Andra Nelki)

Looking closer

The familiarity of many objects and the assumptions that we might make about them can lead us to close down our avenues of inquiry. If we know it is a candle holder, what more do we want to know? Getting out of this frame of mind and training ourselves to look to look beyond the familiar is something which takes practice. There are plenty of ways, however, to help students look a little closer or delve a little deeper. How about trying some of these games, which promote creativity and teamwork and are also fun:

- **Guess who** Gather a collection of objects. Get one person to shut their eyes while the others secretly choose an object. The person who shut their eyes then asks yes/no questions about the objects to try to work out which one they chose.

Playing musical instruments made from different parts of plants (Andra Nelki)

- **Blindfold pictionary** In a small group, get one person to sit with their back to the group while the others look at an object which was previously hidden in a box or under a cloth. The people who can see the object must then get the person with their back to the group (and the object) to draw the object from their description of it.

- **If an object could talk** Give the group an object to explore. Then ask them to write the story of their life as that object, using the first-person voice – where did they come from, how they came to be, the people they have met, the things they might have seen?

You don't need a museum!

If you do have some budget and would like to build a collection of objects for learning then I would recommend taking a look at Starbeck for their range and value (www.starbeck.com). I cannot emphasize enough, however, that effective object-based learning does not require a museum full of objects: a single object can tell a thousand stories. For botanical and conservation education we also know that the best and most stimulating kinds of objects are those that the natural world around us provides for free.

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RÉSUMÉ

L'apprentissage par la démarche d'investigation (ou ADI) n'est pas une simple méthode éducative, mais plutôt une approche évolutive d'éducation ancrée dans une méthodologie constructiviste. De nombreux débats sont actuellement en cours quant à sa conceptualisation théorique et à ce que constituerait une mise en œuvre efficace d'activités d'investigation dans les écoles et dans les lieux d'apprentissage hors du cadre scolaire. Lorsque le débat est déjà en place, les caractéristiques centrales de l'ADI émergent. Par exemple, l'accent est mis sur l'élève en tant que force motrice de son propre apprentissage. De même, les méthodes d'ADI sont souvent axées sur l'importance d'utiliser des questions pour que l'élève s'engage dans un processus d'auto-découverte. Dans cet article, je présente mon expérience de la mise en place d'une méthode d'apprentissage à partir d'objets (une approche couramment utilisée dans les musées), afin de contribuer à développer le type de compétences cognitives qui peuvent favoriser l'apprentissage par l'investigation.

Les objets, soigneusement sélectionnés, stimulent les questions et peuvent ainsi pousser les étudiants à parcourir les chemins de l'investigation. En même temps, les objets eux-mêmes contiennent des indices : les preuves nécessaires à faire progresser les recherches. Mes propres travaux pratiques au musée et aux jardins Horniman m'ont amené à concevoir l'apprentissage à partir d'objets comme un processus d'investigation à part entière. Cet article a pour but de démontrer que l'apprentissage à partir d'objets est une approche qui peut être adaptée à tout type d'environnement éducatif pour stimuler la curiosité naturelle des individus.

RESUMEN

El aprendizaje basado en la indagación (ABI), no es un simple método educativo, sino más bien una corriente educativa en constante evolución y que tiene sus raíces en la metodología constructivista. En la actualidad existe un debate en torno a su conceptualización teórica y lo que podría constituir una eficiente actividad basada en la indagación en colegios y en ambientes de aprendizaje ajenos a la escuela. Donde hay debate surgen las características principales del aprendizaje basado en la indagación. Se ha hecho más hincapié, por ejemplo, en considerar al estudiante como el motor propio de su aprendizaje. Al mismo tiempo, los métodos del aprendizaje basado en la indagación, a menudo, se centran en la importancia de utilizar preguntas para involucrar al estudiante en un proceso de descubrimiento dirigido por el mismo. En este artículo, explico mi experiencia en el uso del aprendizaje basado en el objeto (un enfoque usado normalmente en museos) para ayudar a desarrollar un pensamiento que fomente el aprendizaje basado en la investigación. Objetos, cuidadosamente seleccionados, inducirán a preguntas y de este modo, el estudiante se verá empujado hacia vías de investigación. Al mismo tiempo los objetos en sí mismos contienen claves: la prueba necesaria para avanzar en la indagación. A través de mi propia experiencia en el Horniman Museum and Gardens he llegado a entender el aprendizaje basado en el objeto como un proceso de investigación por derecho propio. La finalidad del artículo es demostrar que el aprendizaje basado en el objeto es un enfoque que puede introducirse en cualquier ambiente educativo para estimular la curiosidad natural del individuo.

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Communities in Union

IBSE teacher-training in European botanic gardens

Communities of Learning, Practice or Inquiry? As **Suzanne Kapelari, Asimina Vergou** and **Julia Willison** report, the terms are virtually interchangeable, but with Inquiry Based Science Education (IBSE) providing its conceptual framework, the pan-European INQUIRE project is promoting Communities of Inquiry in its botanic garden-based teacher training initiatives.

At Botanika in Bremen teachers and educators, on their own initiative, collaborated to develop an IBSE lesson plan (Botanika Rhododendron Park Bremen, Germany)

From their earliest incarnation as 'physic gardens' in 16th Century Renaissance Italy, botanic gardens have always been centres of learning and teaching. Created originally for apothecaries and physicians, they later attracted biologists, botanists and horticulturalists as they spread, first through Europe and then around the world. As agents of botanical exploration during the 18th and 19th centuries, their pre-eminence in the scientific community was assured. Paradoxically, however, while their collectors roamed the world in search of new plants, the gardens themselves became increasingly introspective and detached from the rest of society. Indeed it wasn't until the last century that a handful of pioneering gardens began to re-examine their public responsibilities, with two gardens in particular, Kirstenbosch National Botanical Garden, Cape Town and Brooklyn Botanic Garden, New York, leading the way in establishing departments of public education.

These days, however, botanic garden education is no longer confined to the provision of educational programmes for pupils and the general public. Now it includes the training and support of teachers so that they, in turn, may enhance their own students' botanic garden learning experience. One of the key initiatives in this field is the pan-European INQUIRE project. Launched in December 2010 to provide "inquiry – based teacher training for a sustainable future", INQUIRE aims to develop a model of successful teacher training that embraces the concept of *Learning Outside the Classroom (LOtC)* and establishes Communities of Practice and Learning[1] among participating teachers and botanic garden educators.

[1] The terms Communities of Practice, Communities of Learners and Communities of Inquiry are used interchangeably in this article to describe the relationship and partnerships developed between the participants in the INQUIRE courses

The concept of Communities of Practice (CoP) is hardly new, since its characterisation as groups of people informally bound together by sharing expertise and passion for a joint enterprise would be one recognised by our hunter-gatherer forbears! But it remains a robust and relevant model. In the form that we examine here, a modern CoP may or may not have an explicit agenda and the output is primarily knowledge. Contemporary CoP participants may meet face-to-face on a regular basis or may communicate through email or other social media. Generally they come from the same organisational/sociocultural background and share their experiences and knowledge in creative and innovative ways that foster new approaches to problems (Wenger & Snyder 2000).

Since the 1990s, when Lave and Wenger (1991) introduced the term Communities of Practice to academic research, a considerable body of CoP related literature has emerged, evidence that these learning environments have the potential to improve organisational performance, drive strategy, generate new lines of business, solve problems, help organisations recruit and retain talent as well as promote spread of best practice and develop people's skills (Wenger & Snyder 2000).

It is this last strand that INQUIRE is intent on developing, by encouraging fourteen partners across eleven EU states to support the establishment of CoP in their teacher training courses. CoP established among teachers who work together to refine their teaching and who are also supported by academics or more experienced practitioners, appears to be a highly effective professional development approach in science education (Lumpe, 2007; Akerson *et al*., 2007).

A study by Phillips *et al*. (2007) has suggested that, while LOtC institutions have the potential to support K-12[2] science education, they rarely engage in larger educational reforms. INQUIRE is aiming to enhance the profile of botanic gardens by actively engaging with and supporting a major EU reform initiative in science education. Its Inquiry-Based Science Education (IBSE) training courses (some of which are accredited) are not only intended to modify the practice of teachers and educators but also to showcase how inquiry-based teaching can meet the national curriculum requirements of its eleven host countries. Under INQUIRE's aegis, National Advisory group meetings are organised in each country, bringing together education policy makers, researchers and practitioners in order to disseminate the value of IBSE in formal and informal education.

The INQUIRE programme supports and motivates teachers and botanic garden educators to investigate different IBSE models (Schulbiologisches Zentrum Hannover)

IBSE's proven efficacy as a model for motivating students to engage with science has attracted large-scale EU support and funding, a trend that looks likely to continue (Lena 2009, Rocard 2007). However, as Minner *et al*. (2010) point out, there is a lack of uniformity in ISBE's practical implementation, together with some conceptual variation when ISBE is invoked to describe approaches to science teaching. When it comes to providing teacher training it's worth remembering, therefore, that there's no one single pathway to implement IBSE. Indeed there are likely to be several different strategies available to engage students and develop their inquiry-based learning experiences (Kapelari *et al*. 2012).

INQUIRE project training activities are therefore not confined to the traditional lecture format, in which 'expert' researchers or practitioners talk about how to use IBSE in the school classroom or botanic garden. The INQUIRE programme is aimed at supporting and motivating teachers and botanic garden educators to jointly investigate different ISBE models, choosing whichever is most effective for them. And while course participants collect evidence and draw on their individual and organisational backgrounds to share knowledge, experience and perspectives, they are also encouraged to develop a common understanding of how to create an environment conducive to learning in the school, botanic garden or natural history museum.

The learning communities established in the INQUIRE courses may be more accurately described as Communities of Inquiry (CoI), a term usually associated with online learning communities (Garrison & Arbough 2007). While CoP, according to Lave and Wenger's (1991) definition, usually comprise members that belong to one organisation or have a single socio-cultural background, the INQUIRE course communities are distinctive because they include teachers from different schools with different formal education histories, as well as educators from botanic gardens and natural history museums who come from a scientific or horticultural

[2] K-12 is a term that refers to the publicly-supported school grades (1-12) prior to college in the USA and Canada.

background. Moreover 'inquiry' is a more apt descriptor of INQUIRE learning communities, since the course participants are inducted into a process that actively engages them in their own inquiry project as well encouraging them to reflect on their practice.

Although research has shown that the learning environments fostered in such communities are highly successful, it has also become clear that the task of engendering, nurturing and sustaining such communities is far from simple. Any successful formula would have to enable teacher trainers to co-opt suitable participants, provide an infrastructure in which communities can thrive and measure the communities' value in non-traditional ways (Wenger & Snyder 2000).

According to our partners, who have organized courses around Europe, one of INQUIRE's standout achievements so far has been the positive synergy between teachers and educators as they worked together in communities of learning. In the words of our French partner, Bordeaux Botanic Garden, *"Mixing educators and teachers in the INQUIRE course created good compost".*

Across the INQUIRE project, Partners have used different approaches to fostering CoI with varied levels of success. At the Botanika in Bremen, Germany, teachers and educators first embarked on improving an existing IBSE lesson. Then they moved on to develop an IBSE lesson from scratch. Later, when they sought further roundtable discussions in order to continue their collaboration, Botanika provided the venue and helped organize the meetings. It has been very encouraging to hear that the current CoI group is keen to perpetuate its learning by joining the round-table discussions of future INQUIRE course participants.

In a contrasting experience at Sofia Botanic Garden, Bulgaria, early attempts to persuade participants to engage with each other in developing and implementing IBSE lessons ran into difficulties when they expressed a preference for one-to-one discussions with the course trainers rather than with their peers. The only instance in which a CoI unilaterally formed was where the course participants were teachers from the same school. Their proximity and regular contact seems to have been a key factor. Our colleague, Ljuba Pencheva, discusses the Bulgarian experience in more detail elsewhere in this issue of Roots.

Looking ahead, INQUIRE is planning its 2013 programme in the light of Partner insights and feedback from the project thus far. We're also preparing a "Train the Trainers Manual" that we'll publish on our project website: www.inquirebotany.org. This will include a comprehensive breakdown of best practice strategies for running training courses based on 'communities of inquiry' and examples of practical activities that have already been tested successfully by the project partners.

Teachers and educators during the pilot INQUIRE course in Trento, Italy, collecting evidence for an IBSE activity (MUSE, Italy)

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One of INQUIRE's standout achievements has been the positive synergy between teachers and educators as they work together in communities of learning (Innsbruck University Botanic Garden, Austria)

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RÉSUMÉ

Les techniques modernes d'éducation dans les jardins botaniques comprennent non seulement les programmes éducatifs pour les élèves et les visiteurs, mais proposent également des formations et un soutien aux enseignants afin de leur permettre de tirer le meilleur parti de l'expérience acquise par leurs élèves au cours d'activités d'apprentissage au jardin botanique. Le projet européen «Inquire» (Formation des enseignants basée sur une méthode d'investigation pour un avenir durable) a pour but d'élaborer un modèle de développement professionnel efficace d'apprentissage hors du cadre scolaire (LOtC) et, d'établir une communauté d'investigation parmi les enseignants participants et les animateurs des jardins botaniques. Les formations encouragent les enseignants et les animateurs des jardins botaniques à s'engager dans un projet commun et à s'intéresser à différentes approches d'enseignement et d'apprentissage basés sur la démarche d'investigation. Les participants aux cours rassemblent des preuves et partagent des connaissances, des expériences et des perspectives qui proviennent de différents horizons individuels et institutionnels. Ils développent également une compréhension partagée sur la façon de créer un environnement propice à l'apprentissage dans l'école et au jardin botanique ou au muséum d'histoire naturelle.

RESUMEN

En la actualidad, la formación ofrecida en los Jardines Botánicos no se limita a un programa educativo para alumnos y visitantes sino que además incluye cursos y apoyo a los profesores para obtener el máximo partido de la experiencia de aprendizaje de sus alumnos en el Jardín Botánico. El programa europeo INQUIRE, "formación del profesorado basado en la investigación para un futuro sostenible" aspira a desarrollar un modelo que permita un exitoso desarrollo profesional en el ámbito de los entornos de aprendizaje ajenos al aula (LOtC) y establecer comunidades de investigación entre los profesores participantes y los educadores de los Jardines Botánicos. Las actividades de formación animan a los profesores y a los educadores de los jardines botánicos a establecer una empresa conjunta e investigar los diferentes enfoques para la enseñanza y el aprendizaje de la ciencia basada en la indagación. A la vez que los participantes en los cursos recopilan pruebas y comparten conocimientos, experiencias y perspectivas surgidas desde diferentes orígenes a nivel individual e institucional, se desarrolla un entendimiento común de cómo crear un ambiente que sea propicio para aprender en la escuela y en el jardín botánico o en un museo de historia natural.

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Guide on the side
changes in cultural paradigms

Gail Bromley explores the cultural gear-changes required of botanic gardens in order to move them away from traditional information-led models towards the student-directed inquiry approach of IBSE. It's not an easy transition and entrenched assumptions are severely examined!

Following the pilot INQUIRE course run at Kew, University of Cambridge Botanic Garden has incorporated IBSE pedagogy into several of its programmes (University of Cambridge Botanic Garden)

The snappy definition by Professor Justin Dillon of King's College, London, that teachers and educators become the 'guide on the side' rather than the 'sage on the stage', sums up the approach for the practice of inquiry-based science education. For botanic gardens IBSE requires a cultural shift in educational delivery, holding back from an information-led technique and instead facilitating a student-led, questioning approach – something that doesn't always come easily to educators and is certainly not what visiting schoolteachers naturally look for. However, we know that IBSE can provide good learning outcomes and real engagement. Coordinated through Innsbruck Botanic Garden and managed by BGCI, the aim of the EU project known as INQUIRE (www.inquirebotany.org), is to introduce IBSE jointly to secondary teachers and educators working in LOtC sites such as botanic gardens throughout Europe.

In 2010 the Royal Botanic Gardens, Kew, was invited to join INQUIRE, and to develop and run a training course. Climate change and biodiversity were the key topics for the course, for which the objectives were to develop or enhance understanding of IBSE among participants and to encourage its use both in the school classroom and in botanic garden educational programmes. With a mixture of secondary teachers and botanic garden educators attending, a further objective was to break down barriers between the two groups and develop a new community of practice. All participants were expected to take part in reflective practice and to produce a portfolio of evidence encapsulating an aspect of their learning and development over the duration of the course. Taking place between October 2011 and July 2012, the course lasted over 60 hours and

Objects can provoke an IBSE study. Student examining the palm nut Coco de Mer (Lodoicea maldivica) (University of Cambridge Botanic Garden)

included 3 full days at Kew with on-site activities and lectures, 15 hours of self study and a day of IBSE activities in the botanic garden, designed and led by each participant in turn.

Although a number of teachers in the UK are familiar with, and use IBSE, the practice is less well developed in UK botanic gardens. Five botanic garden educators attended the pilot INQUIRE course at Kew and arrived with a mixture of curiosity, scepticism and excitement. One stage of the course explored the barriers to using IBSE in botanic garden programmes and several themes emerged: IBSE is too time-consuming for a short school visit; gardens have a set numbers of themes that they are expected to deliver and it is too difficult to design IBSE activities for this; it's more difficult to use IBSE with schoolchildren you don't know; IBSE is difficult to translate into an outdoor setting; teachers bringing classes to the garden expect the educator to provide a lot of detailed information that is not easily available in school. The pilot course set out to explore some of these issues and to show how IBSE-designed programmes can offer an engaging and relevant experience for visiting classes and have a positive impact on the students' learning.
A large part of the course involved trying out some IBSE activities which had been designed for participants to take away and adapt to their own needs.

This immediately answered the anxiety over needing to design new programmes that work in a botanic garden setting.

Range of views

So how has the course impacted on Kew and the botanic garden educators? As might be expected, participants left with a range of views, but all agreed that IBSE was a useful tool to include in their regular programme delivery. Feedback from Cambridge Botanic Garden included the view that IBSE is 'not suitable for all ages, but from [age] nine upwards it encourages a lot of interaction and discussion'. On a very positive note, one of the barriers was dismissed thus: 'It is very difficult with a group of "unknown" pupils to immediately engage and get the group to be dynamic and talkative. Setting challenging activities [through IBSE] is a good way in to overcome this difficulty.' There was also recognition that delivering IBSE activities does not need to be time consuming: 'The inquiry-based elements can be as small as need be, so that several small challenges can be set each within a small timeframe. Alternatively one large overarching activity or challenge can be devised that engages the pupils for the whole session (1–1 ½ hrs)'. In the event, several new workshops incorporating IBSE pedagogy have been incorporated into programmes at Cambridge and the general feedback is that these have met with universal approval.

At Westonbirt Arboretum there was a similar response. Christine Meakin, the education officer, reflected, 'Assessing the students' prior learning in a more detailed way and following their progress through the programme, I have been pleasantly surprised that even within a 1 ½ hour programme this approach provides the time to discuss and discover the knowledge and understanding of small groups of students, and from this more valuable starting point I can tailor the rest of the activities to take this into account.' Christine also felt this method engaged the student more: 'The approach sets up a great ethos of questions, inquiry and discovery – this creates a vibrant flow to the programme – and it is clear that students have yet more questions of interest at the end of the programme, which I hope they continue to follow up back at school or home.' The use of the pedagogy can also, according to Christine, 'make global issues and

Teachers discussing how they can convert questions into IBSE questions (Royal Botanic Gardens, Kew)

Teachers and educators become completely absorbed in IBSE activities (Royal Botanic Gardens, Kew)

challenges, such as climate change and biodiversity, more accessible and relevant to students through IBSE questioning, student-led discovery and discussing how these issues impact on their lives . . . the discussions the students have in response to IBSE questions enables them to make connections between their visit experiences and observations, and their lives and actions.' This certainly does away with the notion that any didactic and information heavy, content-led approach is necessary for deeper understanding of conservation and sustainability.

Edinburgh Botanic Garden has also been persuaded by this approach, despite initial misgivings, and is now sending another member of staff to attend the next INQUIRE course. They hope thus to enable Edinburgh to have sufficient in-house capacity to run their own INQUIRE CPD training programme in the coming years, cascading the approach and content to teachers and educators in Scotland. In fact most of the botanic garden educators who attended the Kew course are now keen to adapt and run an IBSE course themselves, as part of their standard CPD offer.

Key tool for Kew

And what of Kew? Kew has moved on apace with its schools and families programme over the last few years and the IBSE approach is fast becoming a key tool in its portfolio. The majority of Kew and Wakehurst Place teachers are being trained in IBSE pedagogy, inheriting an excellent set of ready-made activities and assessment techniques developed prior to, arising from, and after the INQUIRE course. The new multi-million pound refurbishment of the Temperate House has additionally adopted the IBSE pedagogy as core to the schools programme element within the bid. The adoption of this approach does not stop at schools, however. Kew recognizes that inquiry-based learning is a useful approach to informal learning for many of its visitor groups. Members of the interpretation team will join the course next year to see how they can integrate IBSE into interpretative and festival activities across the botanic garden. This participative and 'self-investigation' approach, encouraging long-term dialogue and interaction with audiences to develop displays, exhibitions and programmes, will now form the bedrock of Kew's audience development programme.

Evaluation over the coming years will be critical to gauge the success of this sea change in approach in improving understanding of and support for conserving and valuing plant diversity; it is, of course, early days as yet. However, the question is now not whether 'to IBSE or not to IBSE' at Kew and other UK botanic gardens, but rather, 'We know it works – why aren't you doing it too?'

A significant part of the pilot INQUIRE course involved participants trying out IBSE activities that could be adapted for their own needs (Royal Botanic Gardens, Kew)

IBSE-designed programmes can offer an engaging and relevant experience for visiting classes and have a positive impact on students' learning (University of Cambridge Botanic Garden)

RÉSUMÉ

Au cours des 18 derniers mois, Kew s'est engagé dans «Inquire» (www.inquirebotany.org), un projet collaboratif de l'Union européenne, coordonné par le Jardin botanique d'Innsbruck et dirigé par le BGCI. «Inquire» a pour but de promouvoir la démarche d'investigation dans l'enseignement des sciences (DIES) conjointement avec les professeurs du secondaire et les animateurs qui travaillent sur les sites d'apprentissage hors du cadre scolaire (LOtC), tels que les jardins botaniques, à travers l'Europe. Entre octobre 2011 et juillet 2012, la formation pilote de plus de 60 heures encadrée par Kew a rassemblé 7 animateurs de jardins botaniques et de zoos basés au Royaume-Uni, ainsi que 11 enseignants.

La DIES requiert un changement culturel quant à la manière d'aborder l'aspect éducatif dans un jardin botanique, en s'éloignant d'une approche informative et en valorisant une approche basée sur le questionnement menée par les étudiants. Cette démarche n'est pas facile pour les animateurs, et ne correspond certainement pas à ce que les enseignants recherchent de prime abord lors des visites. Cependant, la DIES procure souvent de bons résultats d'apprentissage et un réel engagement. Cet article s'intéresse aux impacts, internes et externes, de ces cours sur 4 jardins botaniques ainsi que sur les participants qui ont suivi ces formations au Royaume-Uni.

RESUMEN

En los últimos 18 meses, el Kew ha estado involucrado en INQUIRE (www.inquirebotany.org), un proyecto de cooperación Europea, coordinada a través del jardín Botánico de Innsbruck y dirigida por BGCI (Botanic Gardens Conservation International) para promover la educación de las ciencias basada en la indagación (ECBI). El programa aúna a profesores de secundaria y educadores que trabajan en entornos de aprendizaje fuera del aula (LOtC), tales como Jardines Botánicos, de toda Europa. Llevado a cabo desde Octubre del 2011 hasta Julio del 2012, el curso piloto de formación de mas de 60 horas ofrecido por el Kew, atrajo a educadores de 7 jardines botánicos y parques zoológicos de Inglaterra junto con 11 profesores.

La ECBI supone un cambio cultural en el enfoque de los programas educativos en los jardines botánicos, alejándose de un enfoque dirigido hacia la información y acercándose a un enfoque centrado en el estudiante y la formulación de preguntas. Esto es algo que no surge fácilmente de los educadores y que no es lo que los profesores visitantes buscan normalmente. Sin embargo, la ECBI a menudo proporciona unos buenos resultados de aprendizaje y motivación. Este artículo examina los resultados internos y externos que el curso ha tenido en 4 jardines botánicos y en participantes del curso en Inglaterra.

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**The author would like to thank the botanic garden education staff who attended the INQUIRE pilot course at Kew for their comments and input to the course and its evaluation.*

Resources

RESOURCES

Books

Learning Science in Informal Environments: People, Places, and Pursuits

People every year live experiences that involve science which are not included in the traditional educational paths; they visit a science museum, a botanic garden, they attend a lecture or a science show, they read a book or magazine on popular science. But what do we know about what actually happens in these experiences? *Learning Science in Informal Environments* is a comprehensive review of the evidence of science learning in the US across a range of settings. Find out what impact a setting such as a botanic garden may have on promoting science learning, how to set appropriate learning goals and how to broaden participation in science learning. This book is available to download for free.

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, 2009, the National Academy of Sciences, Washington DC, US
https://download.nap.edu/catalog.php?record_id=12190
ISBN-10: 0-309-11955-3
ISBN-13: 978-0-309-11955-9

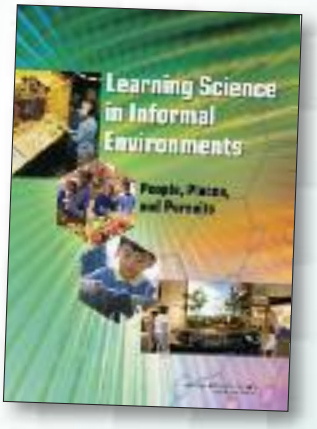
Public garden management

If you are looking for a complete-and-ready reference for establishing, managing, and running a successful and sustainable, profitable public garden, this book is your priority selection. *Public garden management* explores the roles that different gardens are playing and

RESSOURCES

Livres

Apprendre les sciences dans des environnements informels : des gens, des lieux et des loisirs



Chaque année, des gens vivent des expériences scientifiques qui ne suivent pas les chemins traditionnels de la connaissance; ils visitent un musée scientifique, un jardin botanique, assistent à une conférence ou à un évènement scientifique, ils lisent un livre ou un magazine de vulgarisation scientifique. Mais que savons-nous réellement de ces expériences? Apprendre les sciences dans des environnements informels est un inventaire exhaustif, mettant en évidence ces apprentissages scientifiques dans diverses situations aux États-Unis. Découvrez quel impact un jardin botanique peut avoir sur la promotion des apprentissages scientifiques, comment établir des objectifs d'apprentissage appropriés et comment élargir la participation aux apprentissages scientifiques. Ce livre est disponible pour être téléchargé gratuitement.

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, 2009, the National Academy of Sciences, Washington DC, US
https://download.nap.edu/catalog.php?record_id=12190
ISBN-10: 0-309-11955-3
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RECURSOS

Libros

Enseñanza de las Ciencias en Ambientes Informales: Personas, lugares y actividades

Cada año la gente vive experiencias que tienen que ver con la ciencia. Muchas de ellas no forman parte de las vías educativas tradicionales. Visitan un museo de ciencias, un jardín botánico, asisten a una conferencia o a una feria científica, leen un libro o una revista sobre ciencia popular. Pero ¿qué sabemos acerca de lo que realmente sucede en estas experiencias? El libro Enseñanza de las ciencias en Ambientes Informales es una revisión exhaustiva de la evidencia de la enseñanza de las ciencias en los Estados Unidos en diferentes sitios. Averigüe qué impacto puede tener un lugar como un jardín botánico en la promoción de la enseñanza de las ciencias, cómo establecer metas de aprendizaje adecuadas y cómo ampliar la participación en la enseñanza de las ciencias. Este libro está disponible para descargar de forma gratuita.

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, 2009, the National Academy of Sciences, Washington DC, US
https://download.nap.edu/catalog.php?record_id=12190
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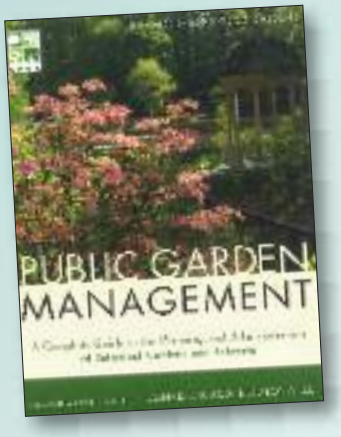


can play in their individual communities and provides amongst other topics an overview and case studies on different ways to engage with your public. The sections on outreach, formal education programmes, professional development, interpretation and evaluation of garden education programmes are of particular relevance to botanic gardens educators. The book's content is presented in a user friendly layout and includes a variety of practical and theoretical up-to-date information written by highly experienced US public gardens' staff.

Donald Rakow and Sharon Lee, 2011, John Wiley & Sons, Inc., Hoboken, New Jersey, US
www.wiley.com
ISBN 10: 0-4705-3213-0
ISBN 13: 978-0-4705-3213-3

10 key ideas. Skills in argumentation and use of evidence

How can a teacher or educator incorporate argumentation in science teaching? This book, published in Spanish, provides strategies and tools on how to develop students' reasoning skills. Language and communication play an important role in the construction of scientific knowledge. It is therefore important to facilitate young people's skills in speaking and debating around scientific ideas. María Pilar Jiménez Alexandre presents in this book why and how to link argumentation to science education. Find out what argumentation means and how to design tasks and a learning environment that encourages argumentation as well as how to evaluate the quality of students' arguments.

María Pilar Jiménez Aleixandre, 2010, Editorial GRAO, de IIF, S.L., Barcelona, Spain
www.grao.com
ISBN 13: 978-84-7827-897-8

Gestion des jardins publics

Si vous cherchez un livre de référence complet pour mettre en place et gérer un jardin public attirant, durable et économiquement viable, ce livre doit être le premier de la liste. *Gestion des jardins publics* explore les rôles que jouent et que peuvent jouer différents jardins dans les communautés qui les entourent et proposent, entre autres sujets, un aperçu et des cas d'études sur les différentes façons d'impliquer votre public. Les parties sur la sensibilisation, les projets pédagogiques formels, la formation professionnelle, l'interprétation et l'évaluation des projets pédagogiques des jardins sont particulièrement intéressants pour les animateurs de jardins botaniques. Le contenu du livre est présenté de façon conviviale et comprend diverses informations pratiques et théoriques à jour, rédigées par des membres du personnel de jardins publics étatsuniens ayant une grande expérience.

Donald Rakow and Sharon Lee, 2011, John Wiley & Sons, Inc., Hoboken, New Jersey, US
www.wiley.com
ISBN 10: 0-4705-3213-0
ISBN 13: 978-0-4705-3213-3

10 idées clé : acquérir des compétences pour débattre et utiliser des preuves

Comment un enseignant ou un éducateur peut-il utiliser l'argumentation dans l'enseignement des sciences ? Ce livre, publié en espagnol, fournit des stratégies et des outils pour développer les compétences de raisonnement des étudiants. Le langage et la communication jouent un rôle important dans la construction de connaissances scientifiques. Il est donc important d'encourager les compétences des jeunes pour parler et débattre autour de concepts scientifiques. Dans ce livre, Maria Pilar Jimenez Alexandre présente pourquoi et comment lier l'argumentation à l'éducation scientifique. Découvrez ce qu'est

Gestión de Jardines Públicos

Si usted está buscando una referencia completa y lista para establecer, administrar y operar un jardín público exitoso, sostenible y rentable, este libro debe ser su elección prioritaria. *Gestión de Jardines Públicos* explora el papel que juegan y que pueden jugar diferentes jardines en sus comunidades particulares y ofrece, entre otros temas, una visión general y estudios de casos sobre las distintas formas de atraer a su público. Las secciones sobre los alcances, los programas de educación formal, desarrollo profesional, interpretación y la evaluación de los programas educativos del jardín son de particular importancia para los educadores de los jardines botánicos. El contenido del libro tiene un formato fácil de usar e incluye una variedad de información teórica y práctica actualizada, escrita por personal de jardines públicos de los Estados Unidos con enorme experiencia.

Donald Rakow and Sharon Lee, 2011, John Wiley & Sons, Inc., Hoboken, New Jersey, US
www.wiley.com
ISBN 10: 0-4705-3213-0
ISBN 13: 978-0-4705-3213-3

10 ideas clave. Habilidades en la argumentación y uso de pruebas

¿Cómo puede un maestro o educador incorporar la argumentación en la enseñanza de las ciencias? Este libro, publicado en español, ofrece estrategias y herramientas sobre cómo desarrollar las habilidades de razonamiento en los estudiantes. El lenguaje y la comunicación juegan un papel importante en la construcción del conocimiento científico por lo que es importante para facilitar las habilidades de los jóvenes para hablar y debatir en torno a las ideas científicas. María Pilar Jiménez Alexandre presenta en este libro por qué y cómo vincular la argumentación a la ciencia de la educación. Averigüe lo que significa la argumentación y cómo diseñar tareas y un ambiente de aprendizaje que la

Teaching, Learning, and Assessing Science 5–12 (Fourth Edition)

This book points out the importance of encouraging students (aged 5 to 12 years) to develop their own understanding of the world, and their critical thinking skills. The author starts off with an introduction to the nature of learning in science and the role of science education in developing scientific literacy and continues with presenting activities that enable children to develop ideas and process skills. Other interesting sections in this book focus on the use of questioning, how to promote students' motivation to learn science and how to engage students in self- and peer-assessment to enhance their learning.

Wynne Harlen (2006). (4th Edition). SAGE Publications Ltd., London, UK
www.sagepub.com
ISBN 978-141-290-872-6

Learning for sustainability: in times of accelerating change

This book is ideal for educators, researchers and students who are concerned about the well-being of the planet and convinced of our ability to improve it. Considering that we live in times of accelerating change, turbulence, uncertainty and complexity the editors argue that in today's world education cannot be 'education as usual', just like business cannot be 'business as usual'. Contributors to this book are professionals and academics from different parts of the world offering perspectives on and examples of new approaches to learning and information and innovations for sustainability.

Arjen E.J. Wals and Peter Blaze Corcoran (Eds), 2012,Waeningen Academic Publishers, Waeningen, the Netherlands.
www.wageningenacademic.com/_clientfiles/download/learn4-e_frontmatter.pdf
ISBN 13: 978-90-8686-203-0

l'argumentation et comment concevoir des travaux et un lieu éducatif qui encouragent l'argumentation, ainsi que comment évaluer la qualité des arguments des élèves.

María Pilar Jiménez Aleixandre, 2010, Editorial GRAO, de IIF, S.l., Barcelona, Spain
www.grao.com
ISBN 13: 978-84-7827-897-8

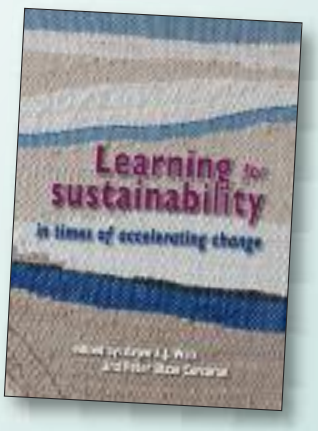
Enseigner, apprendre et évaluer en sciences pour les 5 à 12 ans (4ème édition)

Ce livre montre l'importance d'encourager les élèves (âgés de 5 à 12 ans) à développer leur propre idée du monde et leur aptitude à la pensée critique. L'auteur commence avec une introduction sur la façon d'apprendre en sciences et le rôle de l'éducation scientifique pour développer une connaissance des sciences. Elle continue en présentant des activités qui permettent aux enfants de développer leurs idées et compétences. D'autres sections intéressantes de cette ressources sont centrées sur l'utilisation de l'investigation, sur comment développer la motivation des élèves à apprendre les sciences et sur comment amener les élèves à s'auto-évaluer et s'évaluer entre eux pour apprendre mieux.

Wynne Harlen, 2006 (4th Edition). SAGE Publications Ltd., London, UK

Apprendre pour le développement durable en période d'accélération des changements

Ce livre est idéal pour les éducateurs et étudiants qui se sentent concernés par la santé de la planète, et qui croient que nous pouvons l'améliorer. En partant de l'idée que nous vivons une période d'accélération des changements, de turbulence, d'incertitude et de complexité, les éditeurs pensent que l'éducation, dans le monde d'aujourd'hui, ne peut être une éducation « comme d'habitude », tout comme



fomente, así como la forma de evaluar la calidad de los argumentos de los estudiantes.

María Pilar Jiménez Aleixandre, 2010, Editorial GRAO, de IIF, S.l., Barcelona, Spain
www.grao.com
ISBN 13: 978-84-7827-897-8

Enseñanza, Aprendizaje y Evaluación de la Ciencia 5-12 (Cuarta Edición)

Este libro destaca la importancia de animar a los estudiantes con edades de 5 a 12 años a desarrollar su propia comprensión del mundo y sus habilidades para el pensamiento crítico. El autor comienza con una introducción a la naturaleza del aprendizaje en la ciencia y el papel de la educación en el desarrollo de la cultura científica y continúa con actividades que capacitan a los niños para desarrollar ideas y procesar habilidades. Otras secciones de interés en este recurso se enfoca sobre el uso de los cuestionarios, cómo promover la motivación de los estudiantes para aprender ciencias y cómo involucrar a los estudiantes en la auto-evaluación y la evaluación por pares para mejorar su aprendizaje.

Wynne Harlen2006). (4th Edition). SAGE Publications Ltd., London, UK
www.sagepub.com
ISBN 978-141-290-872-6

El aprendizaje para la sostenibilidad: en tiempos de cambio acelerado

Este libro es ideal para educadores, investigadores y estudiantes que se preocupan por el bienestar del planeta y que están convencidos de nuestra capacidad para mejorarlo. Teniendo en cuenta que vivimos en una época de cambios acelerados, turbulencia, incertidumbre y complejidad, los editores sostienen que la educación en el mundo actual no puede ser "la educación de siempre", al igual que los negocios tampoco pueden ser "los negocios de siempre". Quienes colaboran en

Web links/Websites

Assessing for Learning – workshops designed to introduce teachers to formative assessment

www.exploratorium.edu/ifi/workshops/assessing/index.html

This online resource consists of five workshops which introduce the Formative Assessment Cycle, a process by which science teachers gather evidence of students' thinking and use this evidence for future teaching. These workshops are designed to be carried out sequentially and enable teachers to develop a comprehensive view of formative assessment in the classroom. This resource is also relevant to botanic garden educators who could improve their practice by applying elements of formative assessment in their own teaching environment.

The Fibonacci Project – Resources for implementing inquiry

http://fibonacci.uni-bayreuth.de/resources/resources-for-implementing-inquiry.html

The EU funded Fibonacci Project aims to disseminate Inquire-based Science Education (IBSE) methods in primary and secondary schools throughout Europe. One of the project outcomes is the production and sharing of

Liens internet/ Sites

Evaluer pour apprendre – des ateliers pour initier les enseignants à l'évaluation formative

http://www.exploratorium.edu/ifi/workshops/assessing/index.html

Cette ressource en ligne est composée de 5 ateliers qui présentent le cycle d'évaluation formative, un processus par lequel les professeurs de sciences peuvent rassembler des informations sur les représentations des élèves, et utiliser ces représentations pour leur enseignement futur. Ces ateliers sont conçus pour être menés dans l'ordre et permettent aux enseignants d'avoir une vue d'ensemble de l'évaluation formative dans les classes. Cette ressource est également intéressante pour les animateurs de jardins botaniques pour améliorer leur pratique en mettant en place certains aspects de l'évaluation formative dans leur projet pédagogique.

Le projet Fibonacci – des ressources pour mettre en place une démarche d'investigation

http://fibonacci.uni-bayreuth.de/resources/resources-for-implementing-inquiry.html

Le projet FIBONACCI, financé par l'Union européenne (UE), vise à diffuser des méthodes d'enseignement des sciences basées sur l'investigation, dans des écoles primaires et secondaires à travers l'Europe. L'un des objectifs du projet est la conception et le partage de ressources pédagogiques disponibles sur le site internet du projet. *Le guide pour la mise en place d'un enseignement* les affaires ne peuvent être des affaires « comme d'habitude ». Les contributeurs de ce livre sont des professionnels et universitaires de différentes parties du monde qui offrent des regards et exemples de nouvelles approches de l'enseignement, de l'information et des innovations pour un développement durable.

Arjen E.J. Wals and Peter Blaze Corcoran (Eds), 2012,Waeningen Academic Publishers, Waeningen, the Netherlands.
http://www.wageningenacademic.com/_clientfiles/download/learn4-e_frontmatter.pdf
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Sitios Web

Evaluación para el Aprendizaje - talleres diseñados para introducir a los profesores ra la evaluación formativa

http://www.exploratorium.edu/ifi/workshops/assessing/index.html

Este recurso en línea consta de 5 talleres que presentan el Ciclo del Análisis Formativo, un proceso mediante el cual los profesores de ciencias reúnen evidencias del pensamiento de los estudiantes y las usan para la enseñanza futura. Estos talleres están diseñados para llevarse a cabo de forma secuencial y para capacitar a los maestros para desarrollar una visión integral de la evaluación formativa en el aula. Este recurso también es relevante para los educadores de jardines botánicos, quienes podrían mejorar su práctica mediante la aplicación de los elementos de la evaluación formativa en su propio entorno educativo.

Proyecto Fibonacci – Recursos para implementar la indagación

http://fibonacci.uni-bayreuth.de/resources/resources-for-implementing-inquiry.html

La UE financió el Proyecto Fibonacci tiene como objetivo difundir los métodos de la Enseñanza de las Ciencias Basada en la Indagación (ECBI) en las escuelas primarias y secundarias en toda Europa. Uno de los resultados del proyecto es la producción y distribución de los recursos educativos disponibles en el sitio web del proyecto. La "*Guía para la implementación de la Enseñanza de las Ciencias Basada en la Indagación*" es una publicación que presenta el enfoque de la ciencia basada en la indagación, este libro son profesionales y académicos de distintas partes del mundo que ofrecen perspectivas y ejemplos de nuevos enfoques para el aprendizaje, la información y las innovaciones para la sostenibilidad.

Arjen E.J. Wals and Peter Blaze Corcoran (Eds), 2012,Waeningen Academic Publishers, Waeningen, the Netherlands.
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educational resources available on the project's website. '*Implementing Inquiry-Based Science Education guideline*' is a guide that presents the science inquiry-based approach, key aspects of teaching science through inquiry and gives practical suggestions on how to implement this approach.

'*Learning through inquiry*' is a report that identifies what inquiry means, why it is important as a learning method and how it can be integrated in teaching subjects such as science and mathematics. Nine key patterns are also presented as core structuring elements of IBSE including, among others, developing a problem-based culture, working in a scientific manner and learning from mistakes.

Concept to classroom: Inquiry-based Learning
http://www.thirteen.org/edonline/concept2class/inquiry/

'Concept to classroom' is an education website which offers online workshops for teachers' professional development, including using the inquiry-based science education approach. The online workshop on inquiry-based learning starts off with a section explaining this concept, and continues with demonstrating how inquiry is used in classroom, exploring new techniques and planning step-by-step how to implement this approach in practice. Educators will find particularly helpful the videos showing examples of how students learn through inquiry in classrooms.

CarboSchools: Partnerships between climate researchers and secondary school teachers
www.carboeurope.org/education/

The CarboSchools website offers activities for teachers, educators and scientists who are willing to encourage

des sciences par l'investigation présente cette approche scientifique, les point clés de cet enseignement et donne des conseils pratiques pour la mettre en place.

Apprendre par l'investigation est un rapport qui explique ce qu'est l'investigation, pourquoi c'est une méthode d'apprentissage importante et comment l'intégrer dans des disciplines comme les sciences et les mathématiques. Neuf questions clés sont également présentées comme des éléments structurants de cette méthode, entre autres comment développer une culture des situations-problèmes, comment travailler d'une manière scientifique et comment apprendre de nos erreurs.

Du concept à la classe: l'enseignement basé sur l'investigation
http://www.thirteen.org/edonline/concept2class/inquiry/

Du concept à la classe est un site internet pédagogique qui propose des ateliers en ligne pour la formation professionnelle des enseignants, y compris l'utilisation de méthodes d'enseignement des sciences basées sur l'investigation. L'atelier en ligne concernant l'enseignement par l'investigation commence par une section expliquant ce concept, et continue par une démonstration de comment cette démarche peut être utilisée en classe, l'exploration de nouvelles techniques et une programmation pas-à-pas pour mettre en place cette approche en pratique. Les vidéos montrant des exemples de comment les élèves apprennent à travers l'investigation en classe seront particulièrement utiles aux éducateurs.

los aspectos clave de la enseñanza de las ciencias a través de la indagación y brinda sugerencias prácticas sobre cómo implementar este enfoque.

"*Aprendizaje a través de la indagación*" es un informe que identifica lo que significa la investigación, por qué es importante como método de aprendizaje y cómo se pueden integrar en asignaturas como las ciencias y las matemáticas. Nueve patrones clave también son presentados como elementos estructurales fundamentales del ECBI, incluyendo entre otros, el desarrollo de una cultura basada en problemas y cómo trabajar de manera científica y aprender de los errores.

Del Concepto al Aula: aprendizaje basado en la indagación
http://www.thirteen.org/edonline/concept2class/inquiry/

"*Del Concepto al Aula*" es un sitio web sobre educación que ofrece talleres en línea para el desarrollo profesional de los docentes, incluyendo el uso del enfoque de enseñanza de las ciencias basada en la indagación. El taller en línea sobre el aprendizaje basado en la indagación comienza con una sección que explica este concepto y continúa con la investigación que demuestra cómo se utiliza en el aula, explora nuevas técnicas y planifica paso a paso cómo implementar este enfoque en la práctica. Los educadores encontrarán particularmente útiles los videos que muestran ejemplos de cómo los estudiantes aprenden a través de la indagación en las aulas.

CarboSchools: Alianzas entre investigadores del clima y profesores de secundaria
http://www.carboeurope.org/education/

El sitio web CarboSchools ofrece actividades para profesores, educadores y científicos que estén dispuestos a animar a sus alumnos a aprender más acerca de los impactos del cambio climático, y a actuar localmente para reducir las emisiones de CO^2. CarboSchools es un proyecto financiado por la UE, que ha creado alianzas entre investigadores y profesores con el fin de acercar la ciencia puesta al día en el salón de clases. Los recursos están disponibles en siete idiomas y se

pupils to learn about the impacts of climate change and act locally to reduce CO^2 emissions. CarboSchools is an EU funded project that has created partnerships between researchers and teachers in order to bring science up-to date in the classroom. The resources are available in seven languages and include plant related activities such as the experiment on the: 'Uptake of Carbon Dioxide from Water by Plants' http://www.carboeurope.org/education/CS_Materials/PlantsCO2Uptake.pdf

The Pathway to Inquiry Based Science Teaching
www.pathway-project.eu/

Find out about training opportunities and resources on Inquiry-Based Science Education in Europe by visiting the website of Pathway, another EU funded project. Pathway has developed a network of experts in scientific research and formal and informal science education in order to promote learning through inquiry. Botanic garden educators can also call on ideas and examples from Pathway to create partnerships between their institutions (including their science department) and schools to provide students with first-hand experiences on how science works.

CarboSchools: des partenariats entre chercheurs travaillant sur le climat et enseignants du secondaire
http://www.carboeurope.org/education/

Le site internet Carboschools propose des activités pour les enseignants, éducateurs et scientifiques qui souhaitent encourager leurs élèves à apprendre des choses sur les effets des changements climatiques et à agir localement pour réduire leur émissions de CO^2. Carboschools est un projet financé par l'UE qui a créé des partenariats entre chercheurs et enseignants pour mettre les sciences à jour dans les classes. Les ressources sont disponibles en sept langues et comprennent des activités sur les plantes comme une expérience sur l'absorption par les plantes du CO2 dans l'eau. http://www.carboeurope.org/education/CS_Materials/PlantsCO2Uptake.pdf

Pathway: le chemin vers un enseignement basé sur l'investigation
http://www.pathway-project.eu/

Découvrez les opportunités de formation et les ressources pour l'enseignement des sciences par une démarche d'investigation en visitant le site de Pathway, un autre projet financé par l'UE. Pathway a permis de développer un réseau d'experts en recherche scientifique, en éducation scientifique formelle et informelle afin de promouvoir l'enseignement par investigation. Les animateurs de jardins botaniques peuvent également utiliser des idées et exemples venant de Pathway pour créer des partenariats entre leurs institutions (y compris leurs départements scientifiques) et des écoles, pour fournir aux élèves des expériences directes de comment la science fonctionne.

incluyen actividades relacionadas con las plantas, tales como el experimento sobre la absorción de dióxido de carbono por las plantas a partir de agua. http://www.carboeurope.org/education/CS_Materials/PlantsCO2Uptake.pdf

El Camino a la Enseñanza de las Ciencias Basado en la Indagación
http://www.pathway-project.eu/

Visite este sitio web y averigüe las oportunidades de capacitación y recursos sobre la enseñanza de las ciencias basada en la indagación en Europa. Se trata de otro proyecto financiado por la UE. El Proyecto *Pathway* ha desarrollado una red de expertos en la investigación científica y la enseñanza de las ciencias formal e informal, con el fin de promover el aprendizaje a través de la indagación. Los educadores de los jardines botánicos también pueden recurrir a las ideas y ejemplos en *Pathway* para crear asociaciones entre sus instituciones (incluidos sus departamentos de ciencias) y las escuelas para proveer a los estudiantes con experiencias de primera mano sobre cómo funciona la ciencia.

Teaching resources on plants and faith



seeds of unity

The link between plants, religion and belief offers exciting possibilities for learning. BGCI has created an on-line education pack to encourage gardens to explore these links. The pack is for educators working in botanic gardens and school teachers and the activities are aimed at children 7-11 years of age.

www.bgci.org/education/seedsofunityportal

Supported by

CALOUSTE GULBENKIAN FOUNDATION

BGCI
Plants for the Planet



Botanic Gardens Conservation International

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INQUIRE

Join us for the INQUIRE conference

Raising standards through inquiry: Professional development in the Natural Environment

Royal Botanic Gardens, Kew 9-10 July 2013

Find out how botanic gardens and natural history museums have been working with schools to help reinvigorate inquiry-based science education throughout Europe

Themes addressed during the conference will include:

- IBSE outdoors
- Reflective Practice
- Professional Learning Communities
- Evaluation of IBSE
- Students perspectives on IBSE
- Developing training courses in LOtC sites

Call for papers, posters and workshops will be announced in December and registration will open in March.

More information will be posted soon on the following websites: **www.inquirebotany.org** and **www.bgci.org**

Organised by

Kew ROYAL BOTANIC GARDENS

BGCI Plants for the Planet